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Salla Marttonen

MODELLING FLEXIBLE ASSET MANAGEMENT IN INDUSTRIAL MAINTENANCE COMPANIES AND NETWORKS

Thesis for the degree of Doctor of Science (Technology) to be presented with due permission for public examination and criticism in the Auditorium of the Student Union House at Lappeenranta University of Technology, Lappeenranta, Finland on the 22nd of November, 2013, at noon.

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Supervisor

Professor Timo Kärri
School of Industrial Engineering and Management
Department of Innovation Management
Lappeenranta University of Technology
Finland

Reviewers

Professor Diego Galar
Department of Civil, Environmental and Natural Resources Engineering
Division of Operation and Maintenance Engineering
Luleå University of Technology
Sweden

Doctor David Baglee
Faculty of Applied Sciences
Department of Computing, Engineering and Technology
University of Sunderland
The United Kingdom

Opponent

Professor Jayantha Prasanna Liyanage
Faculty of Science and Technology
Department of Mechanical and Structural Engineering and Materials Science
University of Stavanger
Norway

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ABSTRACT

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Modelling flexible asset management in industrial maintenance companies and networks

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The tightening competition and increasing dynamism have created an emerging need for flexible asset management. This means that the changes of market demand should be responded to with adjustments in the amount of assets tied to the balance sheets of companies. On the other hand, industrial maintenance has recently experienced drastic changes, which have led to an increase in the number of maintenance networks (consisting of customer companies that buy maintenance services, as well as various supplier companies) and inter-organizational partnerships. However, the research on maintenance networks has not followed the changes in the industry. Instead, there is a growing need for new ways of collaboration between partnering companies to enhance the competitiveness of the whole maintenance network. In addition, it is more and more common for companies to pursue lean operations in their businesses.

This thesis shows how flexible asset management can increase the profitability of maintenance companies and networks under dynamic operating conditions, and how the additional value can then be shared between the network partners. Firstly, I have conducted a systematic literature review to identify what kind of requirements for asset management models are set by the increasing dynamism. Then I have responded to these requirements by constructing an analytical model for flexible asset management, linking asset management to the profitability and financial state of a company. The thesis uses the model to show how flexible asset management can increase profitability in maintenance companies and networks, and how the created value can be shared in the networks to reach a win-win situation.

The research indicates that the existing models for asset management are heterogeneous by nature due to the various definitions of ‘asset management’. I conclude that there is a need for practical

asset management models which address assets comprehensively with an inter-organizational, strategic view. The comprehensive perspective, taking all kinds of asset types into account, is needed to integrate the research on asset management with the strategic management of companies and networks. I will show that maintenance companies can improve their profitability by increasing the flexibility of their assets. In maintenance networks, reorganizing the ownership of the assets among the different network partners can create additional value. Finally, I will introduce flexible asset management contracts for maintenance networks. These contracts address the value sharing related to reorganizing the ownership of assets according to the principles of win-win situations.

Keywords: flexible asset management, modelling, industrial maintenance, company networks, maintenance contracts, value sharing, win-win, working capital, fixed assets

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I am grateful to my family and friends. You have supported me along the process, especially by offering me something else to think about during my free time. This has kept my motivation strong towards finishing this thesis. Finally, I wish to thank my fiancé Kimmo. You have urged me over the hurdles I have encountered and listened to all my complaints along the way. Thank you.

Lappeenranta, November 2013

Salla Marttonen

PUBLICATIONS

This thesis consists of an overview (Part I) and related publications (Part II). The publications included in the second part of the thesis are listed below, together with information on their review processes and the contribution of the author of this thesis.

Publication 1

Marttonen, S. and Kärri, T. (2013), 'Top modelling in asset management: a systematic literature review', in Jantunen, E., Komonen, K., Heljo, A., Kuosmanen, P. and Rao, B.K.N. (Eds.), '*Congress proceedings of international congress of condition monitoring and diagnostic engineering management 11-13 June, Helsinki'*, KP-Media Oy, ISBN 978-952-67981-0-3, pp. 198-207.

The author was responsible for designing the research, conducting the literature review, analysing the results and writing the publication. The paper was accepted based on a peer review of the full text.

Publication 2

Marttonen, S., Monto, S. and Kärri, T. (2013),'Profitable working capital management in industrial maintenance companies', *Journal of Quality in Maintenance Engineering*, Vol. 19, No. 4, pp. 429–446.

The author was responsible for gathering the data and conducting the analyses. The research was jointly designed, and the author was mainly responsible for reviewing the existing literature and writing the publication. The paper was accepted based on a peer review of the full text.

Publication 3

Marttonen, S., Viskari, S. and Kärri, T. (2013), 'Appeasing company owners through effective working capital management', *International Journal of Managerial and Financial Accounting*, Vol. 5, No. 1, pp. 64–78.

The author was responsible for gathering the data and conducting the analyses. The research was jointly designed, and the author was mainly responsible for reviewing the existing literature and writing the publication. The paper was accepted based on a double blind review process.

Publication 4

Marttonen, S., Monto, S. and Kärri, T. (forthcoming), 'Enhancing collaboration in maintenance networks through flexible asset management', Accepted for publication in *International Journal of Strategic Engineering Asset Management*.

The author was responsible for gathering the data and conducting the analyses. The research was jointly designed, and the author was mainly responsible for reviewing the existing literature and writing the publication. The paper was accepted based on a peer review of the full text.

Publication 5

Marttonen, S., Viskari, S. and Kärri, T. (2013), 'The missing link between maintenance contracts and flexible asset management', *International Journal of Procurement Management*, Vol. 6, No. 6, pp. 649–665, forthcoming at time of going to print.

The author was responsible for designing the research, gathering the data, conducting the analyses and reviewing the existing literature. The author was mainly responsible for writing the publication. The paper was accepted based on a double blind review process.

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LIST OF ABBREVIATIONS

B	– Average depreciation time of fixed assets
CA	– Current assets
CCC	– Cash conversion cycle, cycle time of operational working capital
D	– Amount of long-term debt
DIO	– Days inventory outstanding, cycle time of inventories
DPO	– Days payables outstanding, cycle time of accounts payable
DSO	– Days sales outstanding, cycle time of accounts receivable
E	– Amount of shareholder equity
EBITDA%	– Profit margin ratio
EVA	– Economic value added
FA	– Fixed assets
FA%	– Amount of fixed assets relative to net sales
FAM model	– Flexible asset management model
GAAP	– Generally accepted accounting principles
i_D	– Average interest rate of long-term debt
i_E	– Return on equity
IFRS	– International financial reporting standards
ILS	– Integrated logistics support
JIT production	– Just-in-time production
p	– Price charged by a company for taking the ownership of additional assets
r	– Residual term
ROI	– Return on investment
SMEs	– Small and medium size enterprises
WACC	– Weighted average cost of capital

PART I: Overview of the Thesis

1 INTRODUCTION

1.1 Background and motivation

The research on asset management is fragmented. Even though standards have been written to increase coherency in the definitions and practices of the theme, there are still various views even on the term 'asset' (see e.g. Amadi-Echendu et al., 2010). An asset could be for example a physical piece of production equipment, a financial investment, or an intangible asset such as a patent. A comprehensive, strategic view on asset management, considering all the assets in the company, has been recognized to be important in pursuing profitability, yet it has not been examined much in previous scientific literature. On the other hand, the tightening competition and the increasing dynamism in the operating environment of companies call for flexible asset management (Gibson, 2000; Navarro, 2009), which briefly means adjusting the amount of assets in a company according to the changes of market demand. This thesis contributes to the discussion by addressing comprehensive flexible asset management (including the management of both fixed assets and working capital) in the context of the industrial maintenance business.

Industrial maintenance has undergone significant changes recently: increasingly complex assets, an extensive maintenance backlog, and manufacturing companies focusing on their core competences followed by a lot of maintenance outsourcings have changed the business extensively and enhanced the strategic importance of maintenance to industrial companies (e.g. Al-Turki, 2011; Komonen & Despujols, 2013; Kumar et al., 2006; Simões et al., 2011; Taracki et al., 2009; Xia et al., 2011). As a result, the number of maintenance networks and inter-organizational partnerships has increased. In this context these networks consist of customer companies (hence the maintenance buyers) and different supplier companies (such as maintenance service providers or equipment manufacturers). Maintenance service providers are companies that create a major share of their cash flow by producing either individual or comprehensive maintenance services for other companies.

The reasons for forming long-term partnerships between companies include striving for win-win situations. The research on maintenance networks, however, has not been able to keep up with the changes in the industry. There are not enough valid tools to support decision making in maintenance networks, promote communication between the network partners, or specifically increase inter-organizational collaboration as regards asset management (Ahonen et al., 2010; MacCarthy &

Jayarathne, 2012; Olsson & Espling, 2004; Panesar & Markeset, 2008; Reinartz & Ulaga, 2008). It is widely believed that in the future competition is no longer between companies but between company networks. It is thus imperative to find new ways of collaboration between the partners to secure the survival and competitiveness of the whole network. As stated by Brandenburger and Nalebuff (1998, p. 21):

"Only recently have people begun to recognise that working with suppliers is just as valuable as listening to the customer."

This thesis integrates the research gaps described above. There is a need to examine how and with what kind of tools flexible asset management can be promoted best to improve profitability at the level of companies and company networks, and how the benefits created by this can then be shared between the network partners. Industrial maintenance companies and networks provide a fruitful setting for the research of the above-described development in the industry.

1.2 Research questions

The objective of this thesis is to prove how flexible asset management can be used in increasing the relative profitability of maintenance companies and networks in dynamic operating conditions. Dynamics is here seen to include rapid changes in e.g. market demand, either upward or downward. The focus of the thesis is on the downward changes and reacting to them, as they tend to cause more challenges in the profitability management of companies. Thus the upward changes of demand and the resulting investment needs are not analysed. The research questions of the thesis are the following:

1) What kind of requirements for asset management models are set by the increasing dynamism and complexity of operational environments?
2) How can flexible asset management increase the relative profitability in industrial maintenance companies and networks when operating in dynamic conditions?
3) How should the companies operating in maintenance networks share the value created by flexible asset management in order to reach a win-win situation?

Figure 1 presents how the publications attached to this thesis contribute to the research. Publication 1 expresses the research gaps present in the academic literature of asset management models, related to question 1. It can be seen that question 2 receives most attention, being addressed in publications 2-4. These three publications aim at unravelling the same major target, but at the same time there is progression in them: publication 2 introduces a basic model for flexible asset management, connecting fixed assets and working capital to profitability. Publication 3 extends the model to the direction of financial issues by including parameters like the return on equity and debt-to-equity ratio to the model. Publication 4 takes the discussion from the level of individual maintenance companies to the level of company networks. This is depicted with the broken lines in Figure 1. Finally, publication 5 is related to question 3 by taking a stand on value sharing in maintenance networks.

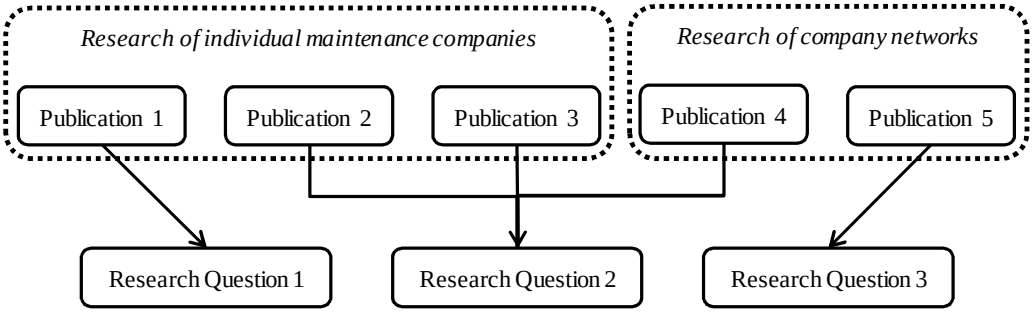

Figure 1. Contribution of the publications to the thesis

1.3 Positioning the research

The focus of the thesis is in the intersection of three broad research areas; asset management, strategic management, and management of company networks, while industrial maintenance forms the background and context for the research. The research has been conducted in maintenance companies and networks, and also the theory base of the thesis is discussed from the perspective of industrial maintenance business. This is illustrated in Figure 2.

This research contributes to the emerged need of flexible asset management, integrating asset management research with a perspective of managing the balance sheet of a company. As regards strategic management, the thesis builds on the research foundations of profitability analysis, as well as growth and profitability models. Considering the research on the management of company

networks, the emphasis of this thesis is on the aspect of value sharing and contracts in maintenance networks, based on the recent structural changes in the maintenance industry.

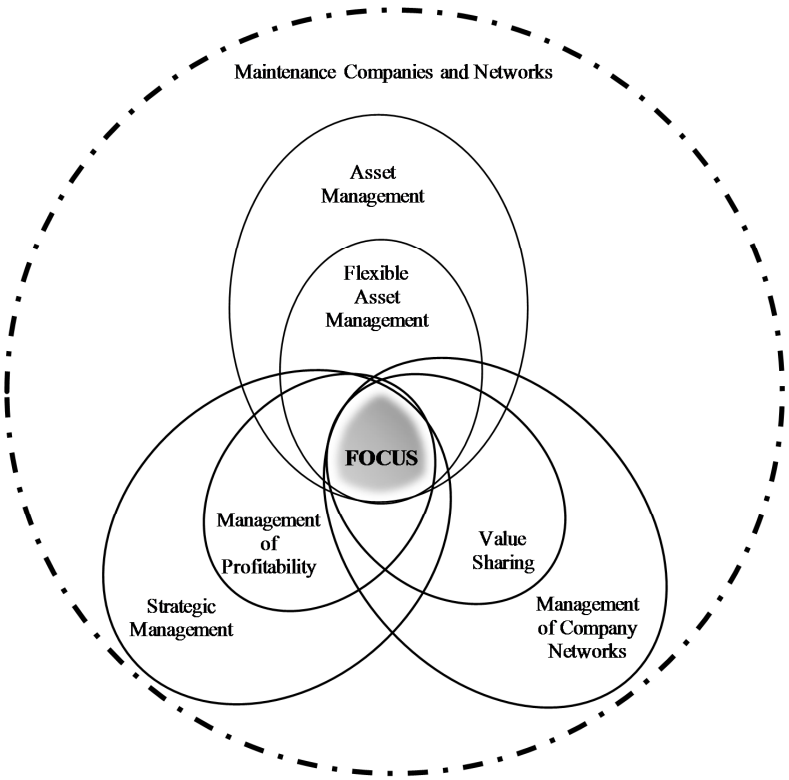

Figure 2. Focus of the thesis

The main research methods used in this research are a systematic literature review and analytical modelling. The modelling has been conducted with publicly available financial statement data of Finnish companies and company networks: the sample of Finnish maintenance service -providing companies was selected from the membership list of the Finnish Maintenance Society, and the analyses were complemented with studies of case networks selected for their particularly close and long-term collaboration.

1.4 Structure of the thesis

The thesis consists of two distinct parts: part I provides an overview of the thesis, while part II includes five individual publications which describe the conducted research in closer detail. Figure 3 illustrates the outline of the thesis, showing the main inputs and outputs for each chapter of part I. Chapter 1 contains the introduction to the thesis, converting the background of the research into a brief specification on the identified research gap, as well as the objective and research questions to fill it. In the introduction the thesis is also positioned in relation to the existing academic research fields and traditions. Chapter 2 includes the theoretical background of the thesis, summarizing the previous scientific discussion on the related topics. The purpose of this chapter is to show how the thesis integrates and complements the existing knowledge. Chapter 3 presents methodological justifications for the research in terms of the used methods and empirical data. After that, in chapter 4 the results of the various analyses presented in the individual publications are summarized and converted into answers to the research questions of the thesis. Finally, chapter 5 contains the conclusions of the thesis. Here the research results discussed in the previous chapter are reflected as regards theoretical contributions, managerial implications, research limitations, and suggestions for further research.

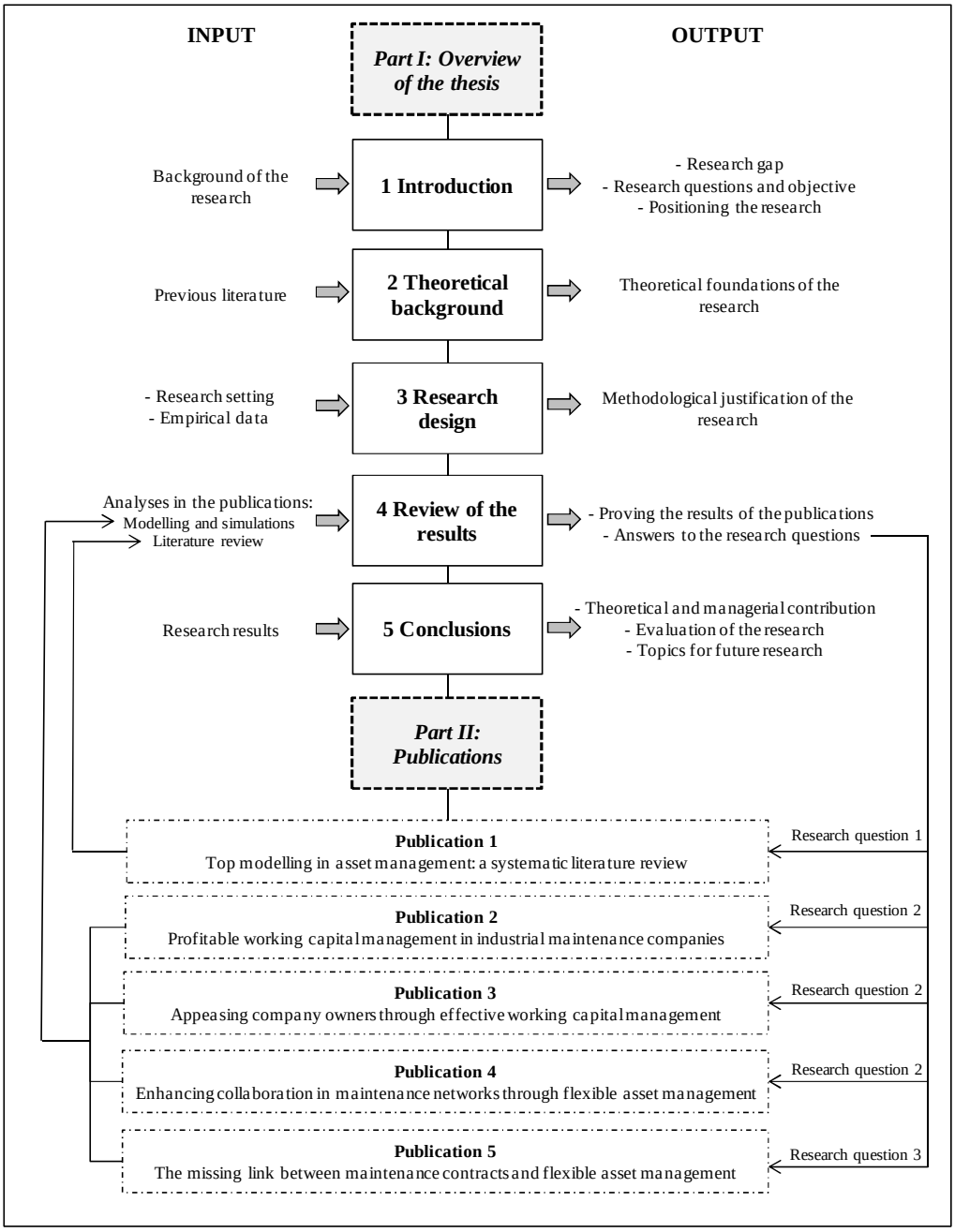

Figure 3. Outline of the thesis

2 THEORETICAL BACKGROUND

2.1 Asset management from the perspective of the balance sheet

There are various definitions for asset management in the existing literature (see e.g. Amadi-Echendu et al., 2010). Applying the definition presented by Herder and Wijnia (2012), asset management can be seen as generating as much value as possible out of assets. However, it remains unclear just how this value should be measured, and what exactly is included in 'assets'. Work has been done to increase coherency in the field through standards: the ISO 55000 series, including the first international standards of asset management, will be published probably in 2014 (Culverson, 2013; The Woodhouse Partnership Ltd, 2012). Before the ISO standards are ready, the British Publicly Available Specifications (PAS) 55-1 and 55-2 (2008) on asset management provide the most extensive definitions for the key terms of the research field. Although the focus of these standards is on physical assets, they highlight the importance of comprehensive asset management, thus managing all assets of a company in a holistic way to achieve the strategic goals of the company. This is the approach adopted also in this thesis.

Asset management has been recognized to be significant for companies in pursuing profitability (Aoudia et al., 2008; Lin et al., 2007; Tam & Price, 2008). In addition, dynamism is an essential part of doing business in today's markets (see e.g. Liyanage, 2007). For example, PAS 55-2 (2008) names adapting the asset management strategy according to the changes in the operational environment as one of the main challenges in asset management. One way to master the dynamism is flexible asset management (Gibson, 2000; Navarro, 2009); the amount of assets in one's balance sheet should follow the progression of changing demand. In dynamic market conditions the importance of flexible management of the balance sheet is emphasised (Komonen et al., 2012; More & Babu, 2011). Competition has globalized and intensified during the last decades. This has increased the importance of asset management; when it is difficult to gain profits due to tighter competition, profitability measures, such as return on investment (*ROI*) can be managed instead via the amount of invested assets (Gibson, 2000; Navarro, 2009). In addition, companies try to achieve lean operations more and more often. Flexible asset management is also important in striving for a lean business philosophy, as lean management calls for the minimization of the levels of many assets, for example inventories (Sawhney et al., 2009).

As regards fixed, physical assets the role of asset management and maintenance is further emphasized due to the extensive maintenance backlog which has in general accumulated lately (see e.g. Al-Turki, 2011; Komonen & Despujols, 2013; Simões et al., 2011). For example in Europe, a large part of the production equipment is becoming outdated, and the level of real investments remains low. Hatinen et al. (2012) have addressed the investment logics of companies providing maintenance services. They conclude that in the future it is of major importance for maintenance companies to forecast the future and adjust their operation according to changes in demand. In addition to the academia, also companies have registered the importance of flexibility in asset management: in an international survey conducted by the European Federation of National Maintenance Societies (2011), 67% of the respondents felt that the flexibility of production assets is either significant or very significant.

The view adopted in this thesis is that of balance sheet -based asset management. Amadi-Echendu et al. (2010) have quite a similar perspective. So far, research themes like capital structure research have contributed to the discussion on the management of liabilities, but comprehensive optimization of companies' assets has not received much attention in the academia. Previous research has addressed the inflexibility of fixed assets (e.g. Kärri, 2007). However, other asset types than fixed assets and long-term capital (see e.g. Chiou et al., 2006) have not usually been encompassed in the discussion on flexible asset management. In order to reach comprehensive asset management, it is necessary to address also the current assets in the company's balance sheet. This can be done for example through operational working capital management, which means management of inventories plus accounts receivable less accounts payable. Working capital management addresses both current assets (through inventories and accounts receivable) and short-term liabilities (through accounts payable). For example Ojanen et al. (2012) highlight the role of working capital management in managing one's assets flexibly. In this thesis, flexible asset management is studied through the management of fixed assets as well as operational working capital management, as illustrated in Figure 4. Also the other current assets and other short-term liabilities were included in the analyses, but their active management in companies and company networks has been left for further research.

Flexible management of fixed assets could be implemented by e.g. increasing capacity utilization, leasing capacity, eliminating bottlenecks, selling unnecessary assets, or developing the allocation of capacity investments in company networks (Kärri, 2007; Ojanen et al., 2012). However, these kinds of measures typically require quite a long time frame. The capital tied to working capital, on the

other hand, can be released more swiftly (Hatinen et al., 2012). Working capital management is currently gaining more visibility in the scientific literature, but in the past it has mostly been left without attention (Protopappa-Sieke & Seifert, 2011; Viskari et al., 2011). The latest economic crisis has raised the interest of both companies and academics towards more efficient working capital management, since it can have a significant impact on both company profitability and liquidity (Johnson & Templer, 2011; Talha et al., 2010).

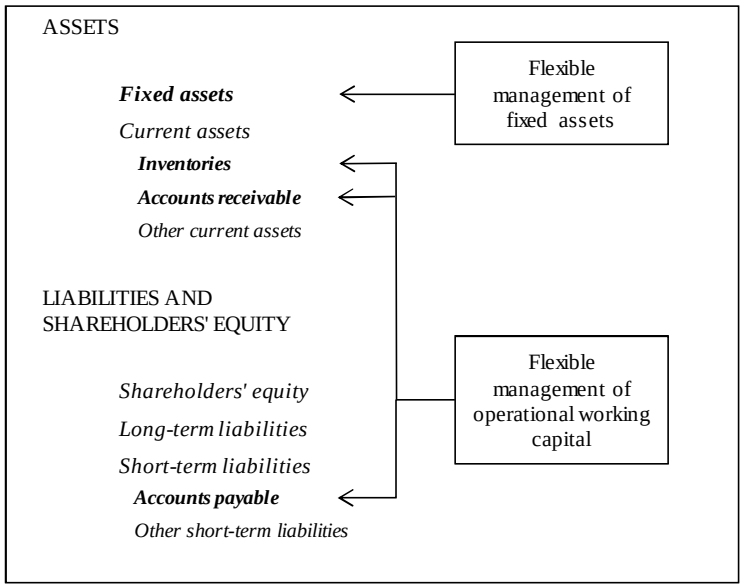

Figure 4. The balance sheet structure covered by the thesis

The relation between working capital management and profitability has been studied before (e.g. Chiou et al., 2006; Hill et al., 2010; Lazaridis & Tryfonidis, 2006). Viskari et al. (2012) conclude that the amount of working capital should be actively optimized and managed according to contextual factors: usually decreasing the amount of working capital can be regarded beneficial for companies (e.g. Deloof, 2003; García-Teruel & Martínez-Solano, 2007; Shin & Soenen, 1998), but not always so (e.g. Blinder & Maccini, 1991; Deloof & Jegers, 1996; Shah, 2009). Companies should balance between reducing the tied-up capital and minimizing the adverse effects caused by too low levels of working capital. These can include for example interruptions of production, delivery problems, worsened customer relationships, dropping sales, and missing the discounts for early payments (Blinder & Maccini, 1991; Molina & Preve, 2009; Ng et al., 1999; Wang, 2002).

Despite the previous literature on the topic, it still remains unclear how great the impact of working capital management on profitability actually is. In addition, Reed and Storrud-Barnes (2009) claim that most management theories focus on manufacturing companies only, and do not address the applicability of the contributions to the service sector. In many respects this is the case also in the research of working capital management. In some studies service companies have been excluded from the sample (see e.g. Deloof, 2003; Dong & Su, 2010), while others have included them in the sample, but not separated them from manufacturing companies (see e.g. Baños-Caballero et al., 2010; Jose et al., 1996). This thesis contributes to the discussion by addressing service providing companies, and by examining how the differences between manufacturing and service companies can be exploited in flexible asset management.

Even though the relation between working capital and profitability has been studied before, the perspective of the company's owners has not been embodied in the discussion. However, the literature on company valuation has linked the management of fixed assets and working capital to the cost of capital and the company owners' perspective through the return on equity (henceforth marked with i_E). For example Black et al. (1998) have presented a free cash flow model of company shareholder value, in which decreasing the amount of assets has a positive impact on future cash flows. Filbeck et al. (2007) on the other hand conclude that shareholders recognise and value efficient working capital management. Lambert and Pohlen (2001) stress the effect of both fixed assets and working capital on the economic value added (*EVA*). Their research topic has been carried on by Losbichler et al. (2008), whose main focus is on the role of working capital in creating shareholder value. This thesis contributes to the previous discussion by modelling the relations between asset management and the i_E explicitly.

2.2 Strategic asset management in profitability modelling

In addition to the company valuation literature, the impact of asset management on profitability and the company owners' contentment has also been recognized by the research area of profitability analysis. The DuPont model for financial ratio analysis was first introduced in the early 1900s by an engineer at the DuPont company (e.g. Burns et al., 2008). The original model simply described the relation between relative profitability and the invested capital. The concept of *EVA* came to the discussion on the efficient use of capital later, in the 1990s (see e.g. Veranen, 1996), and is often integrated with the original DuPont model. Like the DuPont model, the flexible asset management model (henceforth called the FAM model) introduced in this thesis combines aspects of asset

management, profitability and financing. Figure 5 illustrates the logics of the DuPont model and the FAM model to point out the main similarities and differences between the two. The mathematical derivation of the FAM model has been presented in publications 2 and 3 and is not repeated here.

There are three main differences between the presented DuPont model and the FAM model. The first one is related to the financial ratios to be analysed: while the DuPont model examines *EVA* through *ROI* and the weighted average cost of capital (*WACC*), the FAM model focuses on *ROI* as well as i_E. This is because the purpose of the use of the FAM model in this thesis is in inter-organizational contexts and company networks. Thus comparisons of the ratios between companies are of utmost importance, which favours percentage ratios like i_E over monetary ratios like *EVA*. The second difference between the models is the way the invested capital is grouped. As regards the FAM model, the focus in on asset management, and thus fixed assets and operating working capital are highlighted, while the other components of net working capital are pooled into a single residual group. The third and final main difference between the models concerns the cycle times used in the FAM model: unlike in the DuPont model, the amount of working capital is proportioned to the amount of sales to examine the matter through cycle times instead of monetary sums. The cycle times, expressed in days, are easier to grasp than monetary sums, and they also enable inter-organizational comparison.

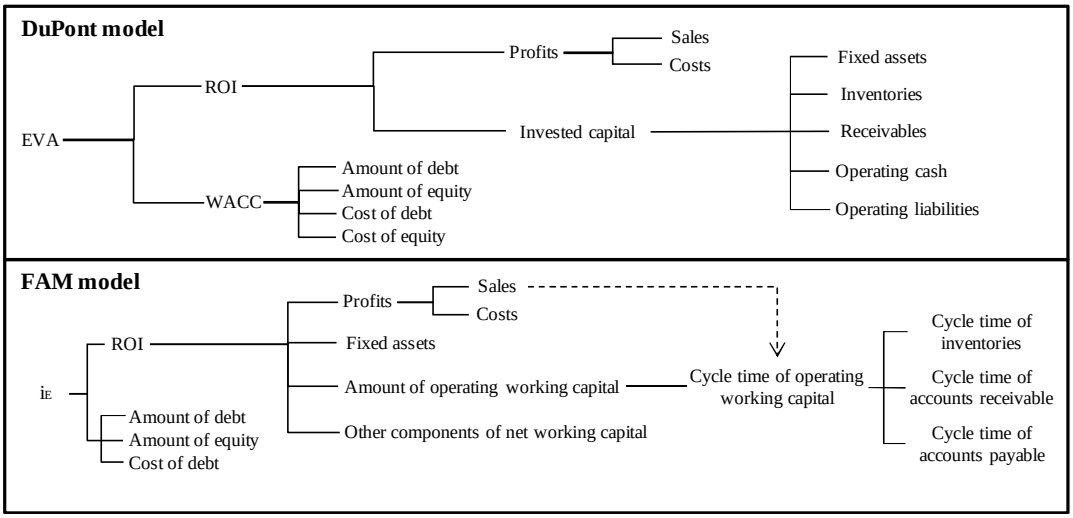

Figure 5. Comparison of the DuPont model (adapted from Petersen & Plenborg, 2012) and the FAM model constructed in this thesis

Some models quite similar to the FAM model have been introduced in previous literature. Higgins (1977) has presented a model for sustainable growth, integrating growth with profitability and capital structure. In his model the sustainable growth rate of a company is composed of profitability, the dividend pay-out ratio, the debt-to-equity ratio, and the ratio of the company's assets to net sales. The model does not separate fixed assets and working capital, but treats all assets together. The main purpose of this kind of models is to help managers preserve a viable capital structure during the growth or decrease of sales. Other growth and profitability models much alike that of Higgins (1977) have been discussed in the literature (see e.g. Aho, 1993; Donaldson, 1984; Ruuhela, 1982; Talonen, 1973). It must be noted that the previous models have only considered the management of individual companies. In this thesis, however, the discussion is brought to the level of company networks.

The FAM model examines asset management on the strategic level. According to Komonen et al. (2012), strategic company-level asset management has not been addressed often in the previous literature, but is currently gaining more and more attention, partly due to the increased dynamism of the operating conditions. As a result, new tools are needed for strategic asset management. It must be noted that, unlike tools like the FAM model may imply, in practice it is not easy for companies to adjust the amount of assets in their balance sheets according to the changes in demand. The management decisions made with strategic tools must be cascaded down in the organization to be implemented. As Parida (2012) emphasizes, it is crucial to translate the strategic level objectives in an appropriate language and to form for the tactical and operational levels of the company. Despite the probable challenges in cascading the strategic objectives downwards, strategic-level tools to support decision making in asset management are necessary.

According to PAS 55-1 (2008), asset management policies and strategies should be built on organizational strategic plans. However, the discussion in the literature has not reached strategies for comprehensive asset management, although more restricted perspectives, such as that of strategies in physical asset management, have been widely discussed. For example Swanson (2001) has classified maintenance strategies into reactive, proactive, and aggressive ones: reactive strategies advice intervention after a failure, proactive strategies try to maintain the asset before the failure occurs, and aggressive strategies, such as total productive maintenance aim at maximal overall effectiveness by adjusting also the function or the design of the physical production assets. This kind of directive typologies and guidelines should be constructed for comprehensive asset

management as well to convey the organizational strategic plans to objectives for the strategies of managing different types of assets.

2.3 Structural change in maintenance networks

There are various methods for structural change that can reform industries, for example mergers, acquisitions, takeovers and restructurings. The motives for these include e.g. increasing efficiency, acquiring new information, and achieving operating synergy such as economies of scale (Kärri, 1999; Weston et al., 2001). As regards the Finnish maintenance industry, many of these changes have taken place. Overall, however, the characteristics of the industry have changed rapidly in the past decades greatly due to the trends towards networking and focusing on core competences. The concept of networks was introduced by Miles and Snow (1986), while Prahalad and Hamel (1990) first addressed the core competences of a company. So far these phenomena have been extended into universal practices, boosted by the tightened competition. Accordingly, many companies are focusing on their core competences and outsourcing supportive business functions to outside suppliers (e.g. Hendry, 1995; Kakabadse & Kakabadse, 2002; Kremic et al., 2006; Kumar & Kumar, 2004; Redondo-Cano & Canet-Giner, 2010).

Numerous studies indicate that the impact of outsourcings has been particularly strong in the field of industrial services (see e.g. Bailey et al., 2002; Benson & Ieronimo, 1996; Broedner et al., 2009; Boulaksil & Fransoo, 2010; Harland et al., 2005; Holschback & Hofmann, 2011; McIvor et al., 2009). The trend has gradually extended to include functions of more importance (Harland et al., 2005; Hui & Tsang, 2006). This structural change has led to the emergence of a demand for a variety of industrial services. Consequently, plenty of start-up industrial service companies have been established throughout the world, rising to meet the demand (Hilletofth & Hilmola, 2010). Also many industrial equipment manufacturers have started to focus more on their service offerings, taking their share of the emerged markets (Ojanen et al., 2010).

Regarding fixed physical assets, maintenance operations have undergone a lot of outsourcings, boosted by the increasingly complex and interconnected assets (Kumar et al., 2006; Tarakci et al., 2009; Xia et al., 2011). The SFS-EN 13306 standard (2010) mentions outsourcing as one of the methods that can be used in the strategic management of maintenance. In addition, an international survey conducted by the European Federation of National Maintenance Societies (2011) shows that 24% of the surveyed companies have outsourced their maintenance activities at least partially. In

Finland the fixed physical assets are relatively aged, which emphasizes the role of maintenance and asset management. Moreover, the maintenance backlog is still increasing, as a vast majority of the production investments of Finnish industrial companies are directed to countries of low-level costs. The average age of the industrial production equipment in Finland had increased to over 17 years already in 2007 (The Finnish Maintenance Society, 2007), while the baseline in developed countries is somewhere between six and eight years (Kornev, 2009). Also the recent profitability problems of the pulp and paper industry have increased maintenance outsourcings in Finland, as pulp and paper companies have struggled to control their costs and outsourced almost anything else than their most important core functions.

Also the changes in production philosophies have affected the maintenance industry. Modern approaches like just-in-time (JIT) production aim at finalizing the products with a smooth material flow and without large inventories or work-in-process (e.g. Miyake et al., 1995). The lack of buffer stocks makes maintenance and reliability crucial for the company and the whole supply chain (Albino et al., 1992; Azadivar & Shu, 1999). This also holds for lean production, which can be considered to be an extended version of JIT. Moayed and Shell (2009) conclude on the basis of their survey that transferring into lean production typically decreases for example the spare part and material costs as well as inventory levels of a company, but increases the level of maintenance training and the costs of maintenance personnel. At the same time, maintenance usually moves from unplanned to preventive and finally towards total productive maintenance. Lately the concept of lean maintenance has been introduced in the literature as a prerequisite for lean production (Ghayebloo & Shahanaghi, 2010). Lean production and maintenance also incorporate the principles of sustainability, which are an important part of maintenance especially during the final phases of the asset life cycle.

The developments discussed above have created increasing collaboration along supply chains (Kroes & Ghosh, 2009; Yazici, 2012). Companies are engaging in more and more inter-organizational long-term partnerships, trying to reach a win-win situation or risk sharing (Duffy, 2008; Tenhunen, 2006). Raut et al. (2012) highlight the important role of these strategic partnerships in controlling the dynamism addressed in the previous subchapters. However, the increased inter-organizational collaboration and networking set their own challenges for decision making: the more complex service networks have created a need for more information. Many of the existing tools and methods to support decision making have become invalid in this new network context, and thus there is a growing need for novel tools to promote communication and trust

between network partners, increase collaboration in asset management, and support the decision making of company managers (e.g. Ahonen et al., 2010; MacCarthy & Jayarathne, 2012; Olsson & Espling, 2004; Panesar & Markeset, 2008; Reinartz & Ulaga, 2008).

An inter-organizational approach to the management of physical assets has been previously introduced by the US Army (2008) through integrated logistics support (ILS). ILS concerns comprehensive development of support strategies for Army material through meeting set objectives at minimum life-cycle costs, cycle times, and duplication of efforts. The elements of ILS include for example maintenance planning, supply support, support equipment, training, storage and transportation. Rutner et al. (2003) emphasize that implementing ILS successfully requires openness and cooperation in and between companies.

Previous research has proved that inter-organizational information sharing can improve the performance of networks or supply chains (e.g. Fantazy et al., 2011; Magnan et al., 2011). Competition has started to move from being between companies into being between company networks. In addition, as the competition between companies providing industrial maintenance services increases, the service providers are forced to make investments and search for new ways of creating value both for themselves and their customers (Hatinen et al., 2012; Paguio, 2010). Despite the recently increased networking, there is not yet much research done on industrial maintenance service companies, let alone maintenance networks. In this regard the research in the field has not been able to follow the rapid changes of the maintenance industry; the existing research has been mainly done from the point of view of service buyers (see e.g. Pintelon et al., 2006.; Sun et al., 2003; Waeyenbergh & Pintelon, 2002).

The structural changes of the maintenance industry emphasize the importance of contracts in maintenance networks. Contracts have been addressed in scientific research as for outsourced services and maintenance (e.g. Campbell, 1995; Hui & Tsang, 2006; Kumar et al., 2004; Levery, 1998; Martin, 1997; Ngwenyama & Bryson, 1999). However, as in the literature of maintenance in general, the perspective of the maintenance service providers has somewhat fallen behind that of maintenance customers. It should be remembered, however, that when operating in maintenance networks, also the maintenance service providers must understand how changes in the contract affect their profitability. When adopting the balance sheet -based perspective of asset management, the elements to be considered include for example the terms of payment and the ownership of spare parts (included in working capital management), and the ownership of the assets to be maintained

(included in the management of fixed assets). In fact, the current research suggests that working capital management should be done above all at the network level (Grosse-Ruyken et al., 2011; Randall & Farris, 2009). Another example of asset management in company networks is provided by Allee (2008), who has focused on the management of intangible assets. According to Markeset and Kumar (2005) it has become quite common for the service provider, instead of the customer, to own the physical assets.

Already at the end of the 1990s, Martin (1997) stated that maintenance companies are looking for new contract types to improve their profitability and to create additional value for their customers. He presented an explicit typology of maintenance contracts, including three different contract types: work package contracts, performance contracts, and lease contracts. Of these contract types the work package contracts are the simplest, meaning that the service provider performs the tasks given by the customer. In typical performance contracts the service company agrees to provide a certain level of asset availability for the customer. Thus the service provider is also responsible for maintenance management. In lease contracts the assets to be maintained are owned by the service provider, and the customer only pays for using them. Lease contracts are thought to decrease the risks of the customer (e.g. Pongpech et al., 2006). However, considering the prosperity of the whole maintenance network, the service provider should of course receive higher profits for accepting higher risks (Wang, 2010).

Compared with the work package contracts, the more complex contract types require more trust between the network partners. It is quite common to assume that each contracting party acts opportunistically, incurring surprising losses for one or both of the contracting companies (Teece, 1988; Vining & Globerman, 1999). As Panesar and Markeset (2008) claim, the conditions in a customer-service provider relationship should urge the service provider to create value for the customer actively. Thus the maintenance network should pursue a win-win situation. So far, the comprehensive perspective of balance sheet -based flexible asset management has not been adopted in this context: the profitability impacts of the assets included in the companies' balance sheets have not been addressed before. This thesis contributes to the existing knowledge by offering new insights into increasing profitability and sharing value in maintenance networks through flexible asset management.

3 RESEARCH DESIGN

3.1 Methods

This thesis represents management science with the focus on model building. In management science, the researchers' role is to bring control into managerial decision making, which is usually based on intuition or tacit knowledge (Fendt & Kaminska-Labbé, 2011). As regards the philosophical approach of the research, management science is often linked with instrumentalism and problem solving, but modelling is usually connected to realism (e.g. Kilduff et al., 2011; Nola & Irzik, 2005). Although the main research method of this thesis is analytical modelling, also a systematic literature review has been conducted in publication 1, as shown in Table 1. This review is necessary in order to discover the main research gaps in the existing knowledge. As Tranfield et al. (2003) highlight, it is rational to assess the existing body of knowledge through a literature review before bringing one's own contribution to the discussion. Conducting the literature review in a systematic way increases the transparency and repeatability of the research significantly, thus making the analysis as unbiased as possible (e.g. Colicchia & Strozzi, 2012; Fink, 2010; Kitchenham et al., 2010).

According to Demski (2007), analytical modelling is all about using deductive logic in depicting constructs or processes. The main advantage of modelling as a research method is its transparency, which promotes high internal validity of the constructs. Different models have traditionally been used a lot in management research: already in 1989 Gorry and Morton (1989) emphasized the importance of models in supporting the decision making of company managers. Since then, analytical models in management research have become even more popular, and are used not just by researchers but also by the actual decision makers (see e.g. Mun, 2008). As stated in a report by the Transportation Research Board of the National Academies (2005), analytical models can be used in asset management for example in analysing and comparing the effects of investment options, or in examining optimal maintenance strategies. The report also states that in general the existing asset management models cannot support decision making in complex situations where e.g. several different asset types or target variables should be considered at the same time. The perspective of the report is that of transportation infrastructure asset management, but the lack of these models is a much more extensive challenge and can also be generalized to the level of comprehensive, balance sheet -based asset management addressed in this thesis. As stated by Galar

et al. (2012), asset managers are in need of decision-making tools that address the 'big picture', thus integrating asset management with company profitability.

Table 1. Research methods used in the publications of the thesis

Publication	*Research Methods*	*Description*
Publication 1	Literature review	A systematic literature review on previous asset management models
Publication 2	Analytical modelling	FAM model is derived and then validated with empirical data
Publication 3	Analytical modelling	FAM model is expanded and then validated with empirical data
Publication 4	Analytical modelling, Simulations,	FAM model is applied at the level of company networks
Publication 5	Analytical modelling, Simulations	A new pricing logic is derived and then validated with empirical data

Analytical modelling can be seen to be connected with design science research, the main driver of which are pragmatic problems in real companies (van Aken & Romme, 2009). However, in this thesis, the role of market testing as a part of modelling is not as extensive as in design science research. Instead, the FAM model and the pricing logic mentioned in Table 1 are validated with empirical data through different analyses and simulations. The purpose of the simulations is to gain a better insight into and to develop real-world systems, which for some reason cannot be experimented directly (Banks, 2009; Robinson, 2004). Regarding this research it is necessary to simulate flexible asset management in maintenance companies and networks (real-world systems) to perceive the possible benefits created by inter-organizational cooperation. This cooperation requires mutual trust and openness between the companies, and the decision makers would not adopt it without prior simulations. The thesis contains features from both descriptive and normative approaches, but the main focus is on descriptive research and thus on gaining more understanding on the subject.

3.2 Data collection

In this subchapter the main aspects of collecting data for the publications is discussed. The research data used in the publications is presented in table 2, while figure 6 shows the companies studied in the publications.

Table 2. Data used in the publications of the thesis

Publication	*Data type*	*Databases used*	*Description of the data*
Publication 1	Literature	Scopus, ISI Web of Science	A systematic literature search in the databases resulted in a sample of 55 journal articles
Publication 2	Financial statements	Voitto+	Financial statements from 2004-2008 of 18 Finnish maintenance companies (5 large companies, 13 SMEs).
Publication 3	Financial statements	Voitto+	Financial statements from 2004-2009 of 18 Finnish maintenance companies (5 large companies, 13 SMEs).
Publication 4	Financial statements	Voitto+	Financial statements from 2006-2010 of two maintenance networks: a pulp network and an energy network
Publication 5	Financial statements	Voitto+	Financial statements from 2010 of two case companies: a maintenance customer and a service provider

The research of this thesis was done with data of Finnish maintenance companies and networks. Data on foreign maintenance industries was not within reach, and comparing companies from different countries with each other would have required extensive understanding on their economic, cultural, and legislative environments. The Finnish maintenance industry is compact and simple to examine, compared to the international markets. Finland is also a favourable environment for research on inter-organizational asset management: Finnish companies tend to pay their accounts payable on time, being notably meticulous compared to average companies in e.g. southern Europe. As regards maintenance, Emmanouilidis and Komonen (2013) have studied the differences between Greece and northern Europe on physical asset management practices. They state that compared to Greece, the companies in northern Europe have adopted a more proactive approach to maintenance, and they also give more weight to developmental aspects like return on assets or asset life cycle. The economic life cycle of physical assets is significantly lower in Greece than in Northern Europe, events are registered in computer software in a less systematic way, and the investment planning tends to be cost-based, as opposed to the profit-based thinking in Northern Europe. Considering all the above-mentioned aspects, it would of course be desirable to conduct this kind of research on maintenance networks of other countries, but this thesis only discusses the Finnish maintenance industry, leaving the international discussion for further research.

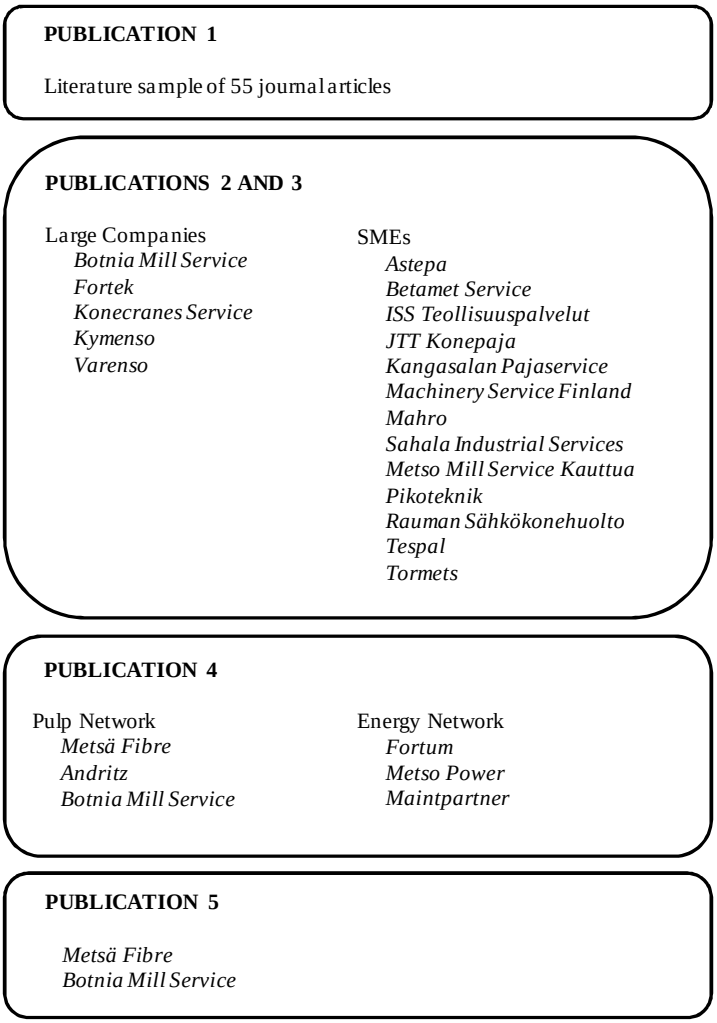

Figure 6. Companies studied in the publications

Publication 1

As opposed to the other publications, publication 1 is not based on empirical data. The purpose of the publication is to search systematically for previous articles on asset management models with a management perspective. To accomplish this, related search terms (asset management, model, framework, tool, profit, profitability, cost) were merged into different combinations and entered into the databases Scopus (Elsevier) and ISI Web of Science (Thomson Reuters). These two databases were chosen for their world-leading reputation and quality. The searches resulted in 449 potentially

relevant publications. To screen and form the final literature sample for the research, the following inclusion criteria were used:

(1) The selected articles had to have the perspective of industrial company management. This was essential, as the theoretical foundation for publication 1 was the balance sheet -based asset management presented in chapter 2.1 of this thesis.

(2) It was required that asset management and modelling had a significant role in the selected articles.

(3) The selected articles had been published in scientific journals.

The 449 publications went first through a title check, then an abstract check and finally a full text check to make sure that the three inclusion criteria would hold. After this literature selection process there was a sample of 55 journal articles on asset management models. The analysis of the sample is described in chapter 4 of this thesis.

Publications 2 and 3

In publications 2-5, the empirical data consisted of financial statements. This type of data features an inherent weakness: the figures include the operations of the whole company, and it is nearly always impossible to analyse the costs or capital incurred by a single customer or a supplier. In a research of inter-organizational asset management this would be highly valuable information. Yet, although the suitability of financial statements as a research data has been widely discussed, no better alternative has been found (Paranko, 2012). Indeed, when integrating research on company profitability, finance, and inter-organizational asset management, it is hard to see the required data being collected anywhere else than financial statements. This has been recognized also by Amadi-Echendu et al. (2010), who state that using the accounting system in examining comprehensive asset management is justified due to the audited data it produces, and because this data is already used in the decision making at the highest levels of the organization.

In publications 2 and 3, the constructed FAM model was validated through empirical analysis done with the data of 18 Finnish industrial maintenance companies. The companies were selected from the membership list of the Finnish Maintenance Society. Probability sampling was not used, because a complete list of the population was not available. The author also considered it important

that the sample would especially represent the features of the industrial maintenance business. Thus companies operating also for example in equipment manufacturing or infrastructural maintenance had to be delimited from the sample: only companies whose main focus is on industrial maintenance were accepted. Also micro enterprises were delimited from the sample, because there are not many micro companies that are members of a maintenance society, their financial statements are not necessarily available, and it was practically impossible to identify micro companies focused on industrial maintenance business, due to inadequate information. Finally, the selected companies had to have existed through the period of analysis, and their financial statements had to be available. This final criterion may feel self-evident at first, but since the industrial maintenance sector in Finland is still quite young and a lot of mergers and acquisitions have been made in the field, it certainly affected the sample size.

Following the sampling criteria presented above, 5 suitable large enterprises were found (see figure 6). After that, 13 equally suitable small and medium size enterprises (SMEs) were included in the sample to make it representable: this kind of structure represents well the Finnish industrial maintenance sector, which consists of only a few large players and mostly small enterprises. Though 18 is not a large sample size, when checked against the reports of the Finnish Maintenance Society (2007), the number of employees in these 18 companies was approximately 26% of the employees of the whole maintenance sector in Finland. The research period was 2004-2008 in publication 2 and 2004-2009 in publication 3. Data on several years was needed to gain understanding on the economic state and development of the maintenance companies. At the time of collecting the financial statements, these were the most recent fiscal years on which data was available. To collect the financial statements, Voitto+ database was used throughout the study. Voitto+ is maintained by Suomen Asiakastieto (loose translation Finnish Customer Information), a leading provider of corporate information in Finland.

Publication 4

In publication 4, the empirical data consisted of the financial statements of two case networks, one representing the pulp industry and the other the energy industry. As depicted in Figure 6, both networks included three companies: a maintenance customer (Metsä Fibre in the pulp network, Fortum in the energy network), an equipment provider (Andritz in the pulp network, Metso Power in the energy network), and a maintenance service company (Botnia Mill Service in the pulp network, Maintpartner in the energy network). Both networks were real, thus the service and

equipment providers were actually responsible for some part of the maintenance operations of the customer companies. The pulp industry represents traditional Finnish knowhow in mature markets, which have recently undergone a drastic decrease in demand. Energy industry, on the other hand, is receiving more and more attention, and the market demand will increase also in the future, enabling major investments by the companies. Thus these case networks provided an interesting ground for the benchmarking research in publication 4.

Metsä Fibre is a large producer of market pulp. In 2010, the net sales of Metsä Fibre were 1.365M€, with a balance sheet total of 996M€. Andritz is a universally known metal company which supplies machinery and related services for pulp and paper companies. Andritz's net sales were 542M€ and balance sheet total 317M€ in 2010. Botnia Mill Service provides comprehensive maintenance services for Metsä Fibre, and had the net sales of 54M€ and balance sheet of 20M€ in 2010. Regarding the energy network, Fortum is a large power and heat producer that operates in northern Europe. The 2010 net sales of Fortum were 6.296M€, and the balance sheet total was 21.964M€. Metso Power provides technology and services for the energy industry, with net sales of 280M€ and balance sheet of 288M€ in 2010. Finally, Maintpartner is an integrative maintenance service provider, selling comprehensive maintenance solutions for e.g. the energy, metal, chemical and food industries. The net sales of Maintpartner were 92M€ in 2010, and the balance sheet total was 50M€.

Selecting these particular companies for the research was done on the basis of the maintenance companies. As stated above, there are not many large Finnish companies providing comprehensive industrial maintenance services. When conducting the research for publication 4, the group of large maintenance companies used in publications 2 and 3 was no longer completely valid: Kymenso had been bought by Empower, Fortek and Varenso had been merged into Efora, and Maintpartner had been launched. Thus the newly shaped group of large maintenance companies consisted of Botnia Mill Service, Efora, Empower, Konecranes Service, and Maintpartner. Of these companies Efora was not incorporated until 2009 (compared to the research period of 2006-2010), the financial statements of Empower reflected energy industry as well as industrial maintenance, and Konecranes Service was not only a service provider but also an equipment manufacturer. Thus Botnia Mill Service and Maintpartner were chosen for the research. Botnia Mill Service has only one main customer: Metsä Fibre, which also partially owns it. Thus Metsä Fibre was selected as the customer company of the pulp network. Andritz was chosen as the equipment provider because it has extensive cooperation with both Botnia Mill Service and Metsä Fibre. As regards the energy

industry, Maintpartner was born from Fortum Service in 2006. Fortum was thus the best choice for the customer company of the energy network. Various large delivery projects between Metso and Fortum had been announced, so Metso Power was chosen as the service provider for the energy network.

Publication 5

Publication 5 approaches flexible asset management in maintenance networks from the perspective of bilateral maintenance contracts. The empirical data of the publication consisted of the financial statements of Metsä Fibre and Botnia Mill Service from 2010. Again, data from more recent years was not available at the time of conducting the research. The author decided to use data of just one year because the publication focused on the profitability impacts of the new contract type on the current state of the companies. Analysing data of several years would also have made the publication overlong. Metsä Fibre and Botnia Mill Service were selected as case companies for their extraordinarily close and long-term collaboration: Botnia Mill Service was originally founded from the internal maintenance department of Metsä Fibre. The contracts discussed in the publication were very collaborative and required trust between the contracting parties. Hence, these specific case companies were particularly suitable for this kind of research, compared with average customer-service provider relationships in the market. The pulp and paper industry also needed new ways of creating additional value due to the recent profitability problems.

In publications 2 and 3, a sample of maintenance companies was examined to gain understanding on their profitability, assets, and financial state. However, in publications 4 and 5 the data was that of case networks and companies. This transition to case research was a necessary simplification to contribute to flexible asset management practices and contracts in maintenance networks, which was the focus of the papers. It can be seen in Table 1 that as opposed to publications 2 and 3 in which the FAM model was validated through empirical data, publications 4 and 5 include more simulations. Simulations require lots of analyses, and thus the amount of empirical data was limited to keep the publications streamlined. Yin (2009) explains that case research contributes to research settings with ‘how’ or ‘why’ –questions and where there is a need of deep understanding of a certain phenomenon. These conditions were fulfilled in publications 4 and 5 to a great extent.

4 REVIEW OF THE RESULTS

4.1 Summary of the publications

In this chapter the research results of each of the five publications are briefly summarized. After that, chapter 4.2 summarizes the objectives and main results of the whole thesis from the perspective of the three research questions set in chapter 1.2.

Publication 1

The objective of publication 1 was to find out, using a systematic literature review, what kind of asset management models have been introduced previously in academic journal publications, and what kind of research gaps there were in the research field. The literature selection process (discussed in chapter 3.2) resulted in a sample of 55 journal articles. These articles were then analysed as regards time distribution, asset type, model perspective, and model features. The results of these analyses are discussed below.

The time distribution of the literature sample shows clearly an increase in the number of scientific journal articles addressing asset management models during the last ten years: of the 55 publications in the sample, as many as 48 were published in 2001 or later. This reflects the emerging need for novel asset management decision-making tools. As regards the various definitions of asset management, discussed in chapter 2.1, it was of high importance to study what kind of assets had been modelled in the previous literature. Figure 7 shows the asset type distribution in the reviewed publications, classified according to the balance sheet -based perspective on asset management. Fixed assets are denoted with FA, while CA stands for current assets. Each of these categories has been divided into a few subclasses. Long-term (FA) investments have been merged with current financial assets, as the articles in question addressed them both.

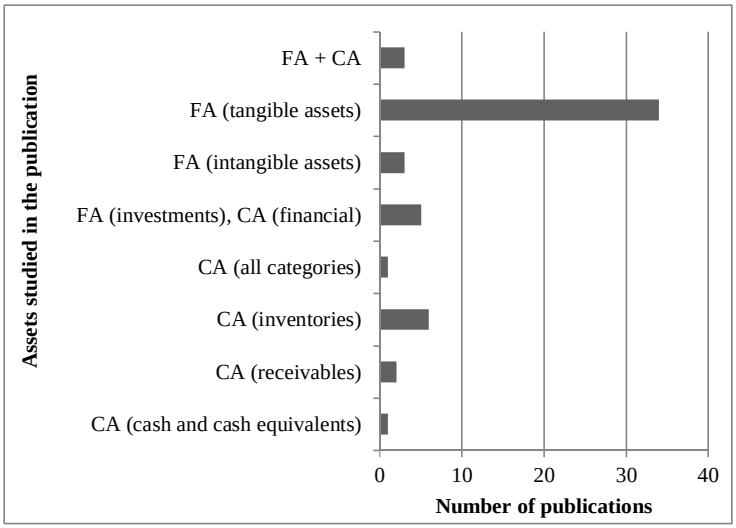

Figure 7. Distribution of asset types in the literature sample of publication 1 (FA stands for fixed assets, CA for current assets)

It can be concluded from Figure 7 that fixed, tangible assets have received attention in a vast majority of previous publications. After them, the largest categories are models for inventory management, as well as financial asset and investment management. These research areas are extensive, so only a small part of the researchers have positioned their research under the term 'asset management'. It can also be noted in Figure 7 that comprehensive asset management (denoted as FA+CA) has not been studied much, even though it would be beneficial especially for strategic asset management tools to adopt a holistic view on the company's assets. I also noted that most of the articles in the literature sample did not include any definition for asset management. Considering the diversity shown by the various categories in Figure 7, this feels irrational.

Next I studied whether the existing asset management models had taken the emergence of inter-organizational networks into account: four articles indicated that the created model could be used by either the asset owner or a supplier company. Most of the articles in the sample did not adopt this inter-organizational perspective. This is also supported by the information in Table 3, which shows the levels of inspection in the publications. A majority of the articles discussed asset management on the level of a single asset or an asset fleet. Only one article considered the issue at the inter-organizational level.

Table 3. Levels of inspection in the literature sample of publication 1

Level of inspection	*Number of publications*	*Share of publications*
Single asset	20	36%
Asset fleet	25	45%
Company	8	15%
Service	1	2%
Customer –service provider relationship	1	2%

Most of the models in the sample addressed long-term asset management: they were designed to support strategic decision making. This can be seen to be inconsistent with the levels of inspection discussed above. Further classification of the models showed that most of the existing models were quantitative: numeric calculations and mathematical models, as opposed to conceptual structures and constructs. In addition, many of these quantitative models were quite scientific and abstract by nature, and thus not very practical to use. For example the reader may not have been properly instructed on applying the model, or the input parameters for the model were very difficult to quantify in real companies. Considering the emerging need for asset management tools of industries, this is a real challenge for future research.

Publication 2

In publication 2 the focus of asset management was on working capital, since it has been studied much less than fixed asset management. The main goal of publication 2 was to model the effect of working capital management on the *ROI* in industrial maintenance service companies. The greatest differences in the cycle times of working capital between large maintenance companies and SMEs were analysed, as well as the impact of the dynamic future on the profitability of the maintenance companies, and the role of working capital management in relation to that. In the publication, the FAM model was introduced as

$$ROI = \frac{EBITDA\% - \left(FA\% * \frac{1}{B-1}\right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%} = \frac{EBITDA\% - \left(FA\% * \frac{1}{B-1}\right)}{\frac{DIO}{365} + \frac{DSO}{365} - \frac{DPO}{365} + \frac{r}{365} + FA\%} \quad (1)$$

where

ROI is the return on investment,

EBITDA%	is the profit margin ratio,
FA%	is the amount of fixed assets relative to the net sales,
B	is the average depreciation time (in years) of fixed assets,
CCC	is the cycle time of operational working capital,
r	is the residual term, consisting of other current assets and other current liabilities,
DIO	is the cycle time of inventories,
DSO	is the cycle time of accounts receivable, and
DPO	is the cycle time of accounts payable.

The mathematical derivation of the model can be seen in publication 2. The model shows that the *ROI* increases if ceteris paribus the *EBITDA%* or the *B* increases, or if the *FA%* or the *r* decreases. The correlation between the *ROI* and the *CCC* is negative: when the cycle time of working capital increases, the *ROI* decreases. This also holds when the *DIO* or the *DSO* increases, or when the *DPO* decreases. Figure 8 presents the impact of the *CCC*, *FA%*, and *EBITDA%* on the *ROI*. In the figure, the *CCC* gets values from zero to 100 days, while the other parameters of the FAM model have been set constant at the average level of the sample of maintenance companies. The curves indicate how the changes in the *CCC* affect the *ROI* on different levels of the *FA%* (the chart on the left) and *EBITDA%* (the chart on the right).

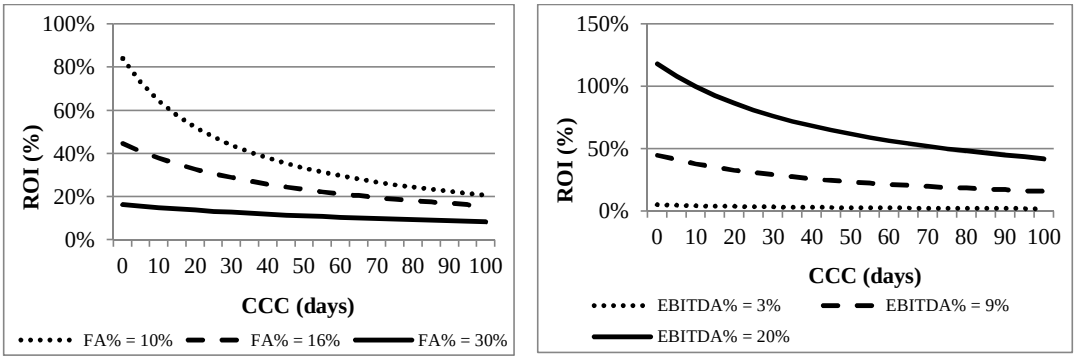

Figure 8. The *ROI* as a function of the *CCC* and the *FA%*, as well as the *CCC* and the *EBITDA%*

It can be seen in Figure 8 that the effect of the *CCC* on the *ROI* is greater in companies with a lower *FA%*, and thus they should pay particular attention to effective working capital management. This is the case for industrial maintenance companies in general, as the analysis in publication 2 showed that their *FA%* was remarkably low. It can also be noted that working capital management cannot save profitability when the *EBITDA%* is very low, but it can certainly destroy profitability when the *EBITDA%* is high.

Next, the parameters of the FAM model were calculated as average values for both large companies and the SMEs of the examined sample of maintenance service providers. I noticed that the *CCC* and *FA%* were significantly lower in the large companies, indicating that they operated with exceptionally light balance sheets. This may be due to economies of scale, but also due to their providing services mostly for their host companies, as Botnia Mill Service or Konecranes Service did. This close cooperation with their customers can have affected the balance sheet structure of the service companies. According to the results shown in Figure 8, the lower *FA%* of the large maintenance companies means that the changes in the *CCC* have more impact on their profitability, compared to the SMEs. Thus especially large maintenance service providers should pay attention to effective working capital management. On the other hand, as highlighted by Baglee and Knowles (2010), SMEs tend to have a static and reactive approach to physical asset management. This observation can most likely be generalized to all asset management in SMEs, meaning that they have a lot to improve as regards flexibility in the dynamic environment.

Finally I analysed how changes in the *EBITDA%*, caused by the dynamic operating conditions, could be compensated with management of the *CCC* to keep the *ROI* from decreasing. Figure 9 shows the results of this analysis for the large maintenance companies and the SMEs separately. The target level of *ROI* was set to 30% for the large companies and 26% for the SMEs. The vertical dotted lines depict the actual state of the companies during the research period 2004-2008. On the basis of Figure 9, it can be concluded that the changes in the *EBITDA%* cause extensive changes in the *ROI*, and that it would be difficult to compensate for these changes by just managing the *CCC*.

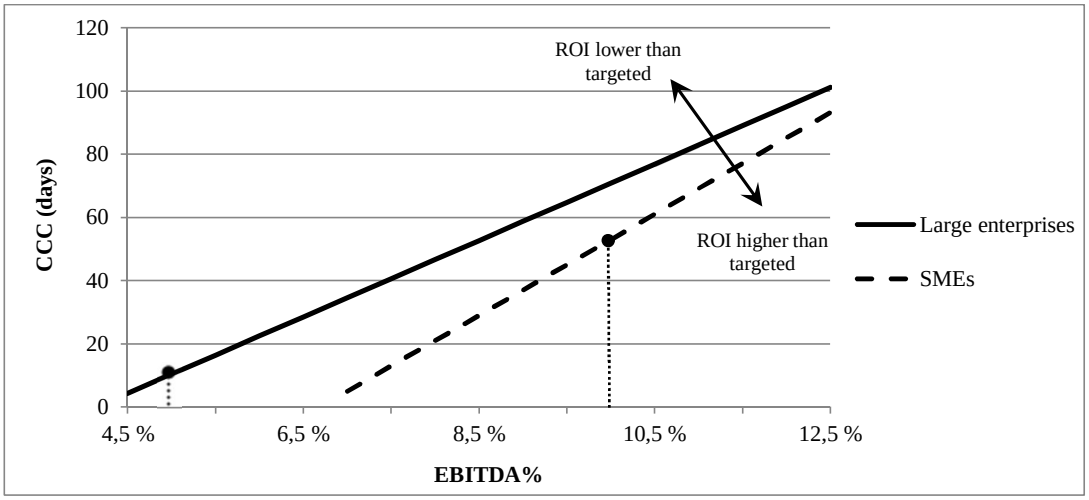

Figure 9. The combinations of the *CCC* and the *EBITDA%* which would result in the target values of the *ROI* in large maintenance companies and SMEs

Publication 3

In publication 3, the research on the FAM model was taken one step further by introducing the return on equity and financial parameters to the equation. The dynamic operating conditions were studied through changes in the interest rate of debt and in the debt-to-equity ratio. The focus was still on working capital management, to gain enough understanding on the subject. In this publication, analytical modelling was used to integrate the managerial and financial components of flexible asset management. Mathematically, the FAM model was extended into

$$i_E = \frac{EBITDA\% - \left(FA\% * \frac{1}{B-1}\right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%} * \left(1 + \frac{D}{E}\right) - i_D * \frac{D}{E} \qquad (2)$$

where

i_E is the return on equity,

D is the amount of long-term debt,

E is the amount of shareholder equity, and

i_D is the average interest rate of long-term debt.

Again, the derivation of the equation is shown in the publication. It can be seen in the equation that, ceteris paribus, the i_E would increase when decreasing the *CCC* or the *FA%*. Another interesting point is that when the *ROI* is greater than i_D, increasing the debt-to-equity ratio would increase the i_E. This is called financial leverage. For the maintenance companies studied in the publication, the i_E was very close to the *ROI*, because their debt-to-equity ratios were low. Thus the financial leverage was not really taken advantage of. It can be also seen that the *FA%* has a large impact on the connection between the *CCC* and the i_E. Thus it would be optimal to manage both fixed assets and working capital at the same time to preserve profitability.

Next, the i_D and the debt-to-equity ratio were altered to see how the *CCC* should change to keep the i_E from changing. Figure 10 shows the results for the maintenance SMEs (the upper half of the figure) and the large companies (the lower half of the figure). The grey circles illustrate the average position of the companies during the research period 2004-2009. I conclude that the maintenance companies could compensate changes in the financial conditions by managing their working capital. However, their debt-to-equity ratios were low (0.25 for the SMEs and 0.08 for the large companies), and incurring more debt would allow them to operate with longer *CCCs*, or to increase their profitability. Of course increasing the debt-to-equity ratios should be done with caution, for if the *ROI* becomes smaller than the i_D, the financial leverage turns into a hindrance.

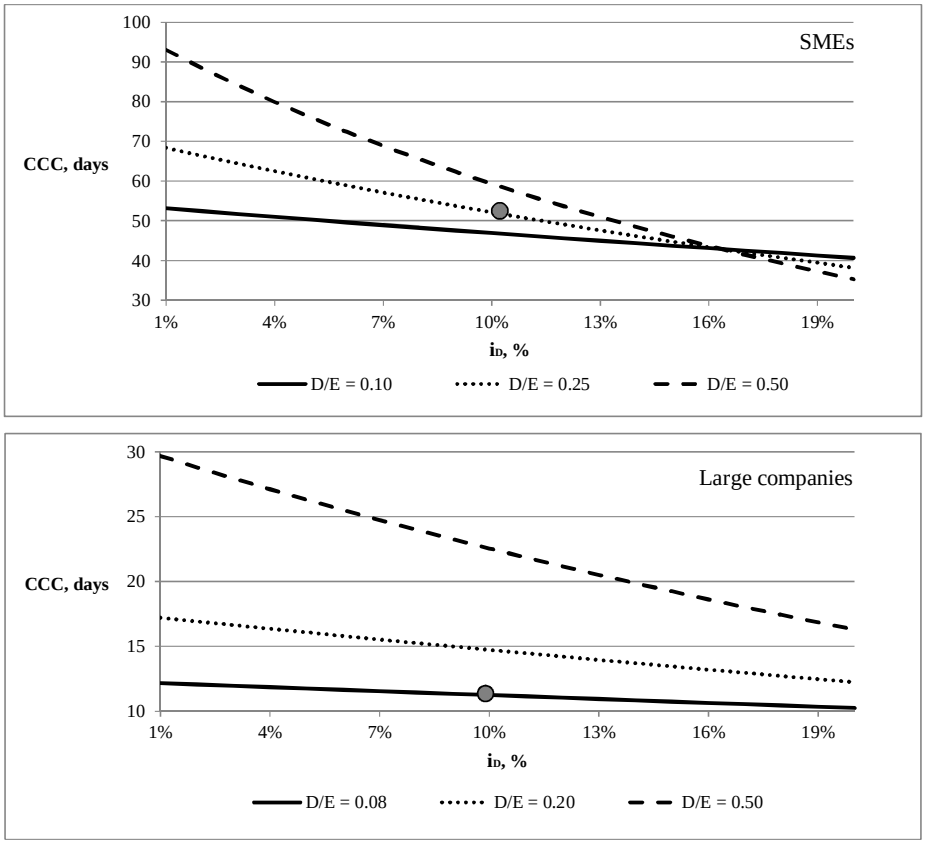

Figure 10. Length of the *CCC* required to keep the return on equity unchanged when both the interest rate of debt and the debt-to-equity ratio vary

Publication 4

Publication 4 studied the profitability of the two case networks through the FAM model, and took a stand on how benchmarking and inter-organizational collaboration in asset management could improve their profitability. Here the focus was on comprehensive asset management, including both working capital and fixed assets. Figure 11 aggregates the average data of the case networks from 2006 to 2010. By comparing the companies and networks to each other, the main differences in the components of profitability were analysed in the publication. As a conclusion, the pulp network had higher *ROIs* and smaller fixed asset ratios than the energy network, thus managing its assets in a more profitable way. The pulp network was also more uniform regarding profitability: in the energy

network Fortum, the maintenance customer company, was by far the most profitable company. On the other hand, the energy industry is much more stable than the cyclical pulp industry.

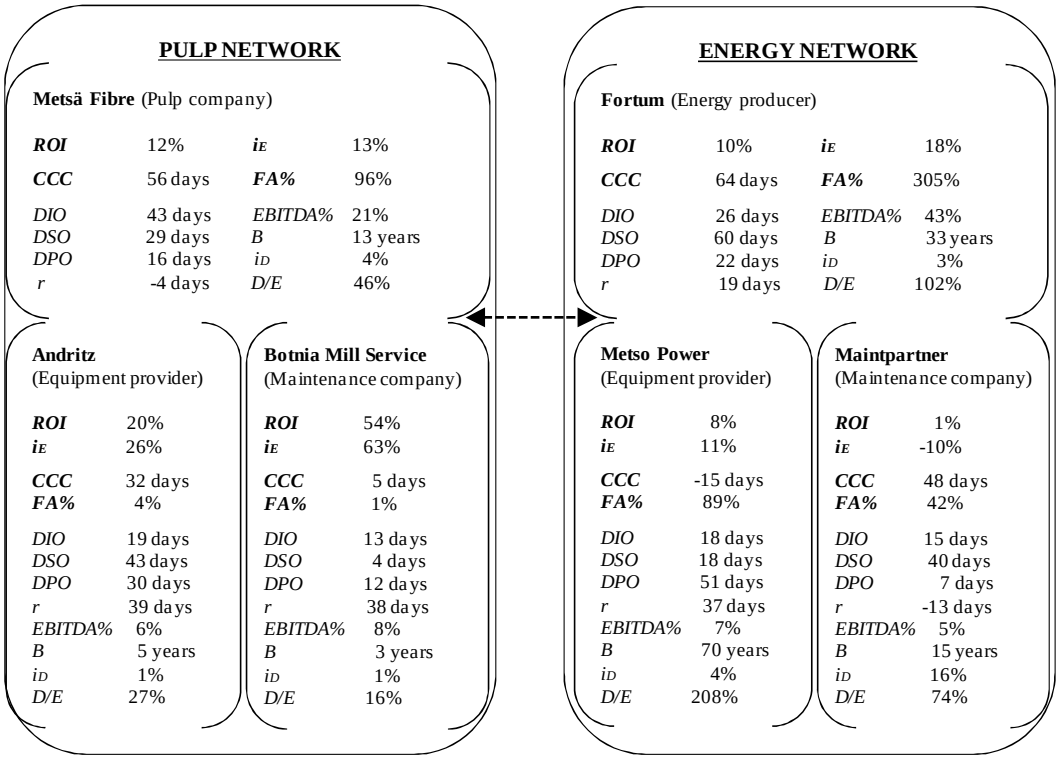

Figure 11. Average data of the case networks in publication 4 from 2006 to 2010

The observations discussed above were next transformed into simulations on improving profitability through rationalizing asset management practices at the network level. Two different simulations were created, one for each case network:

(1) The simulation for the energy network examined whether the supplier companies (Metso Power and Maintpartner) could improve their profitability by benchmarking the asset management practices of their counterparts in the pulp network. Also the impacts on the customer company Fortum were analysed.

(2) The simulation for the pulp network was about staying profitable when the demand is cyclical. The focus was on how the network should manage its assets if there is an extensive collapse in the net sales.

The simulation on the energy network showed that by transferring some fixed assets and working capital from their own balance sheets to the balance sheet of Fortum, Metso Power and Maintpartner could improve their *ROI* and i_E significantly, as illustrated in Table 4. The balance sheet of Fortum is so heavy that the profitability impact of the simulation is minimal. However, Fortum should be somehow compensated for including additional assets into its balance sheet, so that a win-win situation could be achieved: basically, the *ROI* of the company accepting additional assets into its balance sheet would decrease, so a specific price should be set for this asset ownership. Through economies of scale or efficiency increases, value can then be created for each company. This was examined further in publication 5.

Table 4. The effects of simulated changes to the energy network companies in publication 4

The actual situation			
	Fortum	**Metso Power**	**Maintpartner**
FA%	288%	69%	25%
CCC	52 days	-68 days	13 days
ROI	9%	13%	0%
iE	17%	11%	-7%
The possible situation according to the simulation			
	Fortum	**Metso Power**	**Maintpartner**
FA%	289%	57%	7%
CCC	53 days	-68 days	5 days
ROI	9%	21%	54%
iE	17%	20%	75%

Regarding the pulp network, the simulation made the net sales to drop suddenly by 50%. To remain profitable, the companies should be able to adjust the amount of their assets accordingly. Botnia Mill Service and Andritz had light balance sheets and were thus flexible. The pulp company Metsä Fibre, on the other hand, would encounter problems in rearranging its assets. Thus Metsä Fibre should increase the flexibility of its assets proactively through for example leasing and outsourcing arrangements. Table 5 shows what would happen to the profitability of Metsä Fibre if, during the decrease of net sales, it was able to decrease its fixed assets and/or working capital by 0%, 15%, or 30%. Judging from the table it would be crucial to achieve at least partial asset flexibility. Most of

the resources should be used in making the fixed assets more flexible, as the changes in the *FA%* have a far more extensive impact on the profitability than the changes of the *CCC*.

Table 5. The *ROI* and the i_E of Metsä Fibre in different situations of the simulation in publication 4

Actual situation without the simulation	***FA%***	***CCC***	***ROI***	$\boldsymbol{i_E}$
Reference values in 2010	42%	44 days	45%	55%
Asset flexibility as net sales decrease by 50%	***FA%***	***CCC***	***ROI***	$\boldsymbol{i_E}$
Fixed assets and working capital stay unchanged	84%	87 days	20%	23%
Fixed assets and working capital decrease by 15%	72%	74 days	25%	30%
Working capital decreases by 30%, fixed assets by 15%	72%	61 days	26%	31%
Fixed assets decrease by 30%, working capital by 15%	59%	74 days	30%	36%
Fixed assets and working capital decrease by 30%	59%	61 days	31%	37%

Publication 5

In publication 5, the principles of flexible asset management discussed in the previous publications were linked with maintenance contracts to make the additional value visible and shareable. A new type of maintenance contracts, flexible asset management contracts, was introduced, and the pricing logic of these contracts examined through simulations with empirical data of the case companies. Figure 12 shows how flexible asset management contracts are positioned with relation to the traditional maintenance contract types discussed in chapter 2.3.

The main features of flexible asset management contracts are considering the shared ownership of the spare part stocks and fixed assets that the contract concerns, emphasizing the role of payment terms on the profitability of the contract, and being aware of the impact of financial leverage, in other words using debt financing, on the profitability of the contract. The focus is on fixed asset and spare part ownership, and thus not on maintenance work itself. The contracts were discussed from the perspective of both the maintenance buyer and maintenance provider, and the publication focused on promoting win-win situations between them. The flexible asset management contracts are more complex than the other contract types, they require more trust between the contracting parties, and creating and maintaining them incurs more costs, but the potential benefits are also greater than in traditional contracts.

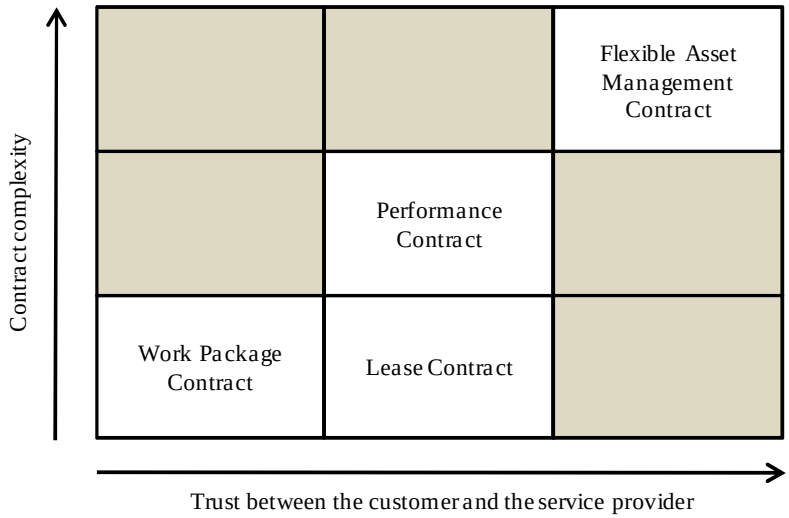

Figure 12. The relation of flexible asset management contracts to traditional contract types

To quantify and share the value created by including inter-organizational asset management in the maintenance contracts, I have created a pricing logic for these contracts. When transferring asset ownership from one company to another, it is likely that profitability decreases in the company taking the assets into its balance sheet (henceforth company A), and increases in the company giving the assets up (henceforth company B). The just price should thus be somewhere between the losses of company A and the additional profits of company B:

$$-\Delta ROI_A * (D_A + E_A) + \Delta i_{EA} * E_A < p < \Delta ROI_B * (D_B + E_B) \quad (3)$$

where

ΔROI_A is the decrease of the *ROI* caused by the increased amount of assets in company A,

D_A is the amount of long-term debt in company A,

E_A is the amount of shareholder equity in company A,

Δi_{EA} is the change of the i_E caused by an adjustment in the capital structure of company A,

p is the price charged by company A from company B for taking the ownership of some of its assets,

ΔROI_B is the increase of the *ROI* caused by the decreased amount of assets in company B,

D_B is the amount of long-term debt in company B,

E_B is the amount of shareholder equity in company B.

The derivation of equation 3 can be seen in publication 5. After introducing the pricing logic for the contracts, the publication illuminates their benefits via simulations through scenarios on the case companies. The first scenario contained shifting a fixed, physical asset of 200,000€, and the second a sum of 3,300,000€ of the components of working capital from Botnia Mill Service to Metsä Fibre. Table 6 demonstrates the value created by these scenarios, and how the profitability of the contract could be improved further if Metsä Fibre used debt in financing the additional assets in its balance sheets. In each scenario the total additional value is positive, meaning that a win-win situation could be achieved in the asset management collaboration. The additional value created by the working capital scenario appears to be extensive, but most of this value is added by the financial leverage. The fixed asset scenario, on the other hand, creates a lot of value even without the financial leverage and with quite small amounts of capital to be transferred from one company to the other.

Table 6. The benefits of the inter-organizational asset management scenarios in publication 5

Scenario	***Amount of shifted capital***	***Additional value for Metsä Fibre***	***Additional value for Botnia Mill Service***	***Additional value in total***
Shifting fixed asset ownership	200,000€	-1,039,000€	1,938,000€	899,000€
Financial leverage in the fixed asset scenario	200,000€	74,000€	-	74,000€
Fixed asset scenario in total	***200,000€***	***-965,000€***	***1,938,000€***	***973,000€***
Shifting components of working capital	3,300,000€	-2,369,000€	2,582,000€	213,000€
Financial leverage in the working capital scenario	3,300,000€	1,209,000€	-	1,209,000€
Working capital scenario in total	***3,300,000€***	***-1,160,000€***	***2,582,000€***	***1,422,000€***

4.2 Summary of the results

The objective of this thesis was to prove how flexible asset management can be used in increasing the profitability of maintenance companies and networks in dynamic operating conditions. Table 7 summarizes the main features of the 5 publications in the thesis, after which the main results of the thesis are discussed in detail.

The thesis had three research questions, the first of which was: what kind of requirements for asset management models are set by the increasing dynamism and complexity of operational environments? A systematic literature review showed that the existing models were very heterogeneous, as there were various definitions of asset management. However, by analysing the previous models I identified four distinct research gaps which should be filled to match the dynamic operating conditions of today:

(1) Most of the existing asset management models consider only fixed, tangible assets, neglecting intangible, financial, and current assets. However, as proved in this thesis, it is important to manage the assets comprehensively, especially because the fixed assets tend to be inflexible and difficult to adjust when needed.

(2) Previous publications on asset management models do not actively take account of the perspective of inter-organizational networks or outside suppliers. Considering the recent trends towards networking and partnerships, this is a serious limitation.

(3) Many of the examined models are abstract or scientific by nature, and challenging for actual decision makers to use. To really contribute to the emerging need of novel tools suitable for the dynamic conditions, the user friendliness of the models should be promoted.

(4) Finally, most of the previous models have a long time span, therefore addressing the strategic level of asset management. However, as opposed to this, nearly all of the models consider either a single asset or an asset fleet. Again, to make the models more pragmatic, there should be at least some models for company- or company network –level strategic asset management.

Table 7. A summary of the publications of the thesis

	Publication 1	***Publication 2***	***Publication 3***	***Publication 4***	***Publication 5***
Title	Top modelling in asset management: a systematic literature review	Profitable working capital management in industrial maintenance companies	Appeasing company owners through effective working capital management	Enhancing collaboration in maintenance networks through flexible asset management	The missing link between maintenance contracts and flexible asset management
Objective	Scrutinizing the existing literature on asset management models and identifying possible research gaps	Examining the role of working capital and its impact on the *ROI* in the industrial maintenance service sector	Studying the connection of working capital and return on equity, as well as the impact of dynamic financial conditions	Advancing comprehensive, inter-organizational asset management collaboration in maintenance networks	Demonstrating the creation of additional value in inter-organizational asset management collaboration
Research question	RQ1	RQ2	RQ2	RQ2	RQ3
Level of research	Company	Company	Company	Company network	Company network
Research methods	Literature review	Analytical modelling	Analytical modelling	Analytical modelling, simulations	Analytical modelling, simulations
Empirical data	Literature sample of 55 journal articles	Financial statements of 18 maintenance companies	Financial statements of 18 maintenance companies	Financial statements of two case networks	Financial statements of two case companies
Main results	Future asset management models should be practical and they should address all kinds of assets from an inter-organizational, company-level perspective.	The FAM model shows that in maintenance companies the *CCC* impacts the *ROI* significantly, but to compensate for changes in profitability, also fixed assets should be taken into account.	In dynamic financial conditions the return on equity can be preserved by decreasing the amount of fixed assets and working capital in a company's balance sheet.	Maintenance networks can benefit from inter-organizational asset management, and in certain conditions win-win situations can emerge through it.	Win-win situations can be promoted through flexible asset management contracts, which can be fairly priced to share the created value in maintenance networks.

The second research question of the thesis was: how can flexible asset management increase profitability in industrial maintenance companies and networks when operating in dynamic conditions? The study discussed adjusting to a decreasing market demand specifically. The investment needs created by a rapidly increasing demand were left out of the analyses and simulations. The starting point for flexible asset management was thus that if the net sales of a company crash, relative profitability can be saved through adjusting the amount of assets (fixed assets and working capital) in the balance sheet. Besides the changes in the net sales, in this study the dynamic conditions also included the development of the interest rate of debt funding and the capital structure of the company. The impact of flexible asset management on profitability was modelled through the *ROI* and the i_E.

Based on the analysis of Finnish maintenance companies and networks it can be concluded that in general, significant decreases of the net sales cannot be compensated by just rationalizing the working capital management; thus there is also a need to adjust the amount of fixed assets in the balance sheet of the company. The changes in the i_D and the debt-to-equity ratio, on the other hand, could be compensated for just through working capital. This is important in practice, since even though fixed asset management has a remarkably greater impact on the profitability than working capital management, it is almost impossible to adjust the fixed assets rapidly just as needed. This study showed that the effect of working capital management on the profitability was exceptionally strong in maintenance companies, as they operate usually with light balance sheets. In the Finnish maintenance industry this seemed to hold especially for the large maintenance companies. Considering maintenance networks, profitability can be improved through increasing the flexibility of the assets, and through reorganizing the ownership of the assets among the companies in the network. The simulations in this thesis illustrated that the different features of maintenance customer companies and their service- and equipment provider companies can create additional value through inter-organizational flexible asset management.

The third and final research question of the thesis was: how should the companies operating in maintenance networks share the value created by flexible asset management to reach a win-win situation? The approach of this research to value sharing was that of maintenance contracts; the traditional typology of maintenance contracts was expanded to include a new contract type, flexible asset management contracts. These contracts include services of fixed asset and spare part ownership, in addition to the actual maintenance work. I concluded that a win-win situation is achieved when the ownership of the assets is priced somewhere between the incurred losses of the

company that takes the assets into its balance sheet and the additional profits of the company that gives up the assets. However, the amount of value created through flexible asset management in a network depends on the features of the contracting companies. Figure 13 summarizes how companies with light or heavy balance sheets can gain value from inter-organizational asset management.

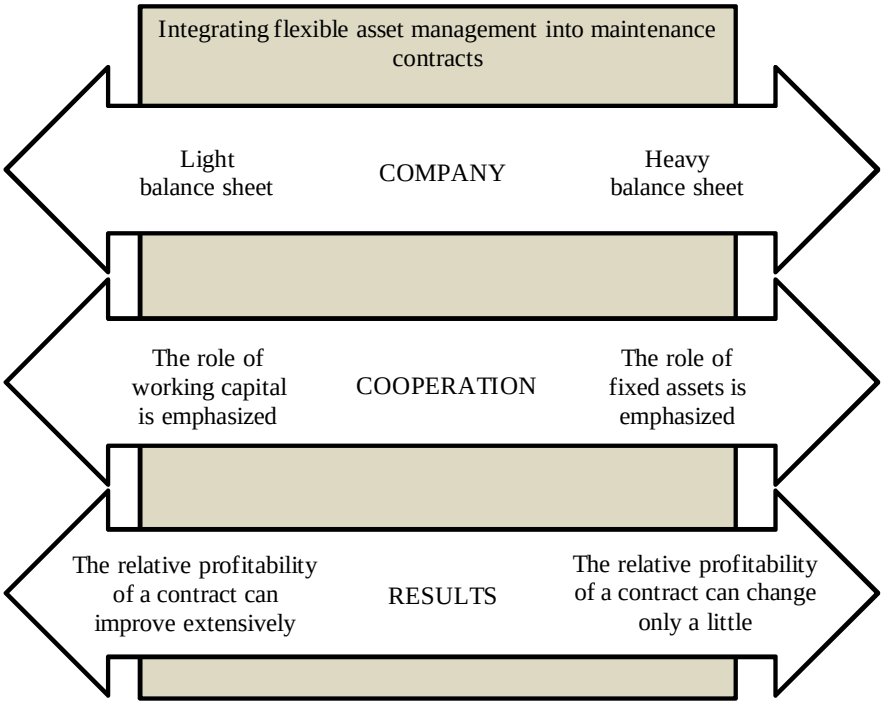

Figure 13. Framework of how different companies should exploit flexible asset management in their maintenance contracts to gain value

Maintenance customer companies carry traditionally heavy assets compared to maintenance service companies. As a result, a specific monetary sum has a different impact on the relative profitability of these companies. This means that transferring assets from the balance sheet of service companies to the customer companies is a feasible way of creating value, but transferring them the other way around is more likely to destroy value than create it. In the Finnish maintenance industry, some maintenance service providers have benefitted from this through working in such close collaboration with their customer and host companies. Usually it is the amount of fixed assets that makes a balance sheet heavy, so I conclude that the role of fixed assets is emphasized in those

companies. In maintenance service companies with light balance sheets, the importance of working capital management is highlighted instead. Finally, compared to the service providers, companies carrying heavy balance sheets need to adjust their assets extensively to gain a large increase in their relative profitability.

5 CONCLUSIONS

5.1 Contribution to theory

The research in this thesis provides four distinct contributions to the existing theoretical discussion. Firstly, an overview of the existing literature of asset management models was presented. Since the definition and content of asset management is multifaceted (see e.g. Amadi-Echendu et al., 2010), the research and developed models on the topic are heterogeneous. To advance understanding, it is thus important to review the existing knowledge systematically. As a result of the literature review I pointed out research gaps which should be filled to meet the requirements set by the recent changes in the business environment.

The second theoretical insight provided by the thesis is the analytical FAM model, which links the management of fixed assets and working capital to the profitability and the financial state of a company. The model contributes to the research gaps identified in the research of asset management models, and on the other hand it promotes the discussion on growth and profitability models presented by for example Higgins (1977). The model provides new insight into comprehensive strategic asset management, which has not been addressed before (Komonen et al., 2012). Due to the balance sheet -based perspective of the model, no other performance measures than financial ones were included. To construct a more diversified model for comprehensive asset management, also internal performance data of companies would have to be assessed. This would be a feasible topic for further research; for example the SFS-EN 15341 standard (2007) states that economic, technical and organizational indicators should be included in maintenance performance measurement. Different life-cycle costing models or total cost of ownership -approaches could be used. The main challenges related to these perspectives include monetary quantification of nonfinancial elements and selecting the level of inspection (Degraeve et al., 2004; Morssinkhof et al., 2011).

The third contribution to the literature is proving the importance of a comprehensive view on asset management. Although the holistic approach has been highlighted by for example Amadi-Echendu et al. (2010) and the Publicly Available Specification 55-1 (2008), most research on asset management still concentrates on one specific type of assets. However, my analyses with the FAM model implied that both working capital and fixed assets should be managed comprehensively: the

management of fixed assets has a more extensive impact on profitability than working capital management, but it is also difficult to adjust the level of fixed assets in the balance sheet, at least in a short time frame. This thesis defended the previous notes on the fact that in the future the research on asset management should discuss all types of assets conjointly to integrate more closely with the research on strategic management of companies and networks.

The fourth and final theoretical contribution of the thesis is complementing the previous typology of maintenance contracts (see Martin, 1997) with flexible asset management contracts. Contracting the maintenance work itself was not addressed; instead the focus was on the additional services of fixed asset and spare part ownership included in these contracts. Through flexible asset management contracts, I considered not just the perspective of maintenance customer companies, but also that of maintenance service providers. This contributes to the existing discussion, for previously the attention has been on the customer side of maintenance contracts. Operating in networks and partnerships has changed the environment of maintenance business, and the academic research should redirect itself accordingly. This study demonstrated that applying flexible asset management contracts can promote win-win situations in maintenance networks.

5.2 Managerial implications

Although the study was mostly descriptive by nature and the main focus was on model building, three main managerial implications can be listed. The first one of these is the FAM model, which can be used as a strategic decision-making tool for example in maintenance contract negotiations to study changes in the profitability of a contract, in discovering positive or negative trends in the performance of the company, or in forecasting the future development of profitability as a function of asset management. In the thesis, the model was used to manage the relative profitability (the *ROI* or the i_E) through changes in fixed asset and working capital management. Of course, the model could also be adjusted to different research settings. Besides improving the relative profitability, the model can create value for companies through promoting for example lean management or innovative asset management practices, such as inter-organizational inventories with joint ownership. Considering the perspective of company networks, the model contributes to the competitiveness and continuity of a network through mutual asset management. In the long term it can be beneficial for a company to make small sacrifices at the company level to keep its network partners profitable.

The second managerial contribution is providing new knowledge on the relations between asset management, profitability and financial parameters in maintenance companies. Although maintenance as a function is old-established, at least in Finland most of the outside maintenance service companies have been founded during the 21st century. Also, industrial maintenance has not been remarked in the Finnish standard industrial classification until 2009. This is why not much previous research on these companies exists. I conclude that maintenance companies should pay attention to effective working capital management, as it has a notable effect on profitability. That being said, fixed assets are more extensive in their profitability impacts, yet challenging to manage flexibly.

The third managerial implication of the thesis is demonstrating the benefits of flexible asset management in maintenance networks and partnerships. I have proved that the relative profitability of each contracting company can be improved through reorganizing the ownership of the assets in the network. Achieving win-win situations calls for proper value sharing and openness between the partners. It can be concluded that the different features of customer and supplier companies in maintenance networks can create potential for inter-organizational asset management collaboration.

5.3 Limitations

I have identified three main limitations in the thesis. The first one is using fictitious scenarios instead of authentic collaboration with the case companies and networks. Even though tendencies like networks, win-win, and open books have been on display in the literature for decades already, not so many companies are actually ready to put these new ideas into operation. Thus implementing inter-organizational flexible asset management in reality had to be left out of this thesis at the moment. This was not contradictory with the objectives of the thesis, as the main purpose of the empirical data was to validate the FAM model.

The second main limitation in the research is that the FAM model was tested only with data of industrial maintenance companies and networks, which of course questions its external validity in terms of generalizing the results of the thesis. Maintenance industry is an optimal research environment; it is a young industry, developing at a high pace towards networked business models, in need of new tools to support decision making, and the differences between the balance sheet structures of maintenance customers and service providers create potential for inter-organizational asset management collaboration. However, the thesis did not systematically prove that the model

could also be used in other industries. In practice, the differences between industries can alter the potential benefits to be gained through the model, as well as the importance of the parameters in the model. For example the differences between capital- and workforce-intensive industries, as well as between different production systems would affect the parameters of the FAM model. Despite the notions mentioned above, I limited the research to maintenance industry, as broad comparable studies would have exceeded the scope of the thesis.

The third main limitation is about not discussing the differences in reporting principles between different countries. The research concerned Finnish companies, which follow the International Financial Reporting Standards (IFRS) in their financial statements. Although work is being done globally to consolidate the different reporting practices under IFRS, there are still many differences left. For example in the United States the integration work has been slow, and companies are using Generally Accepted Accounting Principles (GAAP) in their reporting. There are some differences related to the valuation of assets between the IFRS and the U.S. GAAP, which may hinder any comparative studies in the future using the FAM model. It is thus imperative to analyse these differences before conducting further international research on the model.

5.4 Suggestions for further research

The research conducted in this thesis left me with various suggestions for further research. Here four of these ideas are briefly presented. Firstly, in the future it should be examined how to convert the strategic goals produced by the FAM model into operational action plans. This process was purposely delimited from the thesis, but without solving this issue, the model is not ready to support actual decision making in companies and company networks. It would be relatively easy to conclude that the amount of fixed assets in a company should be reduced to improve the *ROI*, but implementing this is a challenge of its own.

The second topic for further research is conducting comparative studies between different industries and countries. Although the issues related to this kind of further research were discussed in connection with the limitations of the thesis (chapter 5.3), it would be important to recognize the characteristics of different companies as regards asset management and profitability. This way the potential benefits of inter-organizational asset management in company networks could be assessed better before examining the topic in closer detail.

Thirdly, further research should address testing the FAM model with more extensive empirical data, as well as scrutinizing the behaviour of the different parameters of the model. For example, the residual term in the model, consisting of current assets other than inventories and accounts receivable, and current liabilities other than accounts payable, remains obscure. It is not known yet how the value of this parameter can be optimized to maximise long-term profitability. On the other hand, the current version of the model cannot really handle negative profitability and its connection to asset management. However, when the profitability is negative, it would be especially important for a company to react through increasing flexibility to the assets in the balance sheet. It is thus important to solve these shortcomings in the model in the future.

My fourth and final suggestion for future research is communicating the benefits of inter-organizational flexible asset management shown in this thesis to maintenance networks and conducting case studies of the actual implementation of the FAM model. Although not widely discussed in the thesis, the eventual purpose of the model is to support decision making of real companies and networks. This will be extremely challenging due to the protective and introverted attitudes of most companies towards their economic performance data and the ownership of critical assets. Also cascading the model into the organizations for implementation can prove to be challenging: the maturity of the company network may not be sufficient, and the maturity of individual companies in the network may differ. Constructing some kind of maturity models in the networks would thus be necessary in the future. I hope that the analyses presented in this thesis will pique the interest of companies towards new ways of collaborating in asset management, so that little by little these hurdles can be overcome.

REFERENCES

Aho, T. (1993), 'Determining sustainable growth', *The Finnish Journal of Business Economics*, Vol. 42, No. 4, pp. 335–346, (in Finnish).

Ahonen, T., Reunanen, M., Pajari, O., Ojanen, V. and Lanne, M. (2010), 'Maintenance communities – a new model for the networked delivery of maintenance services', *International Journal of Business Innovation and Research*, Vol. 4, No. 6, pp. 560–583.

Albino, V., Carella, G. and Okogbaa, O.G. (1992), 'Maintenance policies in just-in-time manufacturing lines', *International Journal of Production Research*, Vol. 30, No. 2, pp. 369–382.

Allee, V. (2008), 'Value network analysis and value conversion of tangible and intangible assets', *Journal of Intellectual Capital*, Vol. 9, No. 1, pp. 5–24.

Al-Turki, U. (2011), 'A framework for strategic planning in maintenance', *Journal of Quality in Maintenance Engineering*, Vol. 17, No. 2, pp. 150–162.

Amadi-Echendu, J.E., Willett, R., Brown, K., Hope, T., Lee, J., Mathew, J., Vyas, N. and Yang, B.-S. (2010), 'What is engineering asset management?', in Amadi-Echendu, J.E., Brown, K., Willett, R. and Mathew, J. (Eds.), '*Definitions, concepts and scope of engineering asset management*', Springer-Verlag, London, ISBN 978-1-84996-178-3, pp. 3–16.

Aoudia, M., Belmokhtar, O. and Zwingelstein, G. (2008), 'Economic impact of maintenance management ineffectiveness of an oil and gas company', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 3, pp. 237–261.

Azadivar, F. and Shu, V. (1999), 'Maintenance policy selection for JIT production systems', *International Journal of Production Research*, Vol. 37, No. 16, pp. 3725–3738.

Baglee, D. and Knowled, M. (2010), 'Maintenance strategy development within SMEs: the development of an integrated approach', *Control and Cybernetics*, Vol. 39, No. 1, pp. 275–303.

Bailey, W., Masson, R. and Raeside, R. (2002), 'Outsourcing in Edinburgh and the Lothians', *European Journal of Purchasing & Supply Management*, Vol. 8, No. 2, pp. 83–95.

Banks, C.M. (2009), 'What is modeling and simulation?', in Sokolowski, J.A. and Banks, C.M. (Eds.), '*Principles of modeling and simulation. A multidisciplinary approach*', John Wiler & Sons, New Jersey, ISBN 978-0-470-28943-3, pp. 3–24.

Baños-Caballero, S., García-Teruel, P. and Martínez-Solano, P. (2010), 'Working capital management in SMEs', *Accounting and Finance*, Vol. 3, No. 50, pp. 511–527.

Benson, J. and Ieronimo, N. (1996), 'Outsourcing decisions: evidence from Australia-based enterprises', *International Labour Review*, Vol. 135, No. 1, pp. 59–73.

Black, A., Wright, P. and Bachman, J.E. (1998), '*In search of shareholder value. Managing the drivers of performance'*, Price Waterhouse, London, ISBN 0-273-63027-X, 292 p.

Blinder, A.S. and Maccini, L.J. (1991), 'The resurgence of inventory research: what have we learned?', *Journal of Economic Surveys*, Vol. 5, No. 4, pp. 291–328.

Boulaksil, Y. and Fransoo, J.C. (2010), 'Implications of outsourcing on operations planning: findings from the pharmaceutical industry', *International Journal of Operations & Production Management*, Vol. 30, No. 10, pp. 1059–1079.

Brandenburger, A.M. and Nalebuff, B.J. (1998), '*Co-opetition*', Doubleday, New York, ISBN 0-385-47950-6, 288 p.

Broedner, P., Kinkel, S. and Lay, G. (2009), 'Productivity effects of outsourcing – new evidence on the strategic importance of vertical integration decisions', *International Journal of Operations & Production Management*, Vol. 29, No. 2, pp. 127–150.

Burns, D.C., Sale, J.T. and Stephan, J.A. (2008), 'A better way to gauge profitability', *Journal of Accountancy*, Vol. 206, No. 2, pp. 38–42.

Campbell, J. (1995), 'Outsourcing in maintenance management. A valid alternative to self-provision', *Journal of Quality in Maintenance Engineering*, Vol. 1, No. 3, pp. 18–24.

Chiou, J., Cheng, L. and Wu, H. (2006), 'The determinants of working capital', *The Journal of American Academy of Business*, Vol. 1, No. 10, pp. 149–155.

Colicchia, C. and Strozzi, F. (2012), 'Supply chain risk management: a new methodology for a systematic literature review', *Supply Chain Management: An International Journal*, Vol. 17, No. 4, pp. 403–418.

Culverson, K.J. (2013), 'Developing a precision culture for business success', in Jantunen, E., Komonen, K., Heljo, A., Kuosmanen, P. and Rao, B.K.N. (Eds.), '*Congress proceedings of international congress of condition monitoring and diagnostic engineering management 11-13 June, Helsinki'*, KP-Media Oy, Helsinki, ISBN 978-952-67981-0-3, pp. 87–93.

Degraeve, Z., Labro, E. and Roodhooft, F. (2004), 'Total cost of ownership purchasing of a service: the case of airline selection at Alcatel Bell', *European Journal of Operational Research*, Vol. 156, No. 1, pp. 23–40.

Deloof, M. (2003), 'Does working capital management affect profitability of Belgium firms?', *Journal of Business Finance & Accounting*, Vol. 30, No. 3-4, pp. 573–587.

Deloof, M. and Jegers, M. (1996), 'Trade credit, product quality, and intragroup trade: some European evidence', *The Journal of Financial Management Association*, Vol. 25, No. 3, pp.33–43.

Demski, J.S. (2007), 'Analytic modeling in management accounting research', in Chapman, C.S., Hopwood, A.G. and Shields, M.D. (Eds.), '*Handbook of management accounting research. Vol. 1'*, Elsevier, Amsterdam, ISBN 978-0-08-044564-9, pp. 365–371.

Donaldson, G. (1984), '*Managing corporate wealth. The operation of a comprehensive financial goals system'*, Praeger Publishers, New York, ISBN 0-03-063414-8, 198 p.

Dong, H.P. and Su, J. (2010), 'The relationship between working capital management and profitability: a Vietnam case', *International Research Journal of Finance and Economics*, Vol. 5, No. 49, pp. 59–67.

Duffy, R. (2008), 'Towards a better understanding of partnership attributes: an exploratory analysis of relationship type classification', *Industrial Marketing Management*, Vol. 37, No. 2, pp. 228–244.

Emmanouilidis, C. and Komonen, K. (2013), 'Physical asset management practices in industry: comparisons between Greece and the northern Europe', in Jantunen, E., Komonen, K., Heljo, A., Kuosmanen, P. and Rao, B.K.N. (Eds.), '*Congress proceedings of international congress of*

condition monitoring and diagnostic engineering management 11-13 June, Helsinki', KP-Media Oy, Helsinki, ISBN 978-952-67981-0-3, pp. 75–86.

Fantazy, K.A., Kumar, V. and Kumar, U. (2011), 'The impact of information sharing on supply chain performance: an empirical study', *International Journal of Procurement Management*, Vol. 4, No. 3, pp. 274–296.

Fendt, J. and Kaminska-Labbé, R. (2011), 'Relevance and creativity through design-driven action research: introducing pragmatic adequacy', *European Management Journal*, Vol. 29, No. 3, pp. 217–233.

Filbeck, G., Krueger, T. and Preece, D. (2007), 'CFO magazine's "working capital survey": do selected firms work for shareholders?', *Quarterly Journal of Business & Economics*, Vol. 46, No. 2, pp. 3–22.

Fink, A. (2010), '*Conducting research literature reviews. From the internet to paper*', 3rd edition, SAGE Publications, Thousand Oaks, ISBN 978-1-4129-7189-8, 253 p.

Galar, D., Peters, R., Berges, L., Stenström, C. and Kumar, U. (2012), 'Composite indicators in asset management', in *'Proceedings of the 2nd international congress on maintenance performance measurement and management, Sunderland, UK, 12-13 September'*, 14 p.

García-Teruel, P.J. and Martínez-Solano, P. (2007), 'Effects of working capital management on SME profitability', *International Journal of Managerial Finance*, Vol. 2, No. 3, pp. 164–177.

Ghayebloo, S. and Shahanaghi, K. (2010), 'Determining maintenance system requirements by viewpoint of reliability and lean thinking: a MODM approach', *Journal of Quality in Maintenance Engineering*, Vol. 16, No. 1, pp. 89–106.

Gibson, V. (2000), 'Property portfolio dynamics: the flexible management of inflexible assets', *Facilities*, Vol. 18, No. 3, pp. 150–154.

Gorry, G.A. and Morton, M.S.S. (1989), 'A framework for management information systems', *Sloan Management Review*, Vol. 30, No. 3, pp. 49–61.

Grosse-Ruyken, P.T., Wagner, S. and Jönke, R. (2011), 'What is the right cash conversion cycle for your supply chain?', *International Journal of Services and Operations Management*, Vol. 10, No. 1, pp. 13–29.

Harland, C., Knight, L., Lamming, R. and Walker, H. (2005), 'Outsourcing: assessing the risks and benefits for organizations, sectors and nations', *International Journal of Operations & Production Management,* Vol. 25, No. 9, pp. 831–850.

Hatinen, L., Pirttilä, M., Viskari, S. and Kärri, T. (2012), 'The investment logics of Finnish industrial maintenance service providers', *International Journal of Strategic Engineering Asset Management,* Vol. 1, No. 1, pp. 33–48.

Hendry, J. (1995), 'Culture, community and networks: the hidden cost of outsourcing', *European Management Journal,* Vol. 2, No. 13, pp. 193–200.

Herder, P.M. and Wijnia, Y. (2012), 'A systems view on infrastructure asset management', in Van der Lei, T., Herder, P. and Wijnia, Y. (Eds.) '*The state of the art in Europe from a life cycle perspective'*, Springer, Dordrecht, ISBN 978-94-007-2723-6, pp. 31–46.

Higgins, R. (1977), 'How much growth can a firm afford', *Financial Management*, Vol. 6, No. 3, pp. 7–16.

Hill, M.D., Kelly, G.W. and Highfield, M.J. (2010), 'Net operating working capital behavior: a first look', *Financial Management,* Vol. 39, No. 2, pp. 783–805.

Hilletofth, P. and Hilmola, O.-P. (2010), 'Role of logistics outsourcing on supply chain strategy and management. Survey findings from Northern Europe', *Strategic Outsourcing,* Vol. 3, No. 1, pp. 46–61.

Holschbach, E. and Hofmann, E. (2011), 'Exploring quality management for business services from a buyer's perspective using multiple case study evidence', *International Journal of Operations & Production Management,* Vol. 31, No. 6, pp. 648–685.

Hui, E. and Tsang, A. (2006), 'The inter-organizational relationship in a multi-contractor business network', *Journal of Quality in Maintenance Engineering,* Vol. 12, No. 3, pp. 252–266.

Johnson, M. and Templer, S. (2011), 'The relationships between supply chain and firm performance: the development and testing of unified proxy', *International Journal of Physical distribution & Logistics Management,* Vol. 2, No. 41, pp. 88–103.

Jose, M., Lancaster, C. and Stevens, J. (1996), 'Corporate returns and cash conversion cycles', *Journal of Economics and Finance*, Vol. 1, No. 20, pp. 33–46.

Kakabadse, A. and Kakabadse, N. (2002), 'Trends in outsourcing: contrasting USA and Europe', *European Management Journal*, Vol. 2, No. 20, pp. 189–198.

Kilduff, M., Mehra, A. and Dunn, M.B. (2011), 'From blue sky research to problem solving: a philosophy of science theory of new knowledge production', *Academy of Management Review*, Vol. 36, No. 2, pp. 297–317.

Kitchenham, B., Pretorius, R., Budgen, D., Brereton, O.P., Turner, M., Niazi, M. and Linkman, S. (2010), 'Systematic literature reviews in software engineering – a tertiary study', *Information and Software Technology*, Vol. 52, No. 8, pp. 792–805.

Komonen, K. and Despujols, A. (2013), 'Maintenance within physical asset management: a standardization project within CEN TC319', in Jantunen, E., Komonen, K., Heljo, A., Kuosmanen, P. and Rao, B.K.N. (Eds.), '*Congress proceedings of international congress of condition monitoring and diagnostic engineering management 11-13 June, Helsinki'*, KP-Media Oy, Helsinki, ISBN 978-952-67981-0-3, pp. 17–22.

Komonen, K., Kortelainen, H. and Räikkönen, M. (2012), 'Corporate asset management for industrial companies: an integrated business-driven approach', in Van der Lei, T., Herder, P. and Wijnia, Y. (Eds.), '*The state of the art in Europe from a life cycle perspective'*, Springer, Dordrecht, ISBN 978-94-007-2723-6, pp. 47–63.

Kornev, A.K. (2009), 'Possibilities of rapid renewal of active part of fixed assets of branches of industry', *Studies on Russian Economic Development*, Vol. 5, No. 20, pp. 563–567.

Kremic, T., Tukel, O.I. and Rom, W. (2006), 'Outsourcing decision support: a survey of benefits, risks, and decision factors', *Supply Chain Management: An International Journal*, Vol. 6, No. 11, pp. 467–482.

Kroes, J. and Ghosh, S. (2009), 'A framework and scale development for assessing supply chain outsourcing alignment with competitive priorities', *International Journal of Procurement Management*, Vol. 2, No. 1, pp. 1–24.

Kumar, R. and Kumar, U. (2004), 'A conceptual framework for the development of a service delivery strategy for industrial systems and products', *Journal of Business & Industrial Marketing*, Vol. 5, No. 19, pp. 310–319.

Kumar, R., Markeset, T. and Kumar, U. (2004), 'Maintenance of machinery. Negotiating service contracts in business-to-business marketing', *International Journal of Service Industry Management*, Vol. 15, No. 4, pp. 400–413.

Kumar, R., Markeset, T. and Kumar, U. (2006), 'Implementation and execution of industrial service strategy. A case study from the oil and gas industry', *Journal of Quality in Maintenance Engineering*, Vol. 12, No. 2, pp. 105–117.

Kärri, T. (1999), 'Economies of scale in two Finnish forest industry mergers', *The Finnish Journal of Business Economics*, Vol. 48, No. 1, pp. 9–26.

Kärri, T. (2007), '*Timing of capacity change: models for capital intensive industry*', Acta Universitatis Lappeenrantaensis 287, Dissertation, Lappeenranta University of Technology, Lappeenranta, ISBN 978-952-214-476-8, 134 p.

Lambert, D. and Pohlen, T. (2001), 'Supply chain metrics', *The International Journal of Logistics Management*, Vol. 12, No. 1, pp.1–19.

Lazaridis, I. and Tryfonidis, D. (2006), 'Relationship between working capital management and profitability of listed companies in the Athens stock exchange', *Journal of Financial Management and Analysis*, Vol. 19, No. 1, pp. 26–35.

Levery, M. (1998), 'Outsourcing maintenance – a question of strategy', *Engineering Management Journal*, Vol. 8, No. 1, pp. 34–40.

Lin, S., Gao, J., Koronios, A. and Chanana, V. (2007), 'Developing a data quality framework for asset management in engineering organisations', *International Journal of Information Quality*, Vol. 1, No. 1, pp. 100–126.

Liyanage, J.P. (2007), 'Operations and maintenance performance in production and manufacturing assets', *Journal of Manufacturing Technology Management*, Vol. 18, No. 3, pp. 304–314.

Losbichler, H., Mahmoodi, F. and Rothboeck, M. (2008), 'Creating greater shareholder value from supply chain initiatives', *Supply Chain Forum: International Journal*, Vol. 9, No. 1, pp.82–91.

MacCarthy, B.L. and Jayarathne, P.G.S.A. (2012), 'Sustainable collaborative supply networks in the international clothing industry: a comparative analysis of two retailers', *Production Planning & Control*, Vol. 23, No. 4, pp. 252–268.

Magnan, G.M., Fawcett, A.M. and Fawcett, S.E. (2011), 'Supply chain success: key initiatives differentiating high- and low-performing firms', *International Journal of Procurement Management*, Vol. 4, No. 2, pp.181–202.

Markeset, T. and Kumar, U. (2005), 'Product support strategy: conventional versus functional products', *Journal of Quality in Maintenance Engineering*, Vol. 11, No. 1, pp. 53–67.

Martin, H.H. (1997), 'Contracting out maintenance and a plan for future research', *Journal of Quality in Maintenance Engineering*, Vol. 3, No. 2, pp. 81–90.

McIvor, R., Humphreys, P., McKittrick, A. and Wall, T. (2009), 'Performance management and the outsourcing process – lessons from a financial services organization', *International Journal of Operations & Production Management*, Vol. 29, No. 10, pp. 1025–1048.

Miles, R. and Snow, C. (1986), 'Organizations: new concepts for new forms', *California Management Review*, Vol. 3, No. 28, pp. 62–73.

Miyake, D.I., Enkawa, T. and Fleury, A.C.C. (1995), 'Improving manufacturing systems performance by complementary application of just-in-time, total quality control and total productive maintenance paradigms', *Total Quality Management Journal*, Vol. 6, No. 4, pp. 345–363.

Moayed, F.A. and Shell, R.L. (2009), 'Comparison and evaluation of maintenance operations in lean versus non-lean production systems', *Journal of Quality in Maintenance Engineering*, Vol. 15, No. 3, pp. 285–296.

Molina, C.A. and Preve, L.A. (2009), 'Trade receivables policy of distressed firms and its effect on the costs of financial distress', *Financial Management*, Vol. 3, No. 38, pp. 663–686.

More, D. and Babu, A.S. (2011), 'Managing supply chain flexibility using an integrated approach of classifying, structuring and impact assessment', *International Journal of Services and Operations Management*, Vol. 8, No. 1, pp.46–75.

Morssinkhof, S., Wouters, M. and Warlop, L. (2011), 'Effects of providing total cost of ownership information on attribute weights in purchasing decisions', *Journal of Purchasing and Supply Management*, Vol. 17, No 2, pp. 132–142.

Mun, J. (2008), '*Advanced analytical models*', John Wiley & Sons, New Jersey, ISBN 978-0-470-17951-5, 1013 p.

Navarro, P. (2009), 'Recession-proofing your organization', *MIT Sloan Management Review*, Vol. 50, No. 3, pp. 45–51.

Ng, C.K., Smith, J.K. and Smith, R.L. (1999), 'Evidence on the determinants of credit terms used in interfirm trade', *Journal of Finance*, Vol. 54, No. 3, pp. 1109–1129.

Ngwenyama, O. and Bryson, N. (1999), 'Making the information systems outsourcing decision: a transaction cost approach to analyzing outsourcing decision problems', *European Journal of Operational Research*, Vol. 115, No. 2, pp. 351–367.

Nola, R. and Irzik, G. (2005), *'Philosophy, science, education and culture'*, Science and technology education library –series Vol. 28, Springer, Dordrecht, ISBN 978-1-4020-3770-6, 488 p.

Ojanen, V., Hatinen, L., Kärri, T., Kässi, T. and Tuominen, M. (2012), 'Flexible investment planning and collaborative maintenance management', in Van der Lei, T., Herder, P. and Wijnia, Y. (Eds.), *'The state of the art in Europe from a life cycle perspective'*, Springer, Dordrecht, ISBN 978-94-007-2723-6, pp. 65–77.

Ojanen, V., Kolehmainen, J., Ahonen, T. and Tuominen, M. (2010), 'Developing collaborative relationship between industrial service providers and their client: the case of industrial maintenance management', in '*Proceeding of PICMET '10, Phuket, Thailand, 18–22 July*', ISBN 1-890843-22-9.

Olsson, U. and Espling, U. (2004), 'Part I. A framework of partnering for infrastructure maintenance', *Journal of Quality in Maintenance Engineering*, Vol. 10, No. 4, pp. 234–247.

Paguio, R. (2010), 'CRM technology: can adoption increase service quality and perceived value in maintenance services?', *International Journal of Services Sciences*, Vol. 3, No. 2–3, pp. 250–268.

Panesar, S.S. and Markeset, T. (2008), 'Development of a framework for industrial service innovation management and coordination', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 2, pp. 177–193.

Paranko, J. (2012), *'Profitability in mechanical engineering industry – longitudinal case study'*, Publication 1020, Dissertation, Tampere University of Technology, Tampere, ISBN 978-952-15-2764-7, 229 p., (in Finnish).

Parida, A. (2012), 'Asset performance assessment', in Van der Lei, T., Herder, P. and Wijnia, Y. (Eds.), '*The state of the art in Europe from a life cycle perspective'*, Springer, Dordrecht, ISBN 978-94-007-2723-6, pp. 101–113.

Petersen, C.V. and Plenborg, T. (2012), '*Financial statement analysis*', Prentice Hall, Harlow, ISBN 978-0-273-75235-6, 478 p.

Pintelon, L., Pinjala, S.K. and Vereecke, A. (2006), 'Evaluating the effectiveness of maintenance strategies', *Journal of Quality in Maintenance Engineering*, Vol 12, No. 1, pp. 7–20.

Pongpech, J., Murthy, D.N.P. and Boondiskulchock, R. (2006), 'Maintenance strategies for used equipment under lease', *Journal of Quality in Maintenance Engineering*, Vol. 12, No. 1, pp.52–67.

Prahalad, C.K. and Hamel, G. (1990), 'The core competence of the corporation', *Harvard Business Review*, Vol. 68, No. 3, pp. 71–91.

Protopappa-Sieke, M. and Seifert, R. (2011), 'Interrelating operational and financial performance measurements in a multiproduct inventory system', *International Journal of Services and Operations Management*, Vol. 10, No. 3, pp. 328–347.

Publicly Available Specification (PAS) 55-1 (2008), 'Specification for the optimized management of physical assets', British Standards Institution, ISBN 978-0-580-50975-9, 24 p.

Publicly Available Specification (PAS) 55-2 (2008), 'Guidelines for the application of PAS 55-1', British Standards Institution, ISBN 978-0-580-50976-6, 56 p.

Randall, W.S. and Farris II, M.T. (2009), 'Supply chain financing: using cash-to-cash variables to strengthen the supply chain', *International Journal of Physical Distribution and Logistics Management*, Vol. 39, No. 8, pp.669–689.

Raut, R.D., Bhasin, H.V. and Kamble, S.S. (2012), 'Analysing the effect of uncertain environmental factors on supplier-buyer strategic partnership (SBSP) by using structural equation model (SEM)', *International Journal of Procurement Management*, Vol. 5, No. 2, pp. 202–228.

Redondo-Cano, A. and Canet-Giner, M.T. (2010), 'Outsourcing agrochemical services: economic or strategic logic?', *Service Business*, Vol. 4, No. 3–4, pp. 237–252.

Reed, R. and Storrud-Barnes, S. (2009), 'Systematic performance differences across the manufacturing-service continuum', *Service Business*, Vol. 4, No. 3, pp. 319–339.

Reinartz, W. and Ulaga, W. (2008), 'How to sell services more profitable', *Harward Business Review*, Vol. 86, No. 5, pp. 90–96.

Robinson, S. (2004), '*Simulation: the practice of model development and use*', John Wiley and Sons, Chichester, ISBN 0-470-84772-7, 316 p.

Rutner, S.M., Gibson, B.J. and Williams, S.R. (2003), 'The impacts of the integrated logistics systems on electronic commerce and enterprise resource planning systems', *Transportation Research Part E: Logistics and Transportation Review*, Vol. 39, No. 2, pp. 83–93.

Ruuhela, R. (1982), *'Some models for analyzing the profit, profitability and financial growth of the firm'*, Acta Wasaensia 16, University of Vaasa, Vaasa, ISBN 951-683-156-7, 46 p.

Sawhney, R., Kannan, S. and Li, X. (2009), 'Developing a value stream map to evaluate breakdown maintenance operations', *International Journal of Industrial and Systems Engineering*, Vol. 4, No. 3, pp. 229–240.

SFS-EN 13306 (2010), 'Maintenance. Maintenance terminology', Finnish Standards Association, 53 p.

SFS-EN 15341 (2007), 'Maintenance. Maintenance key performance indicators', Finnish Standards Association, 43 p.

Shah, N.H. (2009), 'Optimisation of pricing and ordering under the two-stage credit policy for deteriorating items when the end demand is price and credit period sensitive', *International Journal of Business Performance and Supply Chain Modelling*, Vol. 1, No. 2–3, pp. 229–239.

Shin, H. and Soenen, L. (1998), 'Efficiency of working capital management and corporate profitability', *Financial Practice and Education*, Vol. 8, No. 2, pp. 37–45.

Simões, J.M., Gomes, C.F. and Yasin, M.M. (2011), 'A literature review of maintenance performance measurement. A conceptual framework and directions for future research', *Journal of Quality in Maintenance Engineering*, Vol. 17, No. 2, pp. 116–137.

Sun, H., Yam, R. and Wai-Keung, N. (2003), 'The implementation and evaluation of total productive maintenance (TPM) - an action case study in a Hong Kong manufacturing company', *International Journal of Advanced Manufacturing Technology,* Vol. 22, No. 3–4, pp. 224–228.

Swanson, L. (2001), 'Linking maintenance strategies to performance', *International Journal of Production Economics,* Vol. 70, No. 3, pp. 237–244.

Talha, M., Christopher, S.B. and Kamalavalli, A.L. (2010), 'Sensitivity of profitability to working capital management: a study of Indian corporate hospitals', *International Journal of Managerial and Financial Accounting,* Vol. 2, No. 3, pp. 213–227.

Talonen, P. (1973), 'Growth and profitability of the firm', *The Finnish Journal of Business Economics,* Vol. 22, No. 3, pp. 167–179, (in Finnish).

Tam, A.S.B. and Price, J.W.H. (2008), 'A maintenance prioritization approach to maximise return on investment subject to time and budget constraints', *Journal of Quality in Maintenance Engineering,* Vol. 14, No. 3, pp. 272–289.

Tarakci, H., Tang, K. and Teyarachakul, S. (2009), 'Learning effects on maintenance outsourcing', *European Journal of Operational Research,* Vol. 192, No. 1, pp. 138–150.

Teece, D.J. (1988), 'Capturing value from technological innovation: integration, strategic partnering, and licensing decisions', *Interfaces*, Vol. 18, No. 3, pp. 46–61.

Tenhunen, J. (2006), '*Management accounting in networks. Application possibilities and companies' needs'*, Acta Universitatis Lappeenrantaensis 241, Dissertation, Lappeenranta University of Technology, Lappeenranta, ISBN 952-214-209-3, 270 p., (in Finnish).

The European Federation of National Maintenance Societies. (2011), 'Intermediate results of the asset management survey for all national maintenance societies', available at: http://e-lomake.fi/raportti/efnms_2011_survey (accessed 1 August 2011).

The Finnish Maintenance Society. (2007), '*Maintenance in national economy of Finland*', Kunnossapitoyhdistys ry, 24 p., (in Finnish).

The Woodhouse Partnership Ltd, (2012), 'ISO 55000 international standard for asset management', available at: http://www.assetmanagementstandards.com/index.html (accessed 3 October 2013).

Tranfield, D., Denyer, D. and Smart, P. (2003), 'Towards a methodology for developing evidence-informed management knowledge by means of systematic review', *British Journal of Management*, Vol. 14, No. 3, pp. 207–222.

Transportation Research Board of the National Academies (2005), '*National cooperative highway research program report 545. Analytical tools for asset management*', Cambridge Systematics, Cambridge, ISBN 0-309-08832-1, 61 p.

US Army (2008), *'Army regulation 700-127. Logistics. Integrated logistics support'*, Headquarters, Department of the Army, Washington, DC, 74 p.

van Aken, J.E. and Romme, G. (2009), 'Reinventing the future: adding design science to the repertoire of organization and management studies', *Organization Management Journal*, Vol. 6, No. 1, pp. 5–12.

Veranen, J. (1996), *'Profit-demanding owners – to success with owner-centered management'*, WSOY, Porvoo, ISBN 951-0-21136-2, 148 p., (in Finnish).

Vining, A. and Globerman, S. (1999), 'A conceptual framework for understanding the outsourcing decision', *European Management Journal*, Vol. 17, No. 6, pp. 645–654.

Viskari, S., Lind, L., Kärri, T. and Schupp, F. (2012), 'Using working capital management to improve profitability in the value chain of automotive industry', *International Journal of Services and Operations Management*, Vol. 13, No. 1, pp. 42–64.

Viskari, S., Lukkari, E. and Kärri, T. (2011), 'State of working capital management research: bibliometric study', *Middle Eastern Finance and Economics*, No. 14, pp. 99–108.

Wang, W. (2010), 'A model for maintenance service contract design, negotiation and optimization', *European Journal of Operational Research*, Vol. 201, No. 1, pp.239–246.

Wang, Y.J. (2002), 'Liquidity management, operating performance, and corporate value: evidence from Japan and Taiwan', *Journal of Multinational Financial Management*, Vol. 12, No. 2, pp. 159–169.

Waeyenbergh, G. and Pintelon, L. (2002), 'A framework for maintenance concept development', *International Journal of Production Economics*, Vol. 77, No. 3, pp. 299–313.

Weston, J.F., Siu, J.A. and Johnson, B.A. (2001), *'Takeovers, restructuring, and corporate governance'*, 3rd edition, Prentice Hall, Upper Saddle River, New Jersey, ISBN 0-13-026505-5, 689 p.

Xia, B.-Z., Liu, J., Yu, D.-J. and Zhou, A.-M. (2011), 'A study on ally searching in maintenance alliance based on relation web model', *International Journal of Industrial and Systems Engineering*, Vol. 9, No. 4, pp. 412–433.

Yazici, H. (2012), 'Buyer perceptions on the buyer-supplier collaborative relationship and performance: a service example', *International Journal of Services and Operations Management*, Vol. 12, No. 2, pp. 165–187.

Yin, R.K. (2009), '*Case study research – design and methods'*, 4th edition, Sage Publications, Thousand Oaks, ISBN 978-1-4129-6099-1, 217 p.

PART II: Publications

PUBLICATION 1

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Top Modelling in Asset Management: a Systematic Literature Review

Salla Marttonen[1], Timo Kärri[2]

[1]Innovation Management, Lappeenranta University of Technology, Finland, salla.marttonen@lut.fi
[2]Innovation Management, Lappeenranta University of Technology, Finland, timo.karri@lut.fi

Keywords – Asset management, Model, Literature review

Abstract

Previous research on asset management models is examined through a systematic literature review. The goal is to find out what kind of models exist and how future research should be directed in order to fill the present research gaps. The results show that a vast majority of previous research has considered tangible fixed assets, neglecting the other assets of a company. Even though the importance of inter-organisational cooperation is remarkable today, the number of studies with the perspective of an asset management service provider, or an asset management network, is still negligible. In addition, a large part of the models is not very practical, but rather abstract or scientific. Finally, in most models the logic of asset management is presented from the perspective of either an individual asset or an asset fleet. Thus the perspectives of entire companies or company networks have not been explored much, even though they can be seen to be inherent in strategic asset management. In the future, practical models are needed to help different decision-makers in asset management networks to manage both their fixed and current assets at the company– or network level. The paper contributes to the understanding of asset management decision-making through pinpointing research gaps in previous literature. Considering the recent changes in business environments, it is important to alter the research themes of asset management accordingly.

1. Introduction

This paper sheds light on previous research on asset management, as well as on its aims, perspectives, and contribution. Lately, companies have often outsourced their support functions to outside suppliers (Kremic et al., 2006; Redondo-Cano & Canet-Giner, 2010). Inter-organisational cooperation and networking have thus increased, creating a need for novel asset management models and tools (Ahonen et al., 2010; Kroes & Ghosh, 2009).

However, asset management does not have one definite meaning, but multiple and diverse definitions. Thus academics from various, highly different research areas have contributed to the discussion about asset management. In order to respond to the practical need for up-to-date asset management models, it is first necessary to examine what has already been done, and what are the main research gaps in the field. The objective of this paper is to scrutinise the existing literature on asset management models, tools and frameworks. We have conducted a systematic literature review using the databases Scopus (Elsevier) and ISI Web of Science (Thomson Reuters). Our research questions are the following:

1. What kind of asset management models have been presented in academic journal publications?
2. What kind of, if any, research gaps can be identified in the research of asset management models?

We contribute to the existing discussion by articulating research gaps in the literature of asset management models and tools. Thus we identify the needed direction of future research on the topic. Section 2 of this paper focuses on the background of the study and presents a balance sheet –based view of asset management, which is the foundation behind our analysis. Section 3 addresses the process of literature selection. The results of the literature review are presented in section 4. The paper finishes with conclusions in section 5.

2. Need for Asset Management Models

Several researchers have acknowledged the significant role of asset management for a company's profitability (e.g. Aoudia et al., 2008; Lin et al., 2007; Tam & Price, 2008b). The importance of asset management has increased

through globalising competition and companies pursuing lean operations. As regards fixed physical assets, the phenomenon has been boosted by machinery becoming outdated, lack of maintenance and a low level of real investments. Recently, business models have changed when companies have started to concentrate more on their core competences, outsourcing supportive business functions to outside suppliers (e.g. Hendry, 1995; Kakabadse & Kakabadse, 2002; Kremic et al., 2006; Kumar & Kumar, 2004; Redondo-Cano & Canet-Giner, 2010).

The impact of focusing on core competences has been especially strong in the field of industrial services (Broedner et al., 2009; Boulaksil & Fransoo, 2010; Holschbach & Hofmann, 2011). As regards fixed, tangible assets, the maintenance functions have undergone a lot of outsourcings, which have been boosted by increasing complexity of assets (Kumar et al., 2006; Xia et al., 2011).

The trends described above have led to increasing collaboration along supply chains (Kroes & Ghosh, 2009; Yazici, 2012). Duffy (2008) states that companies form more and more inter-organisational long-term partnerships. Raut et al. (2012) highlight that the increasing dynamism of the business environment can be controlled through building strategic partnerships.

The importance of inter-organisational networks has created a need for novel tools and methods to support the decision making of company managers (e.g. Ahonen et al., 2010; MacCarthy & Jayarathne, 2012; Reinartz & Ulaga, 2008). These tools should promote the communication between network partners in order to increase collaboration in asset management.

Research on this topic can be considered challenging, not least because there are various interpretations of the term “asset management”. This has been widely acknowledged, for the international organisation for standardisation is currently working on a series of standards on asset management. It has been decided that the management of both tangible and intangible assets will be included in the upcoming standards, though the main focus will be on the tangible, physical assets (Pulkkanen, 2012).

We have adopted a holistic view on asset management as well. Our view is based on the balance sheet structure, which specifies assets and liabilities. The management of liabilities has received attention through for example capital structure research, but comprehensive optimisation of a company’s assets has not been studied extensively. Figure 1 shows the balance sheet –based view of asset management.

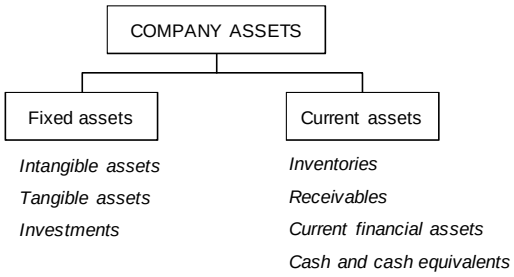

Figure 1 Balance sheet –based view of asset management

According to our view, assets can be divided into fixed and current assets. Fixed assets include intangible assets (consisting of for example goodwill, R&D expenses, and intangible rights), tangible assets (mostly equipment, buildings, constructions, land, and water), and investments (long-term financial assets). Current assets include inventories (on raw materials, supplies, work-in-process, and finished products), receivables (including short-term and long-term receivables), current financial assets (short-term investments), and cash and cash equivalents (including cash in hand and at banks). The balance sheet –based view takes all types of assets of a company into consideration. We have adopted this view as a basis for analysing the literature sample in this paper.

3. Literature Selection

This section presents how the literature review was conducted, and especially how the process of literature selection was performed. A systematic literature review was done to examine what kind of asset management models and tools have been introduced in academic journal articles previously. We chose to leave maintenance, inventory and portfolio management models out of the research, unless the search term “asset management” was used in the publication. One of our goals was to examine how various researchers have comprehended asset management. Thus, extensive inclusion of for example maintenance models in the research would have distorted the results, as they focus exclusively or almost exclusively on managing fixed assets.

As shown in table 1, search terms were created in three different categories. Category A includes only “asset management”, which is the core of this study and the term which we intend to clarify

through this review. Category B includes terms for different constructs used in decision making. We believe that the terms “model”, “framework” and “tool” cover these constructs adequately. Finally, category C reflects the management perspective adopted in this research. Thus the asset management models included in the literature sample must be associated with the economic performance of a company.
The search terms from different categories were then combined, yielding 9 (1 x 3 x 3) different combinations. These combinations were entered into databases Scopus (Elsevier) and ISI Web of Science (Thomson Reuters), which were chosen because they are widely considered to belong to the world-leading databases.

Category A	Category B	Category C
Asset management	*Model*	*Profit*
	Framework	*Profitability*
	Tool	*Cost*

Table 1 Search terms used in the paper

The results of the data search and the overall process of article selection are presented in figure 2. The different combinations of search terms resulted in 449 potentially relevant articles. The titles of these articles were then checked to exclude all the publications which did not meet the predefined inclusion criteria. The title check resulted in 197 articles, which proceeded on to an abstract check. After reviewing the abstracts, we approved 149 publications, after which we moved ahead to a full text check. The full text of 35 articles was not available, and 59 full texts were found not to meet the inclusion criteria. Thus 94 publications were excluded, and 55 articles were included in our sample for the literature review.
Predetermined inclusion criteria were used in the article selection. These criteria were:

(1) Feasibility as regards the balance sheet –based view of asset management was required. Thus the articles had to have a perspective of industrial company management. Papers considering for example management of water assets, transportation assets or infrastructure were excluded if these topics were not directly related to the main business of the company/industry in question. Also articles addressing customer asset management were excluded, as their focus was on customer relationship management, which is not in line with the balance sheet –based view of asset management.
(2) The role of asset management and modelling must be significant in the article. Thus those papers with only marginal remarks on them were excluded from the sample.
(3) Only scientific journal articles were included in the sample. Articles published in trade magazines were excluded.

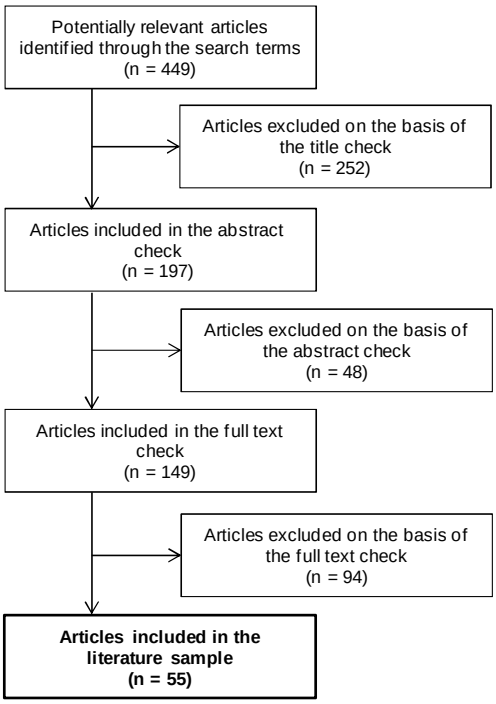

Figure 2 Literature selection process

During the literature selection process we found in total 55 articles that met the criteria stated above. In the next section, the sample of these articles is analysed to reveal the gaps and limitations of previous research on asset management models.

4. Analysing the Results

In the following subsections, different aspects of the literature sample are examined. In order to gain a general view of the research field, subsection 4.1 presents the time distribution of the publications in the sample. Next, subsection 4.2 concerns what type of assets the researchers have included in their definition of “asset management”. The balance sheet –based view of

asset management is used as a theoretical framework here. In subsection 4.3 we analyse the decision-making situations in which the models are meant to be used. Finally, subsection 4.4 reveals what type of models were included in the literature sample.

4.1 Time distribution

It can be seen in figure 3 that the number of scientific journal publications addressing asset management models has escalated during the last ten years. The last bar on the right includes articles published in 2011 or during the first eight months of 2012, before the data search was done. The increasing number of publications reflects the need for asset management decision-making tools, which was described in section 2 above.

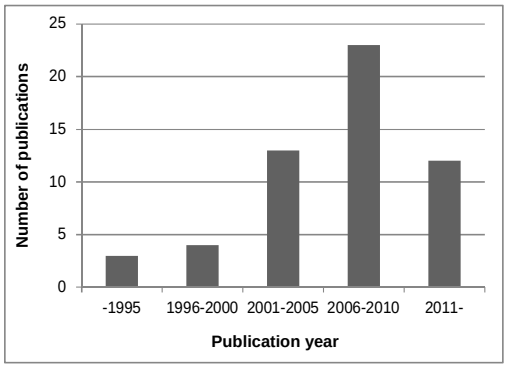

Figure 3 Time distribution of the articles in the sample

4.2 Asset type

As regards the various definitions of asset management, it is important to examine what types of assets have been addressed in the publications. Figure 4 shows the asset type distribution in the reviewed articles. For simplicity, each publication has been connected with just one of the categories described in the figure. Investments in fixed assets have been integrated with current financial assets into a single category, as the articles in question addressed them both.

We can conclude that fixed, tangible assets have received a vast majority of researchers' attention. Thus most researchers see asset management as strictly related to maintenance. The second largest category includes models for inventory management, followed by financial asset and investment management. Both of these are broad research areas, so just a small part of the researchers addressing inventories or financial assets have linked their research with the term "asset management".

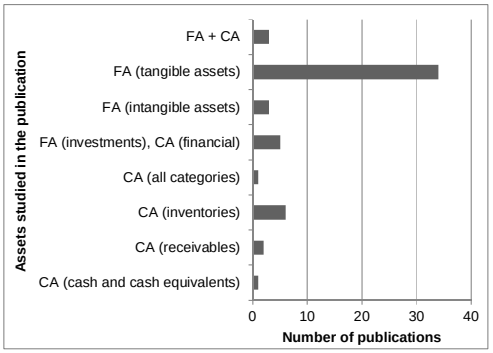

Figure 4 Distribution of asset types in the sample (FA stands for fixed assets, CA for current assets)

Most of the reviewed articles did not include any definition for asset management: instead, the reader had to draw his/her own conclusions of what types of assets were discussed in the paper. Considering the balance sheet –based view this feels irrational, as the asset types are so diverse.

Finally we note that comprehensive asset management (involving both fixed and current assets, denoted as FA+CA in figure 4) has not received much attention. However, it would be logical for decision-making tools, especially strategic ones, to adopt a holistic view in order to reach maximal all-encompassing performance.

4.3 Perspective

Here we study whether the previous literature on asset management models has considered the emergence of inter-organisational networks and the need they create for decision-making tools. In figure 5 the articles have been classified according to their main target group outside the academia: in most articles the introduced model was intended to be used by a company that operates or owns the assets in question. Four of the articles acknowledged the increased role of networks by indicating that the model can be used by either the asset owner or their supplier. In four articles the target group was ambiguous.

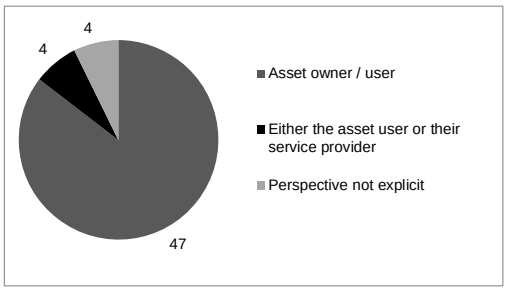

Figure 5 Perspectives of the reviewed articles

The examination above tells us that in general the research on asset management models has not yet adopted the perspective of inter-organisational networks. This is supported by table 2, where the levels of inspection of the articles are shown. As seen in the table, a majority of the publications addresses the management of a single asset or an asset fleet. Eight articles focus on company-level asset management, and just one article examines the topic on the inter-organisational level.

Level of inspection	Number of publications
Single asset	20
Asset fleet	25
Company	8
Service	1
Customer -service provider relationship	1

Table 2 Levels of inspection in the sample

4.4 Model Features

Despite the conclusion stated above about the literature not examining asset management on the level of whole companies or networks, most of the scrutinised models actually covered a long time span. This can be seen in figure 6, where the publications have been categorised on the basis of applying the models introduced in them: we have considered long-term asset management to include strategic management with a time span of several years, while short-term management means a time span of one year or less, and thus stands for more operational decision-making. In five articles the time span was unclear.

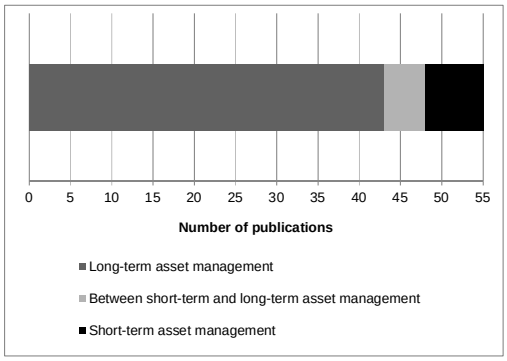

Figure 6 Distribution of time span in the application of the models

Finally we have studied what types of models have been introduced in previous literature. Figure 7 classifies the models into quantitative models and qualitative frameworks. Here we define quantitative models to include all numeric calculations and mathematical models, while qualitative frameworks include mostly conceptual structures and constructs. We have also included a category for models which have both quantitative and qualitative features. It can be seen that most of the existing models are quantitative, while there are only few qualitative and hybrid models.

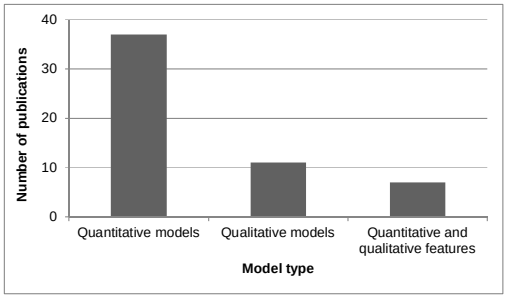

Figure 7 Distribution of model types in the sample

We found that most of the quantitative models were quite abstract by nature (as opposed to practical models). This means for example that applying the model was not explicitly explained to the reader, or that the input parameters of the model were really challenging to acquire in practice. The qualitative models included both abstract and practical constructs, but most of the hybrid models (containing quantitative and qualitative features) were practical. This is interesting, even though the number of these hybrid models is too small to draw any definite conclusions. Also other researchers have stated that the practical applicability of models and tools could be improved through combining quantitative and qualitative modelling and developing the tools in cooperation with case companies (Garg & Deshmukh, 2006; Sharma et al., 2011).

5. Conclusions

We have conducted a systematic literature review on asset management models, based on a sample of 55 journal publications. It can now be concluded that due to various definitions of asset management, the existing models are heterogeneous. We have also identified four distinct research gaps in the literature of asset management models and tools.

The first research gap concerns the types of assets targeted with the models: most existing models only consider fixed, tangible assets, while

intangible, financial, and current assets are neglected. However, companies should manage their assets more comprehensively. The second research gap is that previous publications do not address the perspective of inter-organisational networks or outside suppliers. This is a serious limitation, considering the importance of networks and partnerships for the business of today. The third research gap is the fact that many of the models are abstract or scientific by nature, and are thus challenging to use in actual decision making in companies. In order to truly benefit the decision-makers, the academia should produce more practical models. The fourth and final research gap is related to the time span and level of inspection used in the models. Most models have a long time span, and they are thereby intended to be used in strategic asset management. However, only few publications concern asset management on the company level, while most of them focus on the level of either a single asset or an asset fleet. This is not in line with the emphasis on strategic asset management.

Our contribution is mostly theoretical, as we have offered an overview of the existing literature of asset management models. We have also identified four research gaps, which researchers should fill to provide up-to-date decision-making tools for companies. This way also managerial implications should emerge in the future.

The limitations of this research include not being able to access all the publications that passed the abstract check. Also, the quality of the literature sample was not studied through for example a citation analysis. However, as the publications represent highly different research areas, the comparability of the results of a citation analysis would have been debatable.

We conclude that the research of asset management consists of various different fields. As a result, the previous studies about modelling in asset management are somewhat fragmented. Thus it is imperative that researchers define explicitly what type of assets they are studying, and from which perspective. In the future, practical models are needed to help decision-makers in asset management networks to manage both their fixed and current assets on the company– or network level.

6. References

*Indicates that the study is part of the literature sample.

*Abu-Elanien, A.E.B., Salama, M.M.A. and Bartnikas, R. (2011) A techno-economic method for replacing transformers, IEEE Transactions on Power Delivery, Vol. 26, no. 2, pp. 817-829.

*Ahmad, S.S. (1996) Life assessment study of a 400MW steam boiler at Ghazlan power plant, Journal of Quality in Maintenance Engineering, Vol. 2, no. 4, pp. 48-58.

Ahonen, T., Reunanen, M., Pajari, O., Ojanen, V. and Lanne, M. (2010) Maintenance communities – a new model for the networked delivery of maintenance services, International Journal of Business Innovation and Research, Vol. 4, no. 6, pp. 560-583.

*Alinovi, A., Bottani, E. and Montanari, R. (2012) Reverse logistics: a stochastic EOQ-based inventory control model for mixed manufacturing / remanufacturing systems with return policies, International Journal of Production Research, Vol. 50, no. 5, pp. 1243-1264.

*Allouche, E.N., Ariaratnam, S.T. and MacLeod, C.W. (2003) Software for planning and cost control in directional drilling projects, Journal of Construction Engineering and Management – ASCE, Vol. 129, no. 4, pp. 446-453.

*Andersen, J., Christiansen, M., Crainic, T.G. and Grønhaug, R. (2011) Branch and price for service network design with asset management constraints, Transportation Science, Vol. 45, no. 1, pp. 33-49.

Aoudia, M., Belmokhtar, O. and Zwingelstein, G. (2008) Economic impact of maintenance management ineffectiveness of an oil and gas company, Journal of Quality in Maintenance Engineering, Vol. 14, no. 3, pp. 237-261.

*Banjevic, D., Jardine, A.K.S., Makis, V. and Ennis, M. (2001) A control-limit policy and software for condition-based maintenance optimization, INFOR: Information Systems and Operational Research, Vol. 39, no. 1, pp. 32-50.

*Beltratti, A., Laurant, A. and Zenios, S.A. (2004) Scenario modelling for selective hedging strategies, Journal of Economic Dynamics and Control, Vol. 28, no. 5, pp. 955-974.

*Beranek, L. (2011) Risk analysis methodology used by several small and medium enterprises in the Czech Republic, Information Management and Computer Security, Vol. 19, no. 1, pp. 42-52.

*Bertling, L., Allan, R. and Eriksson, R. (2005) A reliability-centered asset maintenance method for assessing the impact of maintenance in power

distribution systems, IEEE Transactions on Power Systems, Vol. 20, no. 1, pp. 75-82.

Boulaksil, Y. and Fransoo, J.C. (2010) Implications of outsourcing on operations planning: findings from the pharmaceutical industry, International Journal of Operations & Production Management, Vol. 30, no. 10, pp. 1059-1079.

Broedner, P., Kinkel, S. and Lay, G. (2009) Productivity effects of outsourcing – new evidence on the strategic importance of vertical integration decisions, International Journal of Operations & Production Management, Vol. 29, no. 2, pp. 127-150.

*Bumblauskas, D., Meeker, W. and Gemmill, D. (2012) Maintenance and recurrent event analysis of circuit breaker data, International Journal of Quality and Reliability Management, Vol. 29, no. 5, pp. 560-575.

*Chen, J.C.H. (2002) Enterprise computing asset management: a case study, Industrial Management and Data Systems, Vol. 102, no. 1-2, pp. 80-88.

*Cirtita, H. and Glaser-Segura, D.A. (2012) Measuring downstream supply chain performance, Journal of Manufacturing Technology Management, Vol. 23, no. 3, pp. 299-314.

*Cronin, J.J. (1985) A comparison of the relative importance of the marketing, financial, and asset management implications of strategic decisions, Journal of the Academy of Marketing Science, Vol. 13, no. 2, pp. 242-258.

*Davis, P. and Marlow, D. (2008) Asset management: quantifying economic lifetime of large-diameter pipelines, Journal / American Water Works Association, Vol. 100, no. 7, pp. 110-119.

*Dong, M. (2010) A tutorial on nonlinear time-series data mining in engineering asset health and reliability prediction: concepts, models, and algorithms, Mathematical Problems in Engineering, Vol. 2010, Article ID 175936, 22 pages, doi:10.1155/2010/175936.

Duffy, R. (2008) Towards a better understanding of partnership attributes: an exploratory analysis of relationship type classification, Industrial Marketing Management, Vol. 37, no. 2, pp. 228-244.

*Edström, F., Rosenlind, J., Hilber, P. and Söder, L. (2012) Modeling impact of cold load pickup on transformer aging using Ornstein-Unlenbeck process, IEEE Transactions of Power Delivery, Vol. 27, no. 2, pp. 590-595.

*El Hayek, M., Van Voorthuysen, E. and Kelly, D.W. (2005) Optimizing life cycle cost of complex machinery with rotable modules using simulation, Journal of Quality in Maintenance Engineering, Vol. 11, no. 4, pp. 333-347.

*Erera, A.L., Morales, J.C. and Savelsbergh, M. (2005) Global intermodal tank container management for the chemical industry, Transportation Research Part E – Logistics and Transportation Review, Vol. 41, no. 6, pp. 551-566.

*Espie, P., Ault, G.W., Burt, G.M. and McDonald, J.R. (2003) Multiple criteria decision making techniques applied to electricity distribution system planning, IEE Proceedings – Generation, Transmission and Distribution, Vol. 150, no. 5, pp. 527-535.

Garg, A. and Deshmukh, S.G. (2006) Maintenance management: literature review and directions, Journal of Quality in Maintenance Engineering, Vol. 12, no. 3, pp. 205-238.

*Heather, A.I.J. and Bridgeman, J. (2007) Water industry asset management: a proposed service-performance model for investment, Water and Environment Journal, Vol. 21, no. 2, pp. 127-132.

*Hegazy, T., Elhakeem, A., Ahluwalla, S.S. and Attalia, M. (2012) MOST-FIT: support techiques for inspection and life cycle optimization in building asset management, Computer-Aided Civil and Infrastructure Engineering, Vol. 27, no. 2, pp. 130-142.

Hendry, J. (1995) Culture, community and networks: the hidden cost of outsourcing, European Management Journal, Vol. 2, no. 13, pp. 193-200.

*Holmström, J., Brax, S. and Ala-Risku, T. (2010) Comparing provider-customer constellations of visibility-based service, Journal of Service Management, Vol. 21, no. 5, pp. 675-692.

Holschbach, E. and Hofmann, E. (2011) Exploring quality management for business services from a buyer's perspective using multiple case study evidence, International Journal of Operations & Production Management, Vol. 31, no. 6, pp. 648-685.

*Hoskins, R.P., Brint, A.T. and Strbac, G. (1999) A structured approach to asset management within the electricity industry, Utilities Policy, Vol. 7, no. 4, pp. 221-232.

*Johansson, O. and Hellström, D. (2007) The effect of asset visibility on managing returnable transport items, International Journal of Physical Distribution and Logistics Management, Vol. 37, no. 10, pp. 799-815.

*Jostes, T. and Helms, M.M. (1995) Use of buffer inventory as an asset-management tool in a quick-response environment, Production and Inventory Management Journal, Vol. 36, no. 3, pp. 17-22.

Kakabadse, A. and Kakabadse, N. (2002) Trends in outsourcing: contrasting USA and Europe, European Management Journal, Vol. 2, no. 20, pp. 189-198.

*Kissling, R., Fitzpatrick, C., Boeni, H., Luepschen, C., Andrew, S. and Dickenson, J. (2012) Definition of generic re-use operating models for electrical and electronic equipment, Resources, Conservation and Recycling, Vol. 65, pp. 85-99.

*Klint, P. and Verhoef, C. (2002) Enabling the creation of knowledge about software assets, Data and Knowledge Engineering, Vol. 41, no. 2-3, pp. 141-158.

Kremic, T., Tukel, O.I. and Rom, W. (2006) Outsourcing decision support: a survey of benefits, risks, and decision factors, Supply Chain Management: An International Journal, Vol. 6, no. 11, pp. 467-482.

Kroes, J. and Ghosh, S. (2009) A framework and scale development for assessing supply chain outsourcing alignment with competitive priorities, International Journal of Procurement Management, Vol. 2, no. 1, pp. 1-24.

Kumar, R. and Kumar, U. (2004) A conceptual framework for the development of a service delivery strategy for industrial systems and products, Journal of Business & Industrial Marketing, Vol. 5, no. 19, pp. 310-319.

Kumar, R., Markeset, T. and Kumar, U. (2006) Implementation and execution of industrial service strategy. A case study from the oil and gas industry, Journal of Quality in Maintenance Engineering, Vol. 12, no. 2, pp. 105-117.

*Kumar, U.D. and Saranga, H. (2010) Optimal selection of obsolescence mitigation strategies using a restless bandit model, European Journal of Operational Research, Vol. 200, no. 1, pp. 170-180.

*Lee, S., Turner, J., Daskin, M.S., Homem-de-Mello, T.H. and Smilowitz, K. (2012) Improving fleet utilization for carriers by interval scheduling, European Journal of Operational Research, Vol. 218, no. 1, pp. 261-269.

*Lin, G., Ettl, M., Buckley, S., Bagchi, S., Yao, D.D., Naccarato, B.L., Allan, R., Kim, K. and Koenig, L. (2000) Extended-enterprise supply-chain management at IBM personal systems group and other divisions, Interfaces, Vol. 30, no. 1, pp. 7-25.

Lin, S., Jing, G., Koronios, A. and Chanana, V. (2007) Developing a data quality framework for asset management in engineering organisations, International Journal of Information Quality, Vol. 1, no. 1, pp. 100-126.

*Liyanage, J.P. (2007) Operations and maintenance performance in production and manufacturing assets: the sustainability perspective, Journal of Manufacturing Technology Management, Vol. 18, no. 3, pp. 304-314.

*Lynch, J.P. (2007) An overview of wireless structural health monitoring for civil structures, Philosophical Transactions of the Royal Society A: Mathematical Physical and Engineering Sciences, Vol. 365, no. 1851, pp. 345-372.

MacCarthy, B.L. and Jayarathne, P.G.S.A. (2012) Sustainable collaborative supply networks in the international clothing industry: a comparative analysis of two retailers, Production Planning & Control, Vol. 23, no. 4, pp. 252-268.

*Michalski, G. (2007) Portfolio management approach in trade credit decision making, Romanian Journal of Economic Forecasting, Vol. 8, no. 3, pp. 42-53.

*Michalski, G. (2008a) Corporate inventory management with value maximisation in view, Agricultural Economics, Vol. 54, no. 5, pp. 187-192.

*Michalski, G. (2008b) Operational risk in current assets investment decisions: portfolio management approach in accounts receivable, Agricultural Economics – Zemedelska Ekonomika, Vol. 54, no. 1, pp. 12-19.

*Michalski, G. (2008c) Value-based inventory management, Romanian Journal of Economic Forecasting, Vol. 9, no. 1, pp. 82-90.

*Michalski, G. (2009) A value-oriented framework for inventory management, South East European Journal of Economics and Business, Vol. 4, no. 2, pp. 97-102.

*Michalski, G. (2010) Planning optimal from the firm value creation perspective. Levels of operating cash investments, Romanian Journal of

Economic Forecasting, Vol. 13, no. 1, pp. 198-214.

*Naraharisetti, P.K., Karimi, I.A. and Srinivasan, R. (2008) Supply chain redesign through optimal asset management and capital budgeting, Computers and Chemical Engineering, Vol. 32, no. 12, pp. 3153-3169.

*Naraharisetti, P.K., Karimi, I.A. and Srinivasan, R. (2009) Supply chain redesign – multimodel optimization using a hybrid evolutionary algorithm, Industrial and Engineering Chemistry Research, Vol. 48, no. 24, pp. 11094-11107.

*O, J., Lee, J.W. and Zhang, B.-T. (2006) Adaptive stock trading with dynamic asset allocation using reinforcement learning, Information Sciences, Vol. 176, no. 15, pp. 2121-2147.

*Pai, A. and Geltner, D. (2007) Stocks are from mars real estate is from venus – the cross-section of long-run investment performance, Journal of Portfolio Management, Vol. 33, no. 5, pp. 134-144.

*Pandya, K.V. (1995) Review of modelling techniques and tools for decision making in manufacturing management, IEE Proceedings: Science, Measurement and Technology, Vol. 142, no. 5, pp. 371-377.

Pulkkanen, R. (2012) ISO 55000 – compiling a series of standards on asset management moves forward at a good pace, Promaint, Vol. 26, no. 7, pp. 20-21 (in Finnish).

*Rahmawati, S.D., Whitson, C.H., Foss, B. and Kuntadi, A. (2012) Integrated field operation and optimization, Journal of Petroleum Science and Engineering, Vol. 81, no. 1, pp. 161-170.

Raut, R.D., Bhasin, H.V. and Kamble, S.S. (2012) Analysing the effect of uncertain environmental factors on supplier-buyer strategic partnership (SBSP) by using structural equation model (SEM), International Journal of Procurement Management, Vol. 5, no. 2, pp. 202-228.

Redondo-Cano, A. and Canet-Giner, M.T. (2010) Outsourcing agrochemical services: economic or strategic logic?, Service Business, Vol. 4, no. 3-4, pp. 237-252.

Reinartz, W. and Ulaga, W. (2008) How to Sell Services More Profitable, Harward Business Review, Vol. 86, no. 5, pp. 90-96.

*Ruiz-Torrubiano, R. and Suarez, A. (2009) A hybrid optimization approach to index tracking, Annals of Operations Research, Vol. 166, no. 1, pp. 57-71.

*Samis, M., Davis, G.A., Laughton, D. and Poulin, R. (2005) Valuing uncertain asset cash flows when there are no options: a real option approach, Resources Policy, Vol. 30, no. 4, pp. 285-298.

*Scarf, P.A. and Martin, H.H. (2001) A framework for maintenance and replacement of a network structured system, International Journal of Production Economics, Vol. 69, no. 3, pp. 287-296.

*Schuman, C.A. and Brent, A.C. (2005) Asset life cycle management: towards improving physical asset performance in the process industry, International Journal of Operations and Production Management, Vol. 25, no. 5-6, pp. 566-579.

Sharma, A., Yadava, G.S. and Deshmukh, S.G. (2011) A literature review and future perspectives on maintenance optimization, Journal of Quality in Maintenance Engineering, Vol. 17, no. 1, pp. 5-25.

*Svendsen, M. and Huppert, W. (2003) Optimal maintenance in irrigation, Irrigation and Drainage Systems, Vol. 17, no. 1-2, pp. 109-128.

*Tam, A.S.B., Chan, W.M. and Price, J.W.H. (2007) Maintenance scheduling to support the operation of manufacturing and production assets, International Journal of Advanced Manufacturing Technology, Vol. 34, no. 3-4, pp. 399-405.

*Tam, A.S.B. and Price, J.W.H. (2008a) A generic asset management framework for optimising maintenance investment decision, Production Planning and Control, Vol. 19, no. 4, pp. 287-300.

Tam, A. and Price, J. (2008b) A maintenance prioritization approach to maximise return on investment subject to time and budget constraints, Journal of Quality in Maintenance Engineering, Vol. 14, no. 3, pp. 272-289.

*Van Hofwegen, P.J.M. (1999) Asset management programmes for financial planning and management in irrigation and drainage, Irrigation and Drainage Systems, Vol. 13, no. 2, pp. 131-143.

Xia, B.-Z., Liu, J., Yu, D.-J. and Zhou, A.-M. (2011) A study on ally searching in maintenance alliance based on relation web model, International Journal of Industrial and Systems Engineering, Vol. 9, no. 4, pp. 412-433.

Yazici, H. (2012) Buyer perceptions on the buyer-supplier collaborative relationship and

performance: a service example, International Journal of Services and Operations Management, Vol. 12, no. 2, pp. 165-187.

*Zhang, X. and Gockenbach, E. (2007) Component reliability modeling of distribution systems based on the evaluation of failure statistics, IEEE Transactions of Dielectrics and Electrical Insulation, Vol. 14, no. 5, pp. 1183-1191.

*Zhang, X., Zhang, J. and Gockenbach, E. (2009) Reliability centered asset management for medium-voltage deteriorating electrical equipment based on Germany failure statistics, IEEE Transactions on Power Systems, Vol. 24, no. 2, pp. 721-728.

*Zuashkiani, A., Rahmandad, H. and Jardine, A.K.S. (2011) Mapping the dynamics of overall equipment effectiveness to enhance asset management practices, Journal of Quality in Maintenance Engineering, Vol. 17, no. 1, pp. 74-92.

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Profitable working capital management in industrial maintenance companies

Salla Marttonen*, Sari Monto and Timo Kärri

Department of Innovation Management
Lappeenranta University of Technology
P.O. Box 20, FI-53851, Lappeenranta, Finland

salla.marttonen@lut.fi
sari.monto@lut.fi
timo.karri@lut.fi
*Corresponding author

Abstract

Purpose – The purpose of this paper is to analyze the impact of working capital management on profitability. This connection is further studied in industrial maintenance service companies.

Design/methodology/approach – Analytical modeling has been used as the research method. The empirical analyses have been made on the basis of financial statements.

Findings – We present an analytical flexible asset management model, which reveals a significant negative correlation between the cycle times of operational working capital and the return on investment. The importance of working capital management is emphasized in the industrial maintenance service sector, because of light fixed assets and good profitability.

Research limitations – There are some mathematical limitations in the applicability of the model introduced in this paper. These limitations should be addressed in further research.

Practical implications – Our flexible asset management model can be utilized as a tool in decision-making in firms, both in the short term and in the long term. On the basis of this paper, the decision-makers can consider how important working capital management is in their industry. In the industrial maintenance service business, more attention should be paid to active management of working capital.

Originality/value – The flexible asset management model is a new decision-making tool. We also contribute to the unexplored perspective of industrial maintenance companies. This paper is valuable to service companies, as the research of working capital management has mostly focused on manufacturing industries.

Keywords Working capital, Profitability, Industrial maintenance services, Modeling, Flexible asset management model

Paper type Research paper

Introduction

The focus of this paper is on the working capital management of industrial maintenance service providers. There is not much previous research about industrial maintenance service providers, although maintenance performance has grown to be of high importance to industrial companies (e.g. Al-Turki 2011; Simões *et al.*, 2011). Previous research has been mainly done from the point of view of service buyers, concerning mostly outsourcing. However, several researchers have already linked the asset management perspective to the company-level goals and profitability (e.g. Aoudia *et al.*, 2008; Tam and Price 2008). Considering the present state of industrial services, the global trend towards networking and focusing on core competences has led to some notable changes (Broedner *et al.*, 2009; Boulaksil and Fransoo, 2010; Holschbach and Hofmann, 2011). A vast majority of outsourced business functions can be classified as services (Bailey *et al.*, 2002; Benson and Ieronimo, 1996; Kakabadse and Kakabadse, 2002; Harland *et al.*, 2005; McIvor *et al.*, 2009). Bailey *et al.* (2002) reported that 70% of the companies in their research sample had outsourced one or more of their business functions. Gradually the outsourcing practice has extended to more and more important functions (Harland *et al.*, 2005; Hui and Tsang, 2006). Consequently an increasing demand for a variety of industrial services has emerged. This has led to a great number of start-up industrial service companies throughout the world (Hilletofth and Hilmola, 2010). The industrial maintenance of manufacturing enterprises is one of the services outsourced more and more often (Tarakci *et al.*, 2009). In an international survey conducted by the European Federation of National Maintenance Societies (2011), 24% of the surveyed companies had outsourced their maintenance activities. Campbell (1995) states that in his survey implemented in North America, 35% of the companies had outsourced at least some part of their maintenance activities.

Operational working capital management, including inventories, accounts receivable and accounts payable, is an important part of short-term finance and asset management. The past economic crisis raised the interest towards more efficient working capital management. This also increased the academic interest towards the topic. The determinants of working capital management and the relation between working capital management and profitability have been studied by several researchers (e.g. Chiou *et al.*, 2006; Deloof, 2003; Hill *et al.*, 2010). Broad, cross-industry statistical analyses have concluded that companies should apply aggressive strategy to manage their operational working capital, which means shortening the cycle times of inventories, accounts receivable and increasing the cycle time of accounts payable. It should be noted, however, that minimizing working capital is not always the most rational option; instead the cycle times of working capital should be actively optimized and managed according to contextual factors. The literature has not considered individual industries regarding working capital management strategies. In addition, prior research has indicated a range of variables affecting working capital management, but there is still not a clear view of what the affecting variables are and how great their impact is. Also, the focus of previous research has been on manufacturing industries. The special characteristics of service industries have mostly been neglected in studies related to working capital management.

The first objective of this research is to observe the impact of working capital management on the return on investment, ROI, at the general level through analytical modeling. Second objective is to examine the role of working capital and its impact on the ROI in the industrial maintenance service sector. The research questions of this paper are the following:

What is the connection between the cycle times of working capital and the return on investment?

What is the effect of working capital management on the return on investment in the industrial maintenance service companies?

What are the main differences between small and medium size enterprises and large enterprises in the maintenance service sector regarding the cycle times of working capital?

How can a target return on investment be achieved through the management of the cycle times of working capital in the dynamic future of industrial maintenance service companies?

Modeling has been used as the research method in this paper. The flexible asset management model (henceforth called the FAM model) we present here connects working capital management and the ROI, and can be used to observe the impact of working capital management on relative profitability. By analyzing working capital with an analytical model, new insights to the effects of other variables affecting the working capital management-profitability relationship can be observed. The model can be used on a customer or supplier level in contract-bound industries to control the terms of contracts from the perspective of profitability. In this paper we approach one of the managerial implications of our FAM model by analyzing how a target ROI can be achieved in dynamic conditions through working capital management.

This paper sheds light on the working capital management in industrial maintenance service companies. The behavior and features of the model are tested with empirical data of maintenance service providers. Our empirical analysis is done on the basis of the financial statements of 18 Finnish industrial maintenance companies. We show that also service sector needs to take working capital into account, and that companies can increase their profitability by more efficient cycle time of working capital. The impact of working capital is even larger than in capital intensive manufacturing industries. The industrial maintenance service sector is still relatively unknown from academic point of view. This research uncovers new information about the economic state and development of these service providers. It is also noteworthy that this paper accumulates information about the differences between large, and small and medium size maintenance service providers (SMEs).

Working capital management and profitability

Working capital is a part of a firm's capital employed such as fixed assets. Broadly, net working capital is defined as current assets less current liabilities and it measures the financial health of a company. Working capital can also be defined from the operational perspective as inventories plus accounts receivable less accounts payable. We concentrate on operational working capital in this paper. A large amount of working capital ties up funds and can also indicate problems in the operations of a company. Although discussed in textbooks of finance and management accounting, working capital management has received relatively little attention in the academic research (Viskari *et al.*, 2011), which has traditionally concentrated on long-term capital (Chiou *et al.*, 2006), and asset management has mostly concerned fixed assets (Komonen, 2010).

The management of operational working capital is balancing between the reduction of capital tied up to the processes and current assets, which increases profitability, and minimizing the adverse effects caused by too small amount of operational working capital. If the inventory levels are too low, possible interruptions of production, delivery problems, business losses due to scarcity of products, and price fluctuations may cause extra costs (Blinder and Maccini, 1991). Decrease in trade credits granted to customers drops sales (Molina and Preve, 2009), and may harm the relationships with customers (Ng *et al.*, 1999). In addition, paying suppliers with long payment periods mean that discounts for early payments cannot be utilized (Wang,

2002). The interesting question of management is, whether these arguments for long cycle times offset the benefits of reducing working capital. However, answering this question is not a part of the core contents of this paper.

Statistical analyses of the relation between working capital management and profitability have concluded that it is more beneficial for a company to aim for a shorter cycle time of operational working capital and reduce tied-up capital and total assets than to operate with long cycle times (e.g. Deloof, 2003; García-Teruel and Martínez-Solano, 2007; Lazaridis and Tryfonidis, 2006). Besides profitability, the shorter cycle time also improves the liquidity and productivity of a company (Johnson and Templer, 2011). The data of the previous studies has been gathered from large databases, which has enabled large samples. With this kind of research design, statistically significant results can be found, but the previous literature lacks the perspective of individual industries. As we know, there are huge differences in the capital structures, investment logics and profitability between industries. In addition, even if previous literature has found the negative correlation between the cycle time of working capital and profitability, it is still unknown how great the impact of working capital management on profitability actually is. Could managers really affect the return on investment through working capital management or is the relation between the variables insignificant in practice?

According to Reed and Storrud-Barnes (2009), most management theories have concentrated on manufacturing companies, while differences and similarities to service providers have been neglected. Thus the applicability of practical contributions to the service sector often remains unsettled. In many respects this holds true also in studies of working capital management. In some studies of working capital management, service providers have been excluded from the sample in advance (see e.g. Deloof, 2003; Dong and Su, 2010). Other studies have included service providers alongside manufacturing companies (see e.g. Baños-Caballero *et al.*, 2010; Jose *et al.*, 1996). It can be noticed in these studies that the cycle time of operational working capital, cash conversion cycle (CCC), appears to be significantly shorter for service providers than for manufacturing industries. However, this observation has not yet been discussed further, and thus it is reasonable to conduct further research on this subject.

The emergence of the industrial maintenance service sector in Finland

The role of maintenance is significant and still increasing in Finland due to relatively aged industrial assets: a vast majority of the production investments of Finnish industrial companies are nowadays directed to countries with inexpensive work force (Komonen, 2009). The average age of equipment in Finnish industries has thus increased to over 17 years (The Finnish Maintenance Society, 2007). Kornev (2009) states that the base-line for the age of industrial equipment in developed countries is between six and eight years. The structure of the maintenance sector in Finland has changed dramatically in the past decades, greatly because of the trend toward networking and focusing on core competences. Networking is not a very recent phenomenon: Miles and Snow introduced the concept of dynamic networks already in 1986 (Miles and Snow, 1986). Since then, networking has developed to be a universal trend and long-term partnerships have become more and more common (Duffy, 2008). The core competences of a company, on the other hand, were first introduced by Prahalad and Hamel (1990). In twenty years close competition has boosted the willingness of industrial manufacturing companies to concentrate on their core competences and outsource some of their supportive business functions to other companies (Hendry, 1995; Kakabadse and Kakabadse, 2002; Kremic *et al.*, 2006; Kumar and Kumar, 2004; Redondo-Cano and Canet-Giner, 2010).

Industrial maintenance outsourcing is relatively extensive in Finland. The Finnish Maintenance Society (2007) states that out of the 50 000 people employed in industrial maintenance in Finland, 15 000 are employed by maintenance service providers. According to this indicator, 30% of Finnish industrial maintenance has been outsourced. One major element behind this phenomenon is striving for economies of scale in maintenance actions. The recent profitability problems of the forest industry have further increased maintenance outsourcing in Finland. Forest companies have struggled to cut down the costs and to outsource anything but their most crucial core functions.

Both the significance of maintenance performance to industrial companies, and the fact that long-term relationships are becoming more and more common in maintenance highlight the role of contracts in the industrial maintenance business. Contracts in outsourced services and in maintenance have been addressed in scientific research (e.g. Campbell, 1995; Kumar *et al.*, 2004; Martin, 1997; Ngwenyama and Bryson, 1999). However, the perspective of the maintenance service provider remains somewhat unexplored, and the perspective of the customer has been strongly emphasized instead. However, the maintenance service providers must have in advance a good idea of how changes in the contract affect their profitability. Elements to be considered include for example the terms of payment and the ownership of spare parts and assets to be maintained. These can be further inspected with the FAM model.

Methodology

Analytical modeling has been used as a research method in this study. Demski (2007) describes this method as using deductive logic in representing a concept or a process. The advantage of using modeling is transparency, which leads to high internal validity. The FAM model is applied to industrial maintenance business by using an empirical analysis about the behavior of the model. The more extensive testing of the model with different data is left for further research. The empirical analysis is done with the financial statements of 18 Finnish industrial maintenance companies. Though small, the analyzed sample represents a remarkable share of the Finnish industrial maintenance sector. The 3 893 people employed by these 18 enterprises cover

approximately 26% of the employees of the whole sector. The sample net sales of 472 million euro, on the other hand, represents approximately 13% of the sum used yearly in industrial maintenance in Finland. (The Finnish Maintenance Society, 2007) The enterprises selected to the sample are listed in table I together with their personnel numbers and net sales. The sample has been selected by utilizing the membership list of the Finnish Maintenance Society. Structurally the sample represents the Finnish industrial maintenance sector well, consisting of a few large enterprises and mostly SMEs. The sample has been divided into large enterprises and SMEs according to the European Commission recommendation 2003/361/EC (European Commission, 2009). Maintenance companies from outside Finland were excluded from the study because the required data was not within reach. Probability sampling has not been used because a complete list of suitable enterprises was not available.

It was considered crucial that the sample especially reflects the features of industrial maintenance business. Thus, when selecting the sample, only enterprises whose focus was mainly in industrial maintenance were accepted, which means that equipment manufacturers and enterprises offering infrastructural maintenance services were delimited from the sample. Also the smallest micro enterprises were left out of this research. The final criteria of belonging to the sample were that the enterprises had existed for the whole period of analysis, 2004-2008, and their financial statements were available for this period. A period of five years has been chosen because the analysis is to give a clear, comprehensive understanding about the relationship between working capital management and profitability in Finnish industrial maintenance enterprises. At the time of collecting the data, the financial statements of subsequent fiscal years were not yet available through the chosen database. The financial statement data was collected using the Voitto+ database (ISSN 1459-9457). This database is maintained by Suomen Asiakastieto Ltd. (loose translation Finnish Customer Information), which in Finland is a leading service enterprise providing corporate information broadly considered to be reliable and objective.

Given the sampling criteria discussed above, five large enterprises suitable for the analysis were found. Considering that the maintenance sector still evolves quite rapidly, a more extensive sample of large maintenance providers can be selected probably in a few years' time. 13 maintenance SMEs were included in the analysis in order to reach a representative sample. Large enterprises and SMEs are mostly analyzed separately, but the average values of the whole sample are also used. It is justified to have more SMEs than large enterprises in the sample to simulate the actual structure of the maintenance industry.

Table I. The enterprises selected for the research

Large enterprises	Personnel in 2007	Net Sales in 2007, M€
Fortek Ltd.	*858*	*118.2*
Varenso Ltd.	*473*	*83.4*
Konecranes Service Ltd.	*516*	*78.9*
Botnia Mill Service Ltd.	*591*	*73.9*
Kymenso Ltd.	*743*	*45.0*
Large enterprises in total	3 181	399.4
SMEs	**Personnel in 2007**	**Net Sales in 2007, M€**
ISS Teollisuuspalvelut Ltd.	*104*	*12.5*
Tespal Ltd.	*53*	*9.4*
Machinery Service Finland Ltd.	*92*	*8.4*
Maintpartner Industrial Services Ltd.	*109*	*8.0*
Pikoteknik Ltd.	*50*	*7.3*
Tormets Ltd.	*103*	*6.3*
Mahro Ltd.	*25*	*5.5*
Betamet Service Ltd.	*48*	*3.9*
Astepa Ltd.	*46*	*3.1*
Metso Mill Service Kauttua Ltd.	*36*	*2.6*
Kangasalan Pajaservice Ltd.	*16*	*2.6*
JTT Konepaja Ltd.	*20*	*2.2*
Rauman Sähkökonehuolto Ltd.	*10*	*0.8*
SMEs in total	712	72.6
All enterprises in total	3 893	472.0

Flexible asset management model

Kärri (2007) has constructed a model for forecasting the investment needs (consisting of fixed assets and net working capital) of a company or an industry under changing sales. Kärri argues that companies have or should have a long-term target *ROI* level. When the fluctuation of sales is great, the capital structure should be flexible. This means that investments on the fixed assets but also investments on the working capital should be tied down to sales. Kärri's model observes the net working capital rate, but the FAM model used in this paper highlights working capital management when cycle times are added to the model.

The starting point of the FAM model is the basic function of the return on investment. As financial statements are used as a data source, the model is also derived from the balance sheet items. The *ROI* is determined as a function of the operating income (*EBIT*) and the capital invested (*C*).

$$ROI = \frac{EBIT}{C} \tag{1}$$

The depreciations and amortizations (*D*) can be separated from the *EBIT*. If the capital employed is described with the assets of the balance sheet, it consists of the fixed assets (*FA*) and the net working capital (*NWC*) which together equal the equity plus long-term loans.

$$ROI = \frac{EBITDA-D}{NWC+FA} \tag{2}$$

The net working capital can be divided further to current assets (*CA*) less current liabilities (*CL*).

$$ROI = \frac{EBITDA-D}{CA-CL+FA} \tag{3}$$

Further, operational working capital components, inventories (*INV*), the accounts receivable (*AR*) and the accounts payable (*AP*), can be separated from the current assets and the current liabilities leaving the other current assets (*OCA*) and the other current liabilities (*OCL*) consisting of non-operational working capital items, such as the cash and cash equivalents and the current portion of long-term liabilities.

$$ROI = \frac{EBITDA-D}{INV+AR-AP+OCA-OCL+FA} \tag{4}$$

With the help of the fixed assets (*FA*) and the yearly depreciations and amortizations (*D*), the average depreciation period (*B*) can be calculated as follows

$$B = \frac{(FA+D)}{D} = \frac{FA}{D} + 1 \tag{5}$$

and when turned around

$$D = \frac{FA}{B-1} \tag{6}$$

Applying this definition of the depreciations and amortizations (*D*) to the original model gives

$$ROI = \frac{EBITDA-\frac{FA}{B-1}}{INV+AR-AP+OCA-OCL+FA} \tag{7}$$

Cycle times have been used in many studies to measure the operational working capital management. Many studies use the cash conversion cycle (*CCC*) to measure the working capital management. We also apply this approach and observe working capital management through cycle times. For this we have to deduce our FAM model further. The *CCC* is defined through three components, the cycle time of inventories (*DIO*), the cycle time of accounts receivable (*DSO*) and the cycle time of accounts payable (*DPO*)

$$CCC = DIO + DSO - DPO \tag{8}$$

The cycle times of inventories (days inventories outstanding) can be calculated as the inventories divided by sales (*S*).

$$DIO = \frac{INV}{S} \cdot 365 \tag{9}$$

Similarly the cycle time of accounts receivable (days sales outstanding) is

$$DSO = \frac{AR}{S} \cdot 365 \tag{10}$$

and the accounts payable (days payables outstanding)

$$DPO = \frac{AP}{S} \cdot 365 \tag{11}$$

We can also determine the cycle time of other net working capital components in a similar manner. When the cycle time of other current assets and the cycle time of other current liabilities are combined, we get the residual (*r*).

$$r = \frac{OCA}{S} \cdot 365 - \frac{OCL}{S} \cdot 365 \tag{12}$$

In order to calculate the *ROI* using the cycle time defined above, equation 7 has to be divided by sales (*S*). When doing so we can write the equation using only percentages (*EBITDA/S* = *EBITDA%* and *FA/S* = *FA%*), and cycle times as parameters

$$ROI = \frac{EBITDA\% - (FA\% \cdot \frac{1}{B-1})}{\frac{DIO}{365} + \frac{DSO}{365} - \frac{DPO}{365} + \frac{r}{365} + FA\%} \tag{13}$$

and when combining the components of the operating working capital , we can write

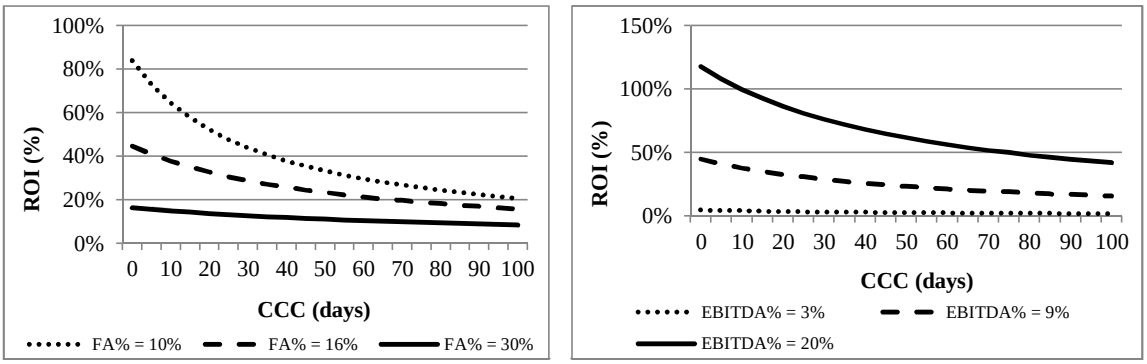
$$ROI = \frac{EBITDA\% - (FA\% \cdot \frac{1}{B-1})}{\frac{CCC}{365} + \frac{r}{365} + FA\%} \tag{14}$$

The *ROI* is thus determined by five parameters. Besides the cycle time of operational working capital (*CCC*), also the profit margin (*EBITDA%*), the fixed asset ratio (*FA%*), the average depreciation period (*B*) and the cycle time of residual (*r*) affect the relative profitability. The *ROI* increases if ceteris paribus the *EBITDA%* or the *B* increases, or the *FA%*, the *CCC* or the *r* decreases. It should be noted that equation 14 works correctly if both the numerator and the denominator are positive and the *B* has a value greater than 1.

The importance of working capital management

The impact of working capital management on profitability is presented in figures 1 and 2 by changing the *CCC* and setting the other parameters of equation 14 as constant in the FAM model. The *CCC* gets values from zero to 100. We have examined how the length of the *CCC* affects the *ROI* on different levels of the FA%, the EBITDA%, the B and the r. The constant values are industry averages in the industrial maintenance service sector calculated with the data used in the empirical analysis. The range of each variable in figures 1 and 2 has been found realistic in the observed industry.

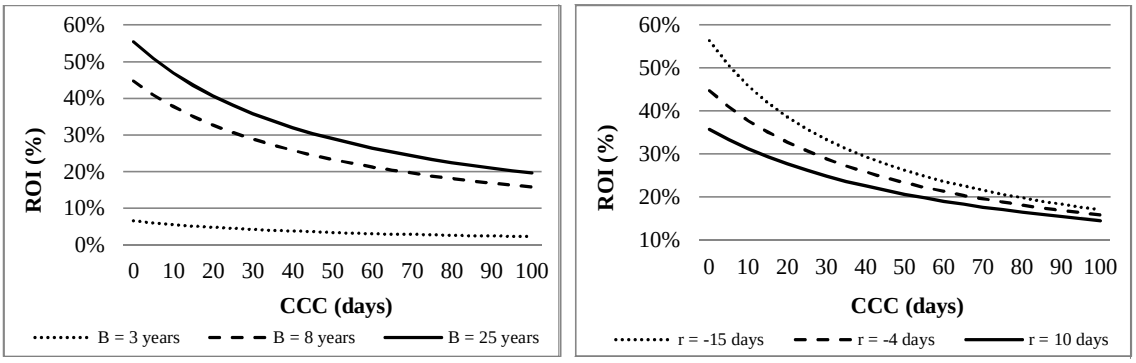
Figure 1. The *ROI* as a function of the *CCC* and the FA% (the chart on the left) and as a function of the *CCC* and the EBITDA% (the chart on the right). Here the B equals 8 years and the r equals -4 days.



If the fixed asset ratio is high, the effect of the cycle time of working capital on profitability remains small. The impact of the *CCC* on profitability is bigger in companies with flexible asset structures and a lower fixed asset ratio, and thus they should pay more attention to working capital management. For comparison, in a big customer industry of the industrial maintenance

service sector, the pulp and paper industry, the FA% is typically over 100 %. The length of the *CCC* gets more important when the EBITDA% grows. If the EBITDA% is low, efficient working capital management cannot save profitability, but on higher levels of the EBITDA, a long *CCC* can destroy profitability.

Figure 2. The *ROI* as a function of the *CCC* and the B (the chart on the left) and as a function of the *CCC* and the r (the chart on the right). Here the EBITDA% equals 9% and the FA% equals 16%.



Since a low fixed asset ratio increases the impact of the *CCC* on profitability, it is only logical that the same thing happens when the average depreciation period shortens. On the other hand, we can see that the shorter the residual term is, the more the *CCC* affects the *ROI*. As regards the FA%, the B and the r, it must be noted, however, that minimizing them is not always the most viable solution. If anything, these parameters should be optimized on the basis of operational, tactical and strategic criteria. Especially the residual term, consisting of other current assets and other current liabilities, calls for further scientific research before any specific comment about the optimal value can be made. Based on this analysis we can now come to a conclusion that the characteristics of the industrial maintenance service sector strongly support the importance of working capital management practices. Operating with light fixed assets and high profitability makes these enterprises vulnerable to changes in profitability caused by fluctuation in the *CCC*.

Comparing large enterprises and SMEs

The parameters for the FAM model for all the enterprises in this research, large enterprises and SMEs separately, have been calculated as average values on the basis of the financial statements of the companies. These parameters are presented in table II. It can be noticed that the EBITDA% is significantly higher in SMEs than in large maintenance service providers. However, when profitability is proportioned to the capital invested and the ROI is inspected, the situation changes. This indicates that the large maintenance service enterprises operate with exceptionally light balance sheets. For SMEs, the CCC is approximately 53 days, whereas for large companies the corresponding figure is roughly 9 days. When reviewing the components of the CCC in table II, it can be concluded that this difference mainly originates from the SMEs having notably longer cycle times for both accounts receivable and inventories. This may signal the existence of considerable economies of scale in the industrial maintenance sector. Large companies may have been able to shorten their DSO by using their bargaining power over their customers, whereas the bargaining power of SMEs over their customers is minor. It is notable that Hecker and Kretschmer (2010) suggest that economies of scale may also end in too powerful service providers which customers are starting to avoid. Thus economies of scale could convert into diseconomies of scale. Considering the DIO, on the other hand, the economies of scale in the industrial maintenance sector are quite different. Generally speaking, large maintenance service providers have more customers, facilities and equipment to be maintained, compared to SMEs. The risk of asset breakdown is thus usually divided between several units. In many respects, economies of scale originate from spare part inventory, because large enterprises can prepare for many risks with each spare part. It should also be noted that the FA% is significantly larger for SMEs than for large enterprises. This may be due to economies of scale related to the use of fixed assets. Previous research suggests that economies of scale truly exist in the industrial maintenance business (Hecker and Kretschmer, 2010; Komonen, 2002; Martin, 1997).

Besides economies of scale, there is another explanation for the differences in the parameters between large enterprises and SMEs. It is notable that large enterprises in the Finnish industrial maintenance service sector are mostly focused on customers operating in specific industries. In fact many of the large service providers have been founded by manufacturing enterprises, who have wanted to outsource their maintenance. This has led to a situation where a vast majority of the net sales of most large maintenance service providers comes from their host companies. For SMEs, this kind of situation is not so

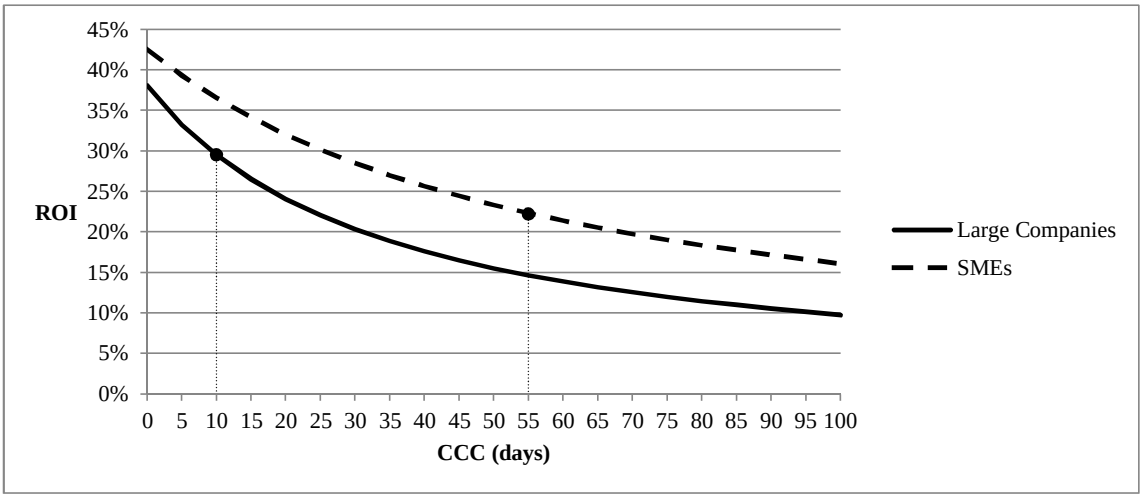
common. Complete conclusions are difficult to make from this basis but close cooperation with their host companies may have had an influence on the studied parameters of large maintenance enterprises. At least the cycle time of accounts receivable, the cycle time of inventories, the fixed asset ratio and the residual depend on the contractual relation between host companies and service providers. The host companies may agree to short payment times, which would shorten the DSO. Some part of the inventories and the fixed assets of maintenance service providers can be owned and stored by their host companies, which reduces the DIO and the FA%. Again, a large amount of receivables from group companies increase the sum of other current assets, which finally makes the r larger. It would seem that the operations and the financial statements of the large maintenance service providers are affected by both the economies of scale and their host companies. It would be very important to know how strong impacts each of these aspects have, but this is left for further research.

Table II. Modeling parameters of industrial maintenance service providers (average numbers from 2004-2008).

	EBITDA%	FA%	B (years)	DSO (days)	DIO (days)	DPO (days)	CCC (days)	r (days)	ROI
Large enterprises	5%	8%	6.9	15	9	15	9	7	30%
SMEs	10%	20%	7.8	45	22	14	53	-10	23%
All enterprises	9%	16%	7.5	37	18	14	41	-4	24%

The EBITDA%, the FA%, the B and the r have been set constant in the FAM model for large maintenance service providers and SMEs separately. We have varied the length of the *CCC* in order to define the impact on the *ROI*. Figure 3 shows how the *ROI* changes for SMEs and for large enterprises. The actual situation for each group is depicted with the vertical lines. The difference between SMEs and large enterprises is remarkable considering the length of the *CCC*. Arising from the shape of the relation between the *CCC* and the *ROI*, this means that for large enterprises changes in the *CCC* have a more extensive effect on the *ROI*. Thus particularly the large industrial maintenance service providers should pay attention to working capital management. The profitability of individual customers can easily be ruined with neglectful policies during the contract formulation. Also Hatinen *et al*. (2011) remark that working capital management is more important for large maintenance service providers than for SMEs. They have come to this conclusion by noticing that in large maintenance enterprises the share of working capital investments in total investments is remarkably larger than in SMEs. On the other hand, it can be seen from figure 3 that the potential for improvements is more extensive for SMEs than for large companies due to the larger value of the *CCC*.

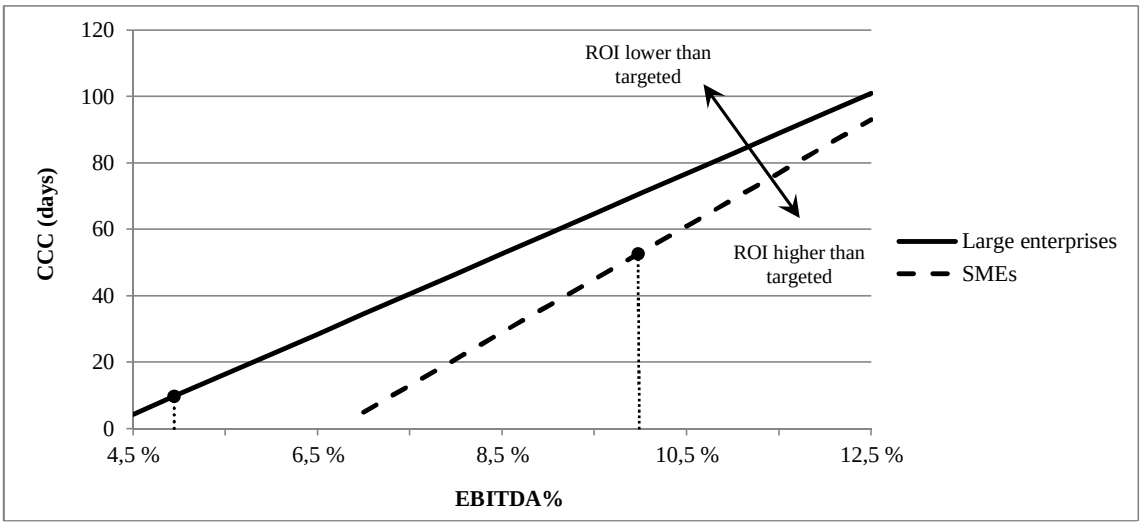
Figure 3. The impact of the *CCC* on the profitability of large companies and SMEs in the maintenance industry. The vertical lines indicate the actual situation of the enterprises.



Analyzing the future possibilities

The maintenance service sector is further explicated through inspecting some future possibilities which are built using the FAM model. The past economic crisis has reshaped the profitability of the maintenance service providers in an unknown way. The FAM model is a valuable management tool especially under this kind of hard circumstances. In order to restore their profitability, companies can either manage their working capital or adjust their fixed assets. Our analysis helps to understand how a target level of the ROI can be achieved through different combinations of the *CCC* and the *EBITDA%*. In other words, it is studied how the changes of the *EBITDA%* can be compensated with the working capital management, so that the ROI will not suffer. It should be remembered that the *EBITDA%* depends on the sales as well as on the fixed and variable costs of the company. Only the *CCC* and the *EBITDA%* have been varied in this analysis, thus the ROI, the FA%, the B and the r are set constant. This is justified, because altering the amount of the fixed assets is a long-term strategy for adaptation, while our analysis focuses on short- and medium term. In addition, it is not common to make investments during the recession, while the companies already have idle capacity. The behavior of the residual term, on the other hand, remains somewhat obscure, which is why we have decided to set r constant and to define the ROI as a function of only the *CCC* and the *EBITDA%*. The period analyzed here is the five-year period from 2009 to 2013. Assuming that the economical crisis depresses the ROI in 2009–2010, but otherwise the maintenance service sector is growing and profitable, we have set the target values of the ROI for the period 2009–2013 to the same level as were the average values in 2004–2008 for the large maintenance service providers and the SMEs separately. The results of the analysis are presented visually in figure 4, where the target value of the ROI is 30% for large enterprises and 23% for SMEs. The vertical lines indicate the actual situation of the enterprises in 2004–2008. Very small positive values or any negative values for the *EBITDA%* are not included in the analysis due to the current limitations of the FAM model. In practice this does not matter, because the resulting graphs are linear: the values of the *CCC* which are required to compensate the small and negative values of the *EBITDA%* can be defined through simple extrapolation.

Figure 4. The combinations of the *CCC* and the *EBITDA%* with which the target values of the ROI can be achieved in large maintenance enterprises and SMEs separately.



It can be seen from figure 4 that the changes of the *EBITDA%* have a considerable effect on the ROI, which means that it is very difficult to compensate these changes completely by altering only the *CCC*. In addition, in practice the difference between the *DSO* and the *DPO* tends to remain nearly constant within companies, so that the required changes of the *CCC* depend greatly on the changes of the *DIO*. On the other hand, the growth of the *EBITDA%* improves the value of the ROI extensively, and therefore any small increase of the *CCC* does not drop the ROI below the target value. It is interesting to notice that the graph of the large enterprises goes above the curve of the SMEs. This indicates that for each value of the *EBITDA%*, the large enterprises can achieve their target ROIs with longer *CCC*s. The area in which the combination of the *CCC* and the *EBITDA%* results in a ROI higher than targeted is more extensive for the large enterprises compared to the SMEs. In order to determine the reasons behind this phenomenon, we have solved the *CCC* from equation 14. This has left us with equation 15.

$$CCC = \frac{365 \cdot \left[EBITDA\% - \left(FA\% \cdot \frac{1}{B-1}\right)\right]}{ROI} - r - 365 \cdot FA\% \qquad (15)$$

From equation 15 it can be concluded that the *CCC* increases if ceteris paribus the *ROI*, the *FA%*, or the *r* decreases, or if the *B* increases. However, from table II it can be seen that the *ROI* and the *r* are higher in the large enterprises than in the SMEs, whereas the *FA%* and the *B* are lower in the large enterprises compared to the SMEs. Thus the *FA%* is the only variable out of these four which actually supports the higher values of the *CCC* for the large enterprises in figure 4. We can now conclude that the impact of the *FA%* on the *CCC* outdoes the synergetic contradictory impact of the other three variables. Thus the large maintenance service providers have a competitive advantage over the SMEs due to their lower fixed assets ratio. This notice is interesting, because it is often assumed that large maintenance companies are more capital intensive than maintenance SMEs.

Discussion

This paper has shed light on the impact of working capital management on the *ROI*, and examined this impact especially in the industrial maintenance service sector. Considering the results of this study, our FAM model has explicit managerial implications. The model can be utilized as a tool in decision-making in firms, both in the short term and in the long term. For example in contract-bound industries the FAM model can be used when negotiating with customers or suppliers to point out any changes in contract profitability caused by for example different terms of payment or arrangements of the ownership of assets. In the long term, decision-makers can use the model to discover any positive or negative trends in the development of their firm, and finally to forecast the future development. On the basis of this paper, the decision-makers of companies can consider how important working capital management is in their industry. In addition, we now know that in the industrial maintenance service business attention should be paid to active management of working capital. We can conclude that this holds true especially in large industrial maintenance service enterprises. Previous studies of industrial maintenance companies have not addressed working capital management, which gains more and more attention under the volatile economic circumstances of the present day. There is a growing need for management tools that focus on the impact of working capital management on profitability. It should be noted that while the paper focuses on Finnish maintenance providers, the model and the logic presented here can be applied to a variety of industries and countries.

Our FAM model can be used as a tool for decision-making in any company. However, for the time being, there are some theoretical limitations in the applicability of the model. Solving this problem is a natural objective for further research. The FAM model could also be extended to cover more the perspective of optimization in working capital management, instead of minimization. The main contribution of this study is analytical, not statistical. The sample used in empirical analysis represents the Finnish industrial maintenance service sector well. However, the scarcity of large enterprises in the market in question must be included in our research limitations, because any single abnormalities in numerical values affect the average values excessively. Despite this, the conducted empirical analysis is valid for testing the FAM model in practice. Another limitation is the absence of the latest financial statements of the studied enterprises. Further research can also include international comparative research about applying the FAM model into practice. However, in Finland generally the terms of payment are strict, and the agreements are adhered to. This may not be the case elsewhere, which would bring additional challenges into working capital management.

Concerning the generality of our results, it can be said that in addition to the industrial maintenance service business, many of our conclusions also hold true in other industries. For example, the impact of the *CCC* on the *ROI* extends while the fixed assets, the average depreciation period or the residual decrease, or when the operating margin ratio increases. This supports the importance of working capital management in unconventional industries, for example in many service industries. Objectives for further research include discussing the residual term consisting of the other current assets less the other current liabilities. The behavior of this variable should be defined so that decision-makers can optimize its value. It should also be further examined how important a role economies of scale truly have in the industrial maintenance business. On the other hand, providing services mostly for their host companies has an impact on the operations and financial statements of industrial maintenance service enterprises. The role of this impact would also be important for both academics and the decision-makers of firms to know.

Conclusions

The analytical FAM model we have derived shows that ceteris paribus the return on investment (*ROI*) correlates negatively with the length of the cycle time of operational working capital (*CCC*). Other parameters affecting the return on investment are the operating margin ratio, the fixed asset ratio, the average depreciation period and the residual term, consisting of the other current assets and the other current liabilities. The effect of the *CCC* on the *ROI* is especially strong in the industrial maintenance service sector, arising from light fixed assets and good profitability. Interestingly, the *CCC* is notably shorter in large Finnish maintenance service enterprises than in SMEs of the same industry. This means that changes in the *CCC* have a much more extensive impact on the *ROI* in large maintenance service providers. The difference between large enterprises and SMEs can be explained through both fixed assets- and working capital-related economies of scale, and the fact that large maintenance service providers often focus on providing services mostly for their host companies. The changes of the *EBITDA%* affect *ROI* so much that compensating them with the management of the cycle times of working capital is

unrealistic in maintenance service companies. Especially in large enterprises the *CCC* cannot be shortened. However, the large enterprises seem to have a competitive advantage over the SMEs due to lower fixed assets ratios.

References

Al-Turki, U. (2011), "A framework for strategic planning in maintenance", *Journal of Quality in Maintenance Engineering*, Vol. 17 No. 2, pp. 150-162.

Aoudia, M., Belmokhtar, O. and Zwingelstein, G. (2008), "Economic impact of maintenance management ineffectiveness of an oil and gas company", *Journal of Quality in Maintenance Engineering*, Vol. 14 No. 3, pp. 237-261.

Bailey, W., Masson, R. and Raeside, R. (2002), "Outsourcing in Edinburgh and the Lothians", *European Journal of Purchasing & Supply Management*, Vol. 8 No. 2, pp. 83-95.

Baños-Caballero, S., García-Teruel, P. and Martínez-Solano, P. (2010), '"Working capital management in SMEs", *Accounting and Finance*, Vol. 3 No. 50, pp. 511-527.

Benson, J. and Ieronimo, N. (1996), "Outsourcing decisions: evidence from Australia-based enterprises", *International Labour Review*, Vol. 135 No. 1, pp. 59-73.

Blinder, A.S. and Maccini, L.J. (1991), "The resurgence of inventory research: what have we learned?", *Journal of Economic Surveys*, Vol. 5 No. 4, pp. 291-328.

Boulaksil, Y. and Fransoo, J.C. (2010), "Implications of outsourcing on operations planning: findings from the pharmaceutical industry", *International Journal of Operations & Production Management*, Vol. 30 No. 10, pp. 1059-1079.

Broedner, P., Kinkel, S. and Lay, G. (2009), "Productivity effects of outsourcing – new evidence on the strategic importance of vertical integration decisions", *International Journal of Operations & Production Management*, Vol. 29 No. 2, pp. 127-150.

Campbell, J. (1995), "Outsourcing in maintenance management. A valid alternative to self-provision", *Journal of Quality in Maintenance Engineering*, Vol. 1 No. 3, pp. 18-24.

Chiou, J., Cheng, L. and Wu, H. (2006), "The determinants of working capital", *The Journal of American Academy of Business*, Vol. 1 No. 10, pp. 149-155.

Deloof, M. (2003), "Does working capital management affect profitability of Belgium firms?", *Journal of Business Finance & Accounting*, Vol. 30 No. 3-4, pp. 573-587.

Demski, J.S. (2007), "Analytic modeling in management accounting research", in Chapman, C.S., Hopwood, A.G. and Shields, M.D. (Ed.), *Handbook of Management Accounting Research*, Elsevier, Amsterdam, pp. 365-371.

Dong, H.P. and Su, J. (2010), "The relationship between working capital management and profitability: a Vietnam case", *International Research Journal of Finance and Economics*, Vol. 5 No. 49, pp. 59-67.

Duffy, R. (2008), "Towards a better understanding of partnership attributes: an exploratory analysis of relationship type classification", *Industrial Marketing Management*, Vol. 37 No. 2, pp. 228-244.

European Commission. (2009), "Definition of micro, small and medium-sized enterprises adopted by the commission", available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF (accessed 6 May 2011).

García-Teruel, P.J. and Martínez-Solano, P. (2007), "Effects of working capital management on SME profitability", *International Journal of Managerial Finance*, Vol. 2 No. 3, pp. 164-177.

Harland, C., Knight, L., Lamming, R. and Walker, H. (2005), "Outsourcing: assessing the risks and benefits for organizations, sectors and nations", *International Journal of Operations & Production Management*, Vol. 25 No. 9, pp. 831-850.

Hatinen, L., Pirttilä, M., Viskari, S. and Kärri, T. (2011), "Investment logics of Finnish industrial maintenance service providers", [manuscript accepted for publication in *International Journal of Strategic Engineering Asset Management*].

Hecker, A. and Kretschmer, T. (2010), "Outsourcing decisions: the effect of scale economies and market structure", *Strategic Organization*, Vol. 8 No. 2, pp. 155-175.

Hendry, J. (1995), "Culture, community and networks: the hidden cost of outsourcing", *European Management Journal*, Vol. 2 No. 13, pp. 193-200.

Hill, M.D., Kelly, G.W. and Highfield, M.J. (2010), "Net operating working capital behavior: a first look", *Financial Management*, Vol. 39 No. 2, pp. 783-805.

Hilletofth, P. and Hilmola, O-P. (2010), "Role of logistics outsourcing on supply chain strategy and management. Survey findings from Northern Europe", *Strategic Outsourcing,* Vol. 3 No. 1, pp. 46-61.

Holschbach, E. and Hofmann, E. (2011), "Exploring quality management for business services from a buyer's perspective using multiple case study evidence", *International Journal of Operations & Production Management,* Vol. 31 No. 6, pp. 648-685.

Hui, E. and Tsang, A. (2006), "The inter-organizational relationship in a multi-contractor business network", *Journal of Quality in Maintenance Engineering,* Vol. 12 No. 3, pp. 252-266.

Johnson, M. and Templer, S. (2011), "The relationships between supply chain and firm performance: the development and testing of unified proxy", *International Journal of Physical distribution & Logistics Management,* Vol. 2 No. 41, pp. 88-103.

Jose, M., Lancaster, C. and Stevens, J. (1996), "Corporate returns and cash conversion cycles", *Journal of Economics and Finance,* Vol. 1 No. 20, pp. 33-46.

Kakabadse, A. and Kakabadse, N. (2002), "Trends in outsourcing: contrasting USA and Europe", *European Management Journal,* Vol. 2 No. 20, pp. 189-198.

Komonen, K. (2002), "A cost model of industrial maintenance for profitability analysis and benchmarking", *International Journal of Production Economics,* Vol. 79 No. 1, pp. 15-31.

Komonen, K. (2009), "Challenges 2009 – the current and future challenges of maintenance in Finland", *Promaint,* Vol. 3 No. 23, pp. 18-22. (in Finnish).

Komonen, K. (2010), "Asset management in the industrial sector: background and conceptual approach", *Maintworld,* Vol. 2 No. 1, pp. 16-19.

Kornev, A.K. (2009), "Possibilities of rapid renewal of active part of fixed assets of branches of industry", *Studies on Russian Economic Development,* Vol. 5 No. 20, pp. 563-567.

Kremic, T., Tukel, O.I. and Rom, W. (2006), "Outsourcing decision support: a survey of benefits, risks, and decision factors", *Supply Chain Management: An International Journal,* Vol. 6 No. 11, pp. 467-482.

Kumar, R. and Kumar, U. (2004), "A conceptual framework for the development of a service delivery strategy for industrial systems and products", *Journal of Business & Industrial Marketing,* Vol. 5 No. 19, pp. 310-319.

Kumar, R., Markeset, T. and Kumar, U. (2004), "Maintenance of machinery. Negotiating service contracts in business-to-business marketing", *International Journal of Service Industry Management,* Vol. 15 No. 4, pp. 400-413.

Kärri, T. (2007), *Timing of capacity change: models for capital intensive industry,* Acta Universitatis Lappeenrantaensis 287, Dissertation, Lappeenranta University of Technology, Lappeenranta.

Lazaridis, I. and Tryfonidis, D. (2006), "Relationship between working capital management and profitability of listed companies in the Athens stock exchange", *Journal of Financial Management and Analysis,* Vol. 19 No. 1, pp. 26-35.

Martin, H.H. (1997), "Contracting out maintenance and a plan for future research", *Journal of Quality in Maintenance Engineering,* Vol. 3 No. 2, pp. 81-90.

McIvor, R., Humphreys, P., McKittrick, A. and Wall, T. (2009), "Performance management and the outsourcing process – lessons from a financial services organization", *International Journal of Operations & Production Management,* Vol. 29 No. 10, pp. 1025-1048.

Miles, R. and Snow, C. (1986), "Organizations: new concepts for new forms", *California Management Review,* Vol. 3 No. 28, pp. 62-73.

Molina, C.A. and Preve, L.A. (2009), "Trade receivables policy of distressed firms and its effect on the costs of financial distress", *Financial Management,* Vol. 3 No. 38, pp. 663-686.

Ng, C.K., Smith, J.K. and Smith, R.L. (1999), "Evidence on the determinants of credit terms used in interfirm trade", *Journal of Finance,* Vol. 54 No. 3, pp. 1109-1129.

Ngwenyama, O. and Bryson, N. (1999), "Making the information systems outsourcing decision: a transaction cost approach to analyzing outsourcing decision problems", *European Journal of Operational Research,* Vol. 115 No. 2, pp. 351-367.

Prahalad, C.K. and Hamel, G. (1990), "The core competence of the corporation", *Harvard Business Review,* Vol. 68 No. 3, pp. 71-91.

Redondo-Cano, A. and Canet-Giner, M.T. (2010), "Outsourcing agrochemical services: economic or strategic logic?", *Service Business*, Vol. 4 No. 3-4, pp. 237-252.

Reed, R. and Storrud-Barnes, S. (2009), "Systematic performance differences across the manufacturing-service continuum", *Service Business*, Vol. 4 No. 3, pp. 319-339.

Simões, J.M., Gomes, C.F. and Yasin, M.M. (2011), "A literature review of maintenance performance measurement. A conceptual framework and directions for future research", *Journal of Quality in Maintenance Engineering*, Vol. 17 No. 2, pp. 116-137.

Tam, A.S.B. and Price, J.W.H. (2008), "A maintenance prioritization approach to maximise return on investment subject to time and budget constraints", *Journal of Quality in Maintenance Engineering*, Vol. 14 No. 3, pp. 272-289.

Tarakci, H., Tang, K. and Teyarachakul, S. (2009), "Learning effects on maintenance outsourcing", *European Journal of Operational Research*, Vol. 192 No. 1, pp. 138-150.

The European Federation of National Maintenance Societies. (2011), "Intermediate results of the asset management survey for all national maintenance societies", available at: http://e-lomake.fi/raportti/efnms_2011_survey (accessed 1 August 2011).

The Finnish Maintenance Society. (2007), "Maintenance in national economy of Finland", available at: http://www.promaint.net/alltypes.asp?menu_id=348 (accessed 5 May 2011). (in Finnish).

Viskari, S., Lukkari, E. and Kärri, T. (2011), "State of working capital management research: bibliometric study", *Middle Eastern Finance and Economics*, June 2011, No. 14, pp. 99-108.

Wang, Y.J. (2002), "Liquidity management, operating performance, and corporate value: evidence from Japan and Taiwan", *Journal of Multinational Financial Management*, Vol. 12 No. 2, pp. 159-169.

PUBLICATION 3

Marttonen, S., Viskari, S. and Kärri, T. (2013)

'Appeasing company owners through effective working capital management'

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Appeasing company owners through effective working capital management

Salla Marttonen*, Sari Viskari and Timo Kärri

Department of Industrial Management,
Lappeenranta University of Technology,
P.O. Box 20, FIN-53851 Lappeenranta, Finland
E-mail: salla.marttonen@lut.fi
E-mail: sari.viskari@lut.fi
E-mail: timo.karri@lut.fi
*Corresponding author

Abstract: In the dynamic financial climate of the present day, companies should be aware of the potential of effective working capital management in reacting to market transformations. It is important to include the company owner's viewpoint in the research perspective. In this paper, we study the connection between working capital management and the return on equity. The managerial and financial perspectives of flexible asset management are integrated through analytical modelling. We conclude that the return on equity can be improved by shortening the cycle time of operational working capital. Both the interest rate of debt and the debt-to-equity ratio are taken into account in order to study the effects of dynamic financial conditions. Changes in the financial conditions could be compensated through effective management of working capital.

Keywords: working capital; return on equity; interest rate of debt; debt-to-equity ratio; modelling; flexible asset management; FAM.

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Biographical notes: Salla Marttonen is a Doctoral student in the Department of Industrial Management at Lappeenranta University of Technology, Finland. She received her MSc (Technology) in Industrial Management in 2010 and after that she has worked in academia. Her research interests include capital, capacity and cost management. Her doctoral studies are related to costs and profitability of industrial maintenance business.

Sari Viskari is a Doctoral student in the Department of Industrial Management at Lappeenranta University of Technology, Finland. She received her MSc (Technology) in Industrial Management in 2006 and after that she has worked in private sector as well as in academic world. Her research interests include capital, capacity and cost management. Her doctoral studies are related to financial supply chain management and accounting in networks, more specifically measuring and management of working capital.

Timo Kärri is a Professor (acting) in the Department of Industrial Management at Lappeenranta University of Technology, Finland. He received his DSc (Technology) in Industrial Management in 2007. His dissertation considered timing of capacity changes in capital intensive industries, and his research interests include capital, capacity and cost management.

1 Introduction

In dynamic operating conditions and under the influence of uncertain demand, companies need to manage their balance sheets and assets flexibly. There are two different aspects of flexible asset management (FAM); firstly, the investments and divestments of a company's fixed assets should be integrated with the changes of demand. Secondly, the amount of working capital should be managed actively, at the same time considering the present and future demand, as well as the more general economic conditions (Ojanen et al., 2012). The amount of fixed assets has often been linked to the studies of return on capital, whereas the role of working capital has remained somewhat obscure to the general public. In this paper, the focus is on the working capital side of FAM. This paper discusses the operational working capital, defined as inventories plus accounts receivable less accounts payable. Managing operational working capital means balancing the amount of capital tied into the operations. Simultaneously, the negative consequences of too small an amount of working capital on company liquidity must be taken into account.

Traditionally, working capital management has interested the research of corporate finance from the perspective of investments and liquidity. In recent years, also a more operational view to working capital management has emerged. The cycle time of working capital, called the cash conversion cycle (*CCC*), has been recognised as an important measure of efficiency in operations management. The *CCC* is also known in the literature as the cash-to-cash (*C2C*) cycle. Previous literature has concluded that by shortening the *CCC*, a company can improve its return on invested capital (*ROI*) (e.g., Deloof, 2003; Shin and Soenen, 1998; Talha et al., 2010; Viskari et al., 2011). There is a research gap in the discussion of the financial aspect of working capital management: the perspective of company owners. It is crucial for companies to keep their owners satisfied. This is highlighted in the dynamic financial conditions under which companies operate. Improved working capital management is one of the possible ways of increasing the value of the return on equity. Some initial ideas about connecting the financing position and the weighted average cost of capital (WACC) to working capital management can be found in the literature (Hofmann and Kotzab, 2010), but more research is needed to understand the connection between the costs of capital, capital structure, and working capital management of a company. The research questions of this paper are the following:

- How are the return on equity and working capital management connected?
- How does an increase in the interest rate of debt and in the debt-to-equity ratio affect the return on equity, and can this effect be compensated with effective working capital management?

This paper offers two main contributions. First, it untangles the connection between the cycle time of operational working capital and the return on equity. Second, the discussion

is extended to include also the cost of debt and the debt-to-equity ratio. All in all, we provide company owners with a way to analyse the importance of working capital management in dynamic financial conditions. Theories of asset and working capital management, corporate finance, and capital structure are integrated into a novel schema, which is verified with empirical data.

The structure of this paper is the following: after the introduction, the research design is presented. Next, working capital management in dynamic financial conditions is discussed through previous studies. After that we introduce our conceptual model, in addition to our financial extension of a previous model for FAM. The verification of the extended model with financial statement data is presented in the subsequent section. This paper finishes with conclusions.

2 Research design

Analytical modelling is used as the research method in this paper. This method is about using a deductive logic in representing a concept or a process (Demski, 2007). Modelling leads to high internal validity due to its transparency. In this paper, the FAM model developed by Marttonen et al. (2011) is expanded to include the financial perspective in addition to the managerial one. The model has been previously used to examine working capital management and *ROI*. We focus on modelling the connection between company return on equity and working capital management, taking into account the cost of debt and the debt-to-equity ratio. Our conceptual framework, as well as the extended FAM-model, is presented in Section 4 of this paper.

The extended model is verified with empirical data from the Finnish industrial maintenance sector. This sector of industrial services is optimal for the verification of the model: previous literature has indicated that the importance of active working capital management is emphasised in industrial maintenance companies (Marttonen et al., 2011). This is caused by their exceptionally small amount of fixed assets, compared to for example traditional manufacturing industrial companies. In addition, the discussion on industrial maintenance has escalated due to increased maintenance outsourcings, more and more complex industrial production equipment, and an extensive transition from corrective maintenance to preventive maintenance.

The verification of the model has been done with the financial statements of 18 Finnish industrial maintenance companies. Though small, the analysed sample represents a remarkable share of the Finnish industrial maintenance sector. The 3,893 persons employed by these 18 enterprises cover approximately 26% of the employees of the whole sector. The net sales of 472 million euro of the sample, on the other hand, represent approximately 13% of the sum used in industrial maintenance in Finland annually (Finnish Maintenance Society, 2007). The enterprises selected to the sample are listed in the Appendix, together with their personnel numbers and net sales. The sample has been selected by utilising the membership list of the Finnish Maintenance Society. Structurally, the sample represents the Finnish industrial maintenance sector well, consisting of a few large enterprises but mostly SMEs. The sample has been divided into five large enterprises and 13 SMEs according to the European Commission (2009) recommendation 2003/361/EC. Maintenance companies from outside Finland have been excluded from the study because the required data was not within reach.

It was considered important that the sample would reflect especially the features of the industrial maintenance business. Thus, when selecting the sample, only enterprises whose focus was mainly on industrial maintenance were accepted, which means that equipment manufacturers and enterprises offering infrastructural maintenance services were delimited from the sample. Also the smallest micro enterprises were left out of this research. The period of analysis was 2004 to 2009. At the time of collecting the data, the financial statements of subsequent fiscal years were not yet available through the chosen database. The financial statement data was collected using the Voitto+ database (ISSN: 1459-9457). This database is maintained by Suomen Asiakastieto Oy (loose translation Finnish Customer Information), which is a leading service enterprise in Finland, providing corporate information broadly considered to be reliable and objective.

3 Literature review

After having introduced our research design in the section above, we will now discuss the previous literature on the topic. This paper highlights the importance of active working capital management on a company level, especially from the company owner's perspective. Previous literature on these aspects is here integrated with the research of capital structure.

In the dynamic conditions of the present day, the importance of flexible management of the balance sheet is emphasised. FAM includes active controlling of both fixed assets and working capital. We concentrate on working capital in this paper. The focus is on managing the return on equity through the cycle time of working capital. Several large statistical studies have shown a negative connection between the *CCC* and the relative profitability *ROI* (e.g., Deloof, 2003; García-Teruel and Martínez-Solano, 2007; Shin and Soenen, 1998; Talha et al., 2010; Viskari et al., 2011; Wang, 2002). This finding has been supported by Marttonen et al. (2011) with analytical modelling. Some studies have suggested that companies can boost their sales with generous credit terms and secure the service level with larger inventories (Blinder and Maccini, 1991; Deloof and Jegers, 1996; Shah, 2009). However, the positive effects of a large amount of working capital have been outdone by the traditional view: working capital increases the invested capital and decreases profitability.

Even though the relation between the *CCC* and the *ROI* has been examined a lot, not many studies embody the owners' perspective in the discussion. In the company valuation literature, working capital has been linked to the cost of capital and the company owners' perspective. For example, Black et al. (1998) present a free cash flow model of company shareholder value, in which the growth of working capital and fixed assets has a negative impact on future cash flows. Yet, Black et al. assume that the ratio of working capital to the net sales is constant, and they do not discuss the active management of this ratio. On the other hand, some financial variables have been included in the statistical analysis, but they have not been analysed extensively. Filbeck et al. (2007) have found some evidence that shareholders do recognise efficient working capital management. They have studied the stock market returns (dividends and capital gains) and the efficiency of working capital management. Lambert and Pohlen (2001) have presented both fixed assets and the elements of working capital as a part of the formation of economic value added. Still, working capital is not in the focus of their

research. Losbichler et al. (2008) have continued from the work of Lambert and Pohlen (2001). They have focused on working capital in creating shareholder value. In this paper, we contribute to this discussion by modelling the connection between the *CCC* and the return on equity explicitly.

The impact of uncertain financial conditions is taken into account here by discussing the company capital structure and the cost of capital. The relation between the debt-to-equity ratio and the interest rate of debt has inspired a long-lasting debate in the academic literature. The traditional view states that an optimal debt-to-equity ratio can minimise the cost of capital; debt-financing is beneficial to a company if not taken too far. However, beyond this optimum, the interest rate of debt starts to increase, and the growth of required return on equity accelerates, both factors causing a decrease in company value (Brealey et al., 2008). This traditional theory was challenged by Modigliani and Miller (1958), who stated that the capital structure of a company affects neither its market value nor its average cost of capital. There is an underlying assumption of perfect capital markets in this theory, but nonetheless, the view of Modigliani and Miller has received extensive support in academia.

Previous literature about managing the debt-to-equity ratio is abundant. Eriotis et al. (2007) bring forth the fact that there are various theories present in the capital structure research. The main theories include, e.g., the trade-off theory, the pecking order theory, and the agency theory, all of which are supported by empirical results (e.g., Eriotis et al., 2007; Harris and Raviv, 1991; Jensen and Meckling, 1976; Kayhan and Titman, 2007). The trade-off theory states that there is an optimal, company-dependent capital structure to be found to maximise the firm value (Graham and Harvey, 2001; Hull, 2011; Kayhan and Titman, 2007; Leary and Roberts, 2005; Parsons and Titman, 2008; Stretcher and Johnson, 2011). This way of thinking has been adopted by many company managers, as it encourages to reasonable incurring of debt-financing. During economic downturns, the application of financial theories should be done with specific care. For example, it should be remembered that the optimal capital structure of a company is dynamic by nature, and the optimum changes according to the financial conditions.

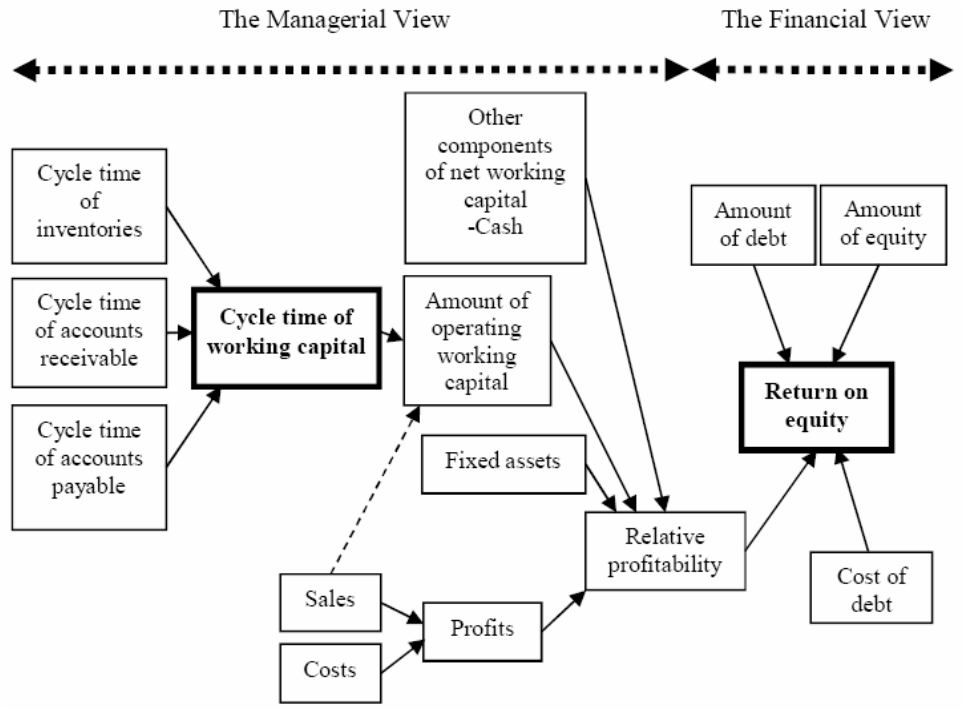
4 Extending the FAM-model to include the financial view

The literature review above reveals that previous studies have recognised the relevance of working capital management to profitability. So far the owner's viewpoint has been linked to working capital in the literature of company valuation. However, the control perspective of this relation still remains unexplored. Previous research has not tried to manage working capital while considering the company owner's interests. The potential of working capital management under different costs of capital and capital structures has not been studied before, either. The financial conditions for companies are getting more volatile. This creates a need for companies to develop novel resorts to succeed in the competition. Working capital management could be one of these resorts. Figure 1 shows our conceptual framework describing the connection between working capital and the return on equity.

The relations between the parameters of Figure 1 are presented mathematically in the FAM-model. The equations of the model are presented in the next paragraphs. Working capital is modelled through the cycle time of operational working capital, the *CCC*. Working capital is regarded more comprehensible when discussing the cycle times rather

than monetary sums of working capital. The other components of net working capital are taken into the model through a residual term (*r*), as our focus is on the operational working capital. The fixed assets are modelled through two different ratios: the first one compares the amount of fixed assets to the amount of net sales (*FA*%), and the second presents the average depreciation time of the fixed assets (*B*). Relative measures like these are preferred over absolute monetary measures, for they enable comparison between companies. The profits are inspected with the profit margin ratio (*EBITDA*%). This way the depreciations can be analysed separately, with relation to the fixed assets. The relative profitability is modelled with the *ROI*, which is one of the most well-known measures for profitability (see e.g., Joshi et al., 2011). On the financial side of Figure 1, the return on equity is simple to derive into the model from the *ROI*. Finally, examining the return on equity requires including the cost of debt, as well as the amount of debt and equity into the model.

Figure 1 Connecting the managerial and financial view of working capital management



The starting point for the modelling is the FAM-model, introduced by Marttonen et al. (2011). This model links the cycle time of operational working capital, the *CCC*, to the *ROI*. Equation (1) presents the FAM-model.

$$ROI = \frac{EBITDA\% - \left(FA\% \times \frac{1}{B-1} \right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%}, \tag{1}$$

where

ROI is the return on investment

EBITDA% is the profit margin ratio

FA% is the amount of fixed assets relative to the net sales

B is the average depreciation time (in years) of fixed assets

CCC is the cycle time of operational working capital

r is the residual term, consisting of other current assets and other current liabilities.

We now extend this model by incorporating the cost of capital, consisting of both the interest rate of debt and the return on equity, into the model. The extension is based on the assumption that the *ROI* consists of the interest rate of long-term debt and the required return of equity [see equation (2)]. In this model, current liabilities and taxes are omitted. Through these definitions, a valid, straightforward connection between the cost of capital and the *ROI* can be constructed. The cost of capital can thus be determined as

$$i = \frac{i_D \times D + i_e \times E}{D + E}, \tag{2}$$

where

i is the cost of capital

i_D is the average interest rate of long-term debt

i_E is the return on equity

D is the amount of long-term debt

E is the amount of shareholder equity.

On the other hand, in a long-term, a company's target *ROI* should be set equal to the company cost of capital. Thus, by merging equations (1) and (2), we get

$$\frac{EBITDA\% - \left(FA\% \times \frac{1}{B-1} \right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%} = ROI = \frac{i_D \times D + i_E \times E}{D + E}. \tag{3}$$

The left side of equation (3) represents the managerial view of the FAM-model, whereas the right side of the equation describes our extension, which highlights the owner's viewpoint. To observe the owner's view, i_E can be defined as

$$i_E = \frac{EBITDA\% - \left(FA\% \times \frac{1}{B-1} \right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%} \times \left(1 + \frac{D}{E} \right) - i_D \times \frac{D}{E}. \tag{4}$$

It can be concluded from equation (4) that the return on equity increases if, ceteris paribus, the profit margin ratio or the average depreciation period increases, or if the fixed asset ratio, the cycle time of operational working capital, the residual term, or the interest rate of debt decreases. When the *ROI* is greater than i_D, an increase in the debt-to-equity ratio causes an increase in the return on equity. On the other hand, when

the *ROI* is less than i_D, the debt-to-equity ratio should decrease for the return on equity to increase. This duality is known as financial leverage. If the *CCC* is observed, the equation can be written as:

$$CCC = \frac{365 \times \left(EBITDA\% - \left(FA\% \times \frac{1}{B-1} \right) \right)}{\left(i_D \times D + i_e \times E \right) \Big/ (D+E)} - 365 \times FA\% - r. \quad (5)$$

In this format, the model could be used to determine the objectives for working capital management. Companies often have target levels for profitability and the cost of capital. In equation (5), these are represented by the *EBITDA*% and the expression in the denominator. The *FA*%, the *B*, and the *r* could be set constant. On the other hand, if the focus is on the management of the fixed assets, the equation could be solved for the *FA*%, and the *CCC* could be set constant. The model can thus be applied to various situations concerning asset management, company profitability, and financing issues.

5 Verifying the extended model with empirical data

5.1 Parameters used in verification

Now when our extension to the FAM-model has been introduced, it is applied to empirical data of industrial maintenance companies. Here, we will present the modelling parameters used in this paper. In order to verify the connection between the *CCC* and the return on equity, the other parameters of the extended model are set as constants. In this research, sample averages from the period 2004 to 2009 are used. Table 1 summarises these averages.

Table 1 Parameters of the maintenance companies used in the modelling

	SMEs	*Large companies*
CCC, days	52	11
EBITDA%	7.7	5.5
FA%	20.7	7.1
B, years	8.4	6.6
r, days	–8.1	9.0
ROI, %	15.2	33.9
D, €	301,000	650,000
E, €	1,207,000	8,469,000
D/*E*	0.25	0.08
i_D, %	10.3	9.9
i_E, %	16.4	35.7

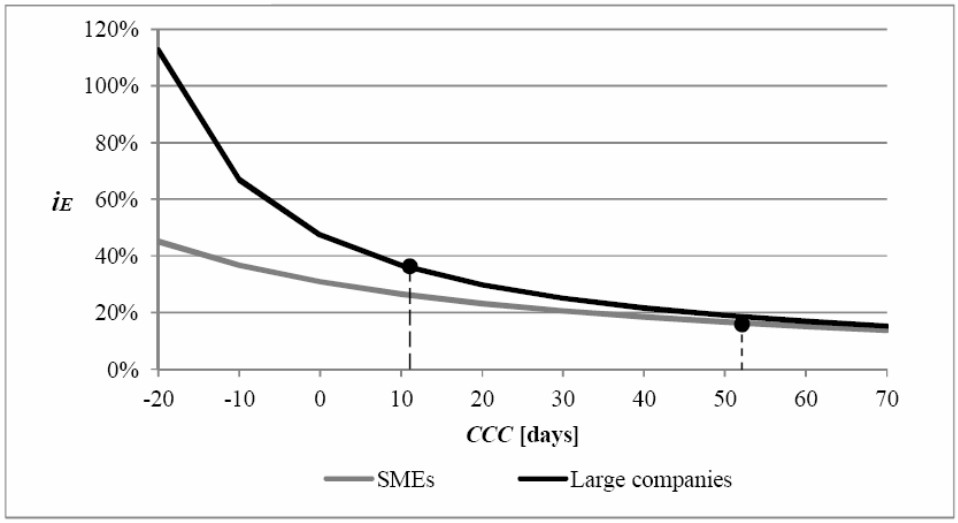
There is a big difference between the SMEs and the large maintenance companies considering the length of the *CCC*. On the basis of the data, it seems that compared with the SMEs, the large maintenance companies benefit from both economies of scale and close cooperation with their host companies. The *EBITDA*% is higher in the SMEs, but

when the *ROI* is inspected, the situation changes because the large maintenance service companies operate with exceptionally light balance sheets. The debt-to-equity ratios of the industry are very low, 0.08 for the large companies and 0.25 for the SMEs, and the interest rate of debt is quite high for both groups. This is because our extension to the FAM-model defines debt as long-term liabilities only, whereas in reality the analysed maintenance companies had also a lot of short-term debt. The return on equity is significantly higher for the large companies. This is due to the higher values for the *ROI*, and lower values for the interest rate of debt.

5.2 Impact of the CCC on the return on equity

Next, the parameters presented above are used to study the connection between the *CCC* and the i_E. In Figure 2, the impact of the *CCC* on the return on equity is presented. The average numbers of the companies from 2004 to 2009 are depicted with the vertical lines. The impact of the *CCC* on the return on equity is very similar to the impact of the *CCC* on the *ROI* showed by Marttonen et al. (2011). This is reasonable, because the debt-to-equity ratios of the maintenance companies are exceptionally low. When the *CCC* is very small or negative, the difference between the *ROI* and the interest rate of debt [see equation (4)] is larger, causing an increase in the return on equity. It is also notable that especially large maintenance companies should pay attention to preserving their good return on equity through keeping the *CCC* from growing uncontrollably. On the other hand, the potential for improvements is larger for SMEs, due to the higher value of the *CCC*.

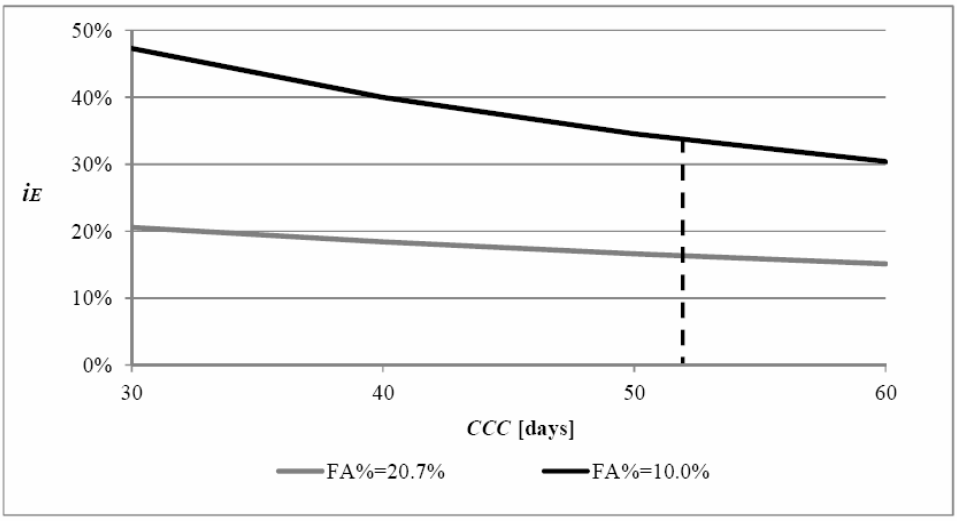
Figure 2 Impact of the *CCC* on the return on equity in maintenance SMEs and large companies



The *FA*% can be concluded to be the parameter having the greatest impact on the connection between the *CCC* and the return on equity. For example, if the SMEs could halve their *FA*% to 10%, the curve connecting their *CCC*s to their i_Es would be steeper. This is depicted in Figure 3. If the *FA*% of the SMEs were only 10%, decreasing the *CCC* from 52 days to 30 days would increase the i_E of the SMEs by over 50 percentage points.

With the actual, higher *FA*%, the corresponding increase of the i_E would be 25 percentage points. Thus, the importance of broader company asset management should be emphasised, taking into consideration both fixed assets and working capital.

Figure 3 The impact of the *FA*% to the connection between the *CCC* and the return on equity in maintenance SMEs



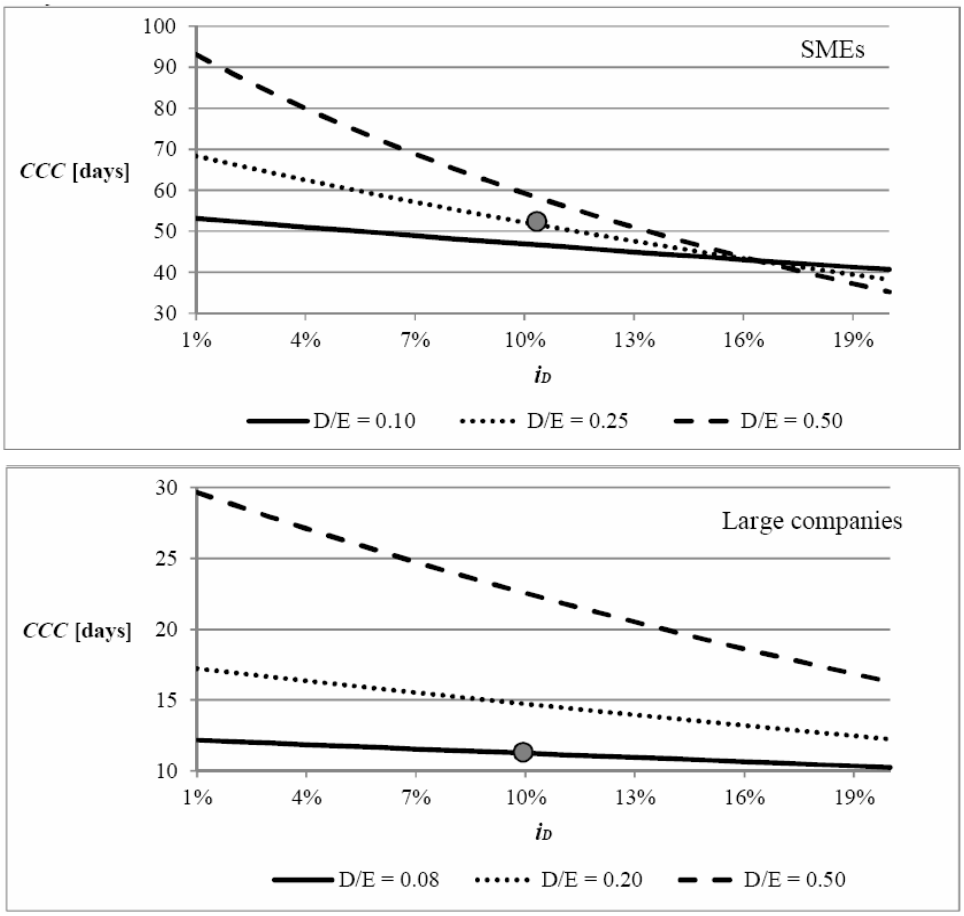
5.3 Impact of different financial positions on working capital management

Now the connection between the *CCC* and the i_E is examined under dynamic financial conditions. Figure 4 shows the varying interest rate of debt and the debt-to-equity ratio of maintenance SMEs and large companies, respectively. The upper side of the figure presents the SMEs, while the lower side shows the large companies. The figure shows how the *CCC* should develop in order to keep the return on equity unchanged. The grey circles illustrate the average position of the companies in 2004 to 2009. The model used in this paper links the debt-to-equity ratio and the interest rate of debt to each other, according to the traditional theory of cost of capital. On the other hand, Figure 4 has been constructed without any specific scenarios, by letting the interest rate of debt to develop independently of the debt-to-equity ratio. This way, the theory presented by Modigliani and Miller (1958) has not been abandoned, either.

For SMEs, the changes of the interest rate of debt and the debt-to-equity ratio cause extensive variation in the *CCC*. We can see that if the debt-to-equity ratio increased to 0.5, the same i_E could be achieved with a six days longer *CCC*. On the other hand, if the debt-to-equity ratio were decreased to 0.1, the *CCC* should be shortened by five days. The impact of the interest rate of debt on the connection between the *CCC* and the i_E is modest with low debt-to-equity ratios. However, the impact increases alongside the debt financing. Because the *CCC* of the SMEs is quite long, it is possible for them to make the proportional changes required to keep the return on equity unaltered. The debt-to-equity ratio of the maintenance SMEs increased in 2004 to 2009. Yet, the average value was still low (0.25), and in theory the maintenance SMEs would gain financial leverage from

increasing it. However, the average *ROI* of the SMEs was about 16%, and if the interest rate of debt grows higher than that, the financial leverage is lost. Also the impact of the financial crisis must be noted. In 2009, the *ROI* of the SMEs was clearly negative.

Figure 4 Length of the *CCC* required to keep the return on equity unchanged when both the interest rate of debt and the debt-to-equity ratio vary



The debt-to-equity ratio of the large companies was very low (0.08), and thus the main emphasis of the analysis was in increasing the share of debt in the capital structure of the companies. If the debt-to-equity ratio of the companies increased to 0.5, the *CCC* could increase by 11 days without the i_E getting worse. In fact, the debt-to-equity ratio increased during 2004 to 2009. As the average *ROI* of the companies at issue was well over 30%, the financial leverage to be gained through getting into debt was rather steady. However, it is possible that the financial downturn hit the large maintenance companies later on, consuming the profitability and the financial leverage potential. This could have altered the optimal capital structure of the companies significantly. It should also be noted that at the moment many companies are trying to avoid running into more debt. The financial crisis has shaken companies, and caution is taken regarding finance and capital structures. Thus, the role of more effective working capital management is

highlighted: decreasing the financial leverage causes the return on equity to reduce. New solutions are needed to appease the company owners.

6 Conclusions

This paper has illustrated how the return on equity can be controlled through effective working capital management. It can be concluded that the return on equity can be improved by shortening the cycle time of operational working capital. The managerial and financial perspectives of FAM can be integrated through analytical modelling, as demonstrated in this paper. The impact of the interest rate of debt and the debt-to-equity ratio have also been taken into account. This way, we have included the dynamic financial conditions of the present day in the discussion. We conclude that changes in these conditions could be compensated through controlling working capital.

We have contributed to the academic discussion with two theoretical implications. First, we have provided an extended analytical model for FAM. This model connects asset management to the perspective of the company owners through the return on equity. The topic is important, yet rather unexplored in academia. Secondly, we have shown that the amount of fixed assets relative to the net sales (*FA*%) has a large impact on the connection between working capital and the return on equity. Thus, it is important to adopt a broader view on asset management: both working capital and fixed assets should be managed at the same time.

The impact of the *FA*% on the connection between working capital and the return on equity led us to the first of our three managerial implications: companies with a small *FA*% should manage their working capital actively. The impact of working capital on profitability is emphasised due to a light balance sheet. This holds for most service industries, and undoubtedly also for some manufacturing industries. Our second managerial implication is about the capital structure of a company: the debt-to-equity ratio affects the scale of financial leverage, and thus also the connection between working capital and return on equity. Basically, whenever a company makes its debt-to-equity ratio lower, financial leverage is lost. This causes some of the company owner's profits to disappear. The diminishing profits should be compensated somehow. Our conclusion is that working capital management is a worthy option for that. Our third and final managerial implication is related to the interest rate of debt: we have shown that the interest rate of debt has an impact on the connection between working capital and the return on equity. The impact is greater when the debt-to-equity ratio is higher. Thus, especially in companies with high debt-to-equity ratios, effective working capital management can offer a solution to profitability changes caused by variation in the interest rate of debt.

We have derived our extended model for FAM with some underlying assumptions. For example, it is important for companies to manage both their working capital and fixed assets. However, when a company has a really high amount of fixed assets, it is possible that the importance of working capital is only modest. In this case, the optimal parameters of the model could include something else than the *CCC*. This matter is included in our research limitations. Also, our research has been done on the company level, but the competition is transferring from being between companies into being between company networks. Thus, it should also be analysed how the changes in the

working capital or asset management practices affect the other companies in the same network. Future research should focus on this as well. The interest in effective working capital management should be maintained in future research. After all, working capital management provides companies with opportunities that should not be left unexploited.

References

Black, A., Wright, P. and Bachman, J.E. (1998) *In Search of Shareholder Value. Managing the Drivers of Performance*, Price Waterhouse, London.

Blinder, A.S. and Maccini, L.J. (1991) 'The resurgence of inventory research: what have we learned?', *Journal of Economic Surveys*, Vol. 5, No. 4, pp.291–328.

Brealey, R.A., Myers, S.C. and Allen, F. (2008) *Principles of Corporate Finance*, 9th ed., The McGraw-Hill Companies, New York.

Deloof, M. (2003) 'Does working capital management affect profitability of Belgium firms?', *Journal of Business Finance & Accounting*, Vol. 30, Nos. 3–4, pp.573–587.

Deloof, M. and Jegers, M. (1996) 'Trade credit, product quality, and intragroup trade: some European evidence', *The Journal of Financial Management Association*, Vol. 25, No. 3, pp.33–43.

Demski, J.S. (2007) 'Analytic modeling in management accounting research', in Chapman, C.S., Hopwood, A.G. and Shields, M.D. (Eds.): *Handbook of Management Accounting Research*, pp.365–371, Elsevier, Amsterdam.

Eriotis, N., Vasiliou, D. and Ventoura-Neokosmidi, Z. (2007) 'How firm characteristics affect capital structure: an empirical study', *Managerial Finance*, Vol. 33, No. 5, pp.321–331.

European Commission (2009) 'Definition of micro, small and medium-sized enterprises adopted by the commission' [online] http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF (accessed 6 May 2011).

Filbeck, G., Krueger, T. and Preece, D. (2007) 'CFO magazine's 'working capital survey': do selected firms work for shareholders?', *Quarterly Journal of Business & Economics*, Vol. 46, No. 2, pp.3–22.

Finnish Maintenance Society (2007) 'Maintenance in national economy of Finland', (in Finnish) [online] http://www.promaint.net/alltypes.asp?menu_id=348 (accessed 5 May 2011).

García-Teruel, P.J. and Martínez-Solano, P. (2007) 'Effects of working capital management on SME profitability', *International Journal of Managerial Finance*, Vol. 2, No. 3, pp.164–177.

Graham, J.R. and Harvey, C.R. (2001) 'The theory and practice of corporate finance: evidence from the field', *Journal of Financial Economics*, Vol. 60, No. 2, pp.187–243.

Harris, M. and Raviv, A. (1991) 'The theory of capital structure', *The Journal of Finance*, Vol. 46, No. 1, pp.297–355.

Hofmann, E. and Kotzab, H. (2010) 'A supply chain-oriented approach of working capital management', *Journal of Business Logistics*, Vol. 31, No. 2, pp.305–330.

Hull, R.M. (2011) 'Debt-equity decision-making with and without growth', *Managerial Finance*, Vol. 37, No. 8, pp.765–787.

Jensen, M.C. and Meckling, W.H. (1976) 'Theory of the firm: managerial behavior, agency costs and ownership structure', *Journal of Financial Economics*, Vol. 3, No. 4, pp.305–360.

Joshi, P.L., Kumar, R. and Al-Ajmi, J. (2011) 'An empirical study of the use and usefulness of financial, non-financial and subjective measures for performance evaluation in industrial companies in Bahrain', *International Journal of Managerial and Financial Accounting*, Vol. 3, No. 2, pp.140–169.

Kayhan, A. and Titman, S. (2007) 'Firms' histories and their capital structures', *Journal of Financial Economics*, Vol. 83, No. 1, pp.1–32.

Lambert, D. and Pohlen, T. (2001) 'Supply chain metrics', *The International Journal of Logistics Management*, Vol. 12, No. 1, pp.1–19.

Leary, M.T. and Roberts, M.R. (2005) 'Do firms rebalance their capital structures?', *The Journal of Finance*, Vol. 60, No. 6, pp.2575–2619.

Losbichler, H., Mahmoodi, F. and Rothboeck, M. (2008) 'Creating greater shareholder value from supply chain initiatives', *Supply Chain Forum: International Journal*, Vol. 9, No. 1, pp.82–91.

Marttonen, S., Viskari, S. and Kärri, T. (2011) 'Modeling the impact of working capital management on the profitability in industrial maintenance business', Paper presented at the *6th World Congress on Engineering Asset Management*, 2–5 October, Cincinnati, USA.

Modigliani, F. and Miller, M.H. (1958) 'The cost of capital, corporation finance and the theory of investment', *The American Economic Review*, Vol. 48, No. 3, pp.261–297.

Ojanen, V., Hatinen, L., Kärri, T., Kässi, T. and Tuominen, M. (2012) 'Flexible investment planning and collaborative maintenance management', in Van der Lei, T., Herder, P. and Wijnia, Y. (Eds.): *The State of the Art in Europe from a Life Cycle Perspective*, pp.65–77, Springer, Dordrecht.

Parsons, C. and Titman, S. (2008) 'Empirical capital structure: a review', *Foundations and Trends in Finance*, Vol. 3, No. 1, pp.1–93.

Shah, N.H. (2009) 'Optimisation of pricing and ordering under the two-stage credit policy for deteriorating items when the end demand is price and credit period sensitive', *International Journal of Business Performance and Supply Chain Modelling*, Vol. 1, Nos. 2–3, pp.229–239.

Shin, H. and Soenen, L. (1998) 'Efficiency of working capital management and corporate profitability', *Financial Practice and Education*, Vol. 8, No. 2, pp.37–45.

Stretcher, R. and Johnson, S. (2011) 'Capital structure: professional management guidance', *Managerial Finance*, Vol. 37, No. 8, pp.788–804.

Talha, M., Christopher, S.B. and Kamalavalli, A.L. (2010) 'Sensitivity of profitability to working capital management: a study of Indian corporate hospitals', *International Journal of Managerial and Financial Accounting*, Vol. 2, No. 3, pp.213–227.

Viskari, S., Pirttilä, M. and Kärri, T. (2011) 'Improving profitability by managing working capital in the value chain of pulp and paper industry', *International Journal of Managerial and Financial Accounting*, Vol. 3, No. 4, pp.348–366.

Wang, Y.J. (2002) 'Liquidity management, operating performance, and corporate value: evidence from Japan and Taiwan', *Journal of Multinational Financial Management*, Vol. 12, No. 2, pp.159–169.

Appendix

The enterprises selected for the research

Large enterprises	*Personnel in 2007*	*Net Sales in 2007, M€*
Fortek Oy	858	118.2
Varenso Oy	473	83.4
Konecranes Service Oy	516	78.9
Oy Botnia Mill Service Ab	591	73.9
Kymenso Oy	743	45.0
Large enterprises in total	3,181	399.4
SMEs	*Personnel in 2007*	*Net sales in 2007, M€*
ISS Teollisuuspalvelut Oy	104	12.5
Tespal Oy	53	9.4
Machinery Service Finland Oy	92	8.4
Sahala Industrial Services Oy	109	8.0
Pikoteknik Oy	50	7.3
Tormets Oy	103	6.3
Mahro Oy	25	5.5
Betamet Service Oy	48	3.9
Astepa Oy	46	3.1
Metso Mill Service Kauttua Oy	36	2.6
Kangasalan Pajaservice Oy	16	2.6
JTT Konepaja Oy	20	2.2
Rauman Sähkökonehuolto Oy	10	0.8
SMEs in total	712	72.6
All enterprises in total	*3,893*	*472.0*

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Enhancing collaboration in maintenance networks through flexible asset management

Salla Marttonen*, Sari Monto and Timo Kärri

Department of Innovation Management
Lappeenranta University of Technology
P.O. Box 20, FI-53851, Lappeenranta, Finland
E-mail: salla.marttonen@lut.fi
E-mail: sari.monto@lut.fi
E-mail: timo.karri@lut.fi
*Corresponding author

Abstract: The aim of the study is to advance the efficient management of asset portfolios through flexible asset management collaboration in maintenance networks. We use analytical modelling, simulations and data of two case networks. Our results show how flexible asset management practices and collaboration in networks improve the profitability of a company and a network in different situations. In the case companies, profitability can be improved through reorganizing the ownership of the assets of the network, and through increasing the flexibility of the companies' balance sheets. This is why companies should manage their balance sheets actively. We also conclude that it can be valuable to organize flexible asset management on the network level. Generally, the different features of network members can create added potential for collaboration.

Keywords: Industrial maintenance; networks; flexible asset management; fixed assets; working capital; return on investment; return on equity; benchmarking.

1 Introduction

In this paper, we discuss collaboration in maintenance networks. Our perspective to the matter is that of flexible asset management. The collaboration between companies in networks is still somewhat limited. However, as the competition tightens, service providers are searching for new possibilities to provide more value for their customers as well as for themselves (Hatinen et al., 2012; Paguio, 2010). Thus there is a need for solutions that create additional value for each network member. In this paper we suggest that collaboration on flexible asset management is one of these solutions.

Nowadays, the maintenance activities of manufacturing companies are often outsourced to outside service providers. As a result, the forms of collaboration in industrial maintenance are becoming more and more complex. This means that there is a concrete need for new information, tools and models in the industry (Ahonen et al., 2010). On the other hand, companies must remain flexible, as the demand can change in a surprising manner at any point of time (Hatinen et al., 2012). This study integrates the issues presented above, as we address flexible asset management practices in maintenance networks.

We use the data of two case networks: one of the networks represents energy industry, and the other pulp industry. Both networks consist of three companies. The case networks

are benchmarked against each other, and simulations are conducted to study the profitability effects of flexible asset management practices. The research questions of the study are the following:

- How profitable are the companies of the two maintenance networks, and what features is their profitability comprised of?
- How could company and network profitability be improved by advancing asset management practices?

The paper contributes to the research field of strategic engineering asset management. Our goal is to advance the efficient management of asset portfolios, as well as the optimization of inter-organizational collaboration in maintenance networks. We show how flexible asset management practices and collaboration in networks improve the profitability of companies and networks in different situations. As regards flexible asset management, we address both fixed assets and working capital, as they complement each other from the perspective of asset management.

The paper is structured as follows: section 2 reviews the previous literature on industrial maintenance networks and flexible asset management. In section 3, we present our research design, consisting of a flexible asset management model and two case networks. Section 4 presents a brief analysis of the case networks, while section 5 contains the simulations conducted with the data of the case networks. The paper finishes with conclusions in section 6.

2 Literature review

2.1 Industrial maintenance networks

In this subsection, we address the emergence of industrial maintenance networks. The industrial maintenance sector has undergone a dramatic structural change in the past decades. Due to for example an increase in asset complexity and focus on core competences, manufacturing companies have outsourced their maintenance activities to outside service providers more and more often (e.g. Kumar, Markeset and Kumar, 2006; Xia et al., 2011). This way, the demand for maintenance services has expanded and the industry of maintenance services has been born. Service providing companies have been formed, and industrial equipment manufacturers have increased their service offerings (Ojanen et al., 2010). The demand still keeps growing, and the number of service providing companies in the maintenance industry increases, creating more competition (Hilletofth et al., 2010; Paguio, 2010). Accordingly, the maintenance service providers are forced to make investments and search for novel ways of creating value for themselves and for their customers (Hatinen et al., 2012; Paguio, 2010).

As maintenance outsourcing has increased, so has the collaboration between maintenance customers and equipment or service providers. The more complex service networks create a need for more information. As the industry of maintenance services is still quite young, this need for information is extensive (Ahonen et al., 2010). On the other hand, Panesar and Markeset (2008) see that this increase in complexity calls for closer collaboration and partnerships between companies. Certainly, considering outsourced services, inter-organizational collaboration is essential. Competition has started to move from being between companies into being between business networks. Further, the objective of partnering is to reach a win-win situation. Olsson and Espling

(2004) discuss partnering in infrastructure maintenance. They underline the importance of relationships and trust between the maintenance partners in outsourcing situations. New, more complex types of networks are often created while pursuing flexibility and risk sharing for a company (Ahonen et al., 2010; Tenhunen, 2006). This remark brings us close to the discourse about flexible asset management thinking, which will be discussed in the next subsection.

In previous literature, industrial maintenance services have usually been studied from the point of view of the maintenance buyer, i.e. the customer company (e.g. Pintelon, Pinjala and Vereecke, 2006; Sun, Yam and Wai-Keung, 2003; Waeyenbergh and Pintelon, 2002). The perspective of the maintenance network remains unfamiliar to the academia. As a result, there is a need for models and methods for maintenance network collaboration (Ahonen et al., 2010; Marttonen et al., 2011).

2.2 Flexible asset management

The business environment is becoming more dynamic, and the demand can vary rapidly. Hatinen et al. (2012) have studied the investment logics of maintenance service - providing companies. They conclude that forecasting future development and the ability to adjust to changes in demand are of major importance to maintenance companies in the future. In order to stay profitable in the midst of these changes, companies should increase their flexibility. Gibson (2000) categorizes flexibility into three classes: physical, functional, and financial flexibility. Of these categories, financial flexibility is the most unknown in the academic literature. This paper addresses financial flexibility, and the assets are examined from the balance sheet perspective. Gibson (2000) has studied the flexibility of a single asset. In this paper, the focus is on the portfolio of assets, as the research is done on the company level.

Flexible asset management is one of the ways to master the dynamism described above (Gibson, 2000; Navarro, 2009). Asset management is of great importance to company success (Lin et al., 2007). Accordingly, several researchers have linked the asset management perspective to company-level goals and profitability (e.g. Aoudia, Belmokhtar and Zwingelstein, 2008; Tam and Price, 2008). Sawhney, Kannan and Li (2009) add that flexible asset management is essential when reaching for a lean business philosophy. Allee (2008) has studied the management of intangible assets in networks. However, in order to really make an impact on network profitability, a more thorough view is needed. In flexible asset management, both the fixed assets and working capital management should be taken into account (Ojanen et al., 2012). While the flexible management of fixed assets requires quite a long time frame, the capital tied to working capital can be released swiftly (Hatinen et al., 2012). Previous studies have mostly considered mere long-term capital (Chiou, Cheng and Wu, 2006) and fixed assets (Komonen, 2010). Working capital management, on the other hand, has not received much attention in previous literature, although it is currently gaining more visibility (Protopappa-Sieke and Seifert, 2011; Viskari, Lukkari and Kärri, 2011).

The flexibility of a company's fixed assets can be increased through for example increasing capacity utilization, leasing capacity, eliminating bottlenecks, selling unnecessary assets, or developing the allocation of capacity investments in company networks (Kärri, 2007; Ojanen et al., 2012). The responsibilities of the contracting companies have been addressed before, for example who accounts for the success of maintenance (Hui and Tsang, 2003; Levery, 1998). However, all the information needs of the present maintenance networks have not been covered yet. Markeset and Kumar

(2005) write that today, many maintenance customers buy performance from their service providers. Thus it is no longer obvious that the customer should own the physical assets. Whoever owns the assets should analyze the effect of the assets on the company's profitability. So far, this aspect has been mostly neglected in the academic literature.

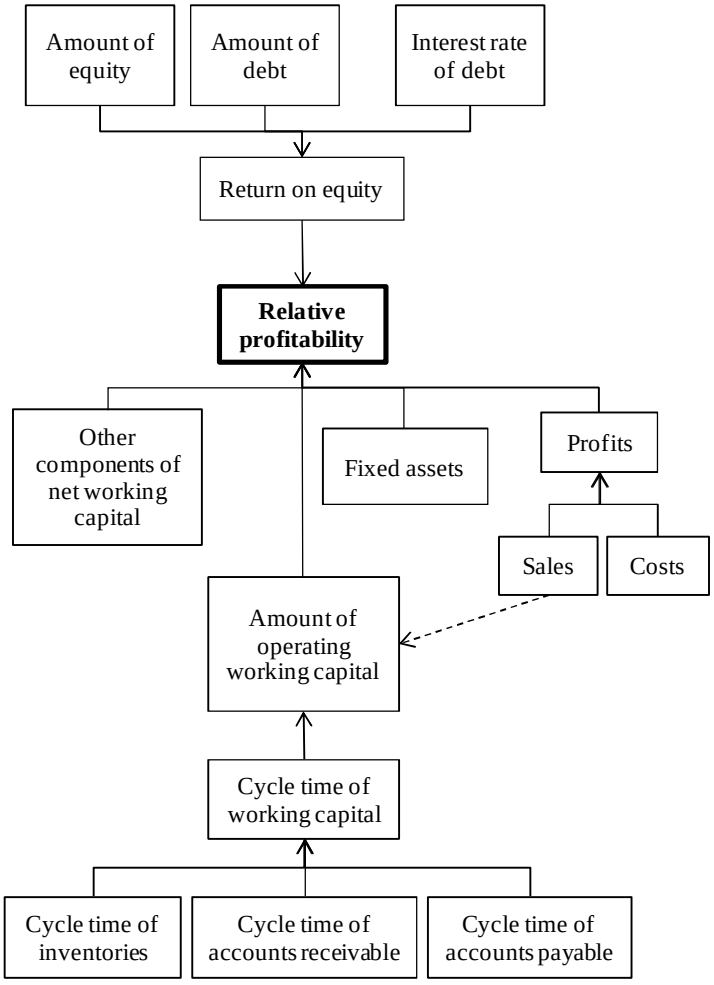
The management of working capital has a direct effect on a company's liquidity and profitability. Profitability increases as the cycle time of working capital decreases. However, the decrease of working capital also cuts back liquidity. Thus working capital can be managed optimally by reaching a balance between these two dimensions. In addition, the current research suggests that companies should include their network partners in their working capital management decisions: at the end of the day the optimization of working capital should be done on the network level (Grosse-Ruyken, Wagner and Jönke, 2011). Talha, Christopher and Kamalavalli (2010) state that manufacturing and service companies should not ignore the importance of active working capital management. Previous studies show that in general the role of working capital management is especially important for service companies, because they carry only little fixed assets (Marttonen, Viskari and Kärri, 2011; 2012).

3 Research design

3.1 Model of flexible asset management

Our research design is introduced briefly below. In this paper analytical modeling is used as the research method to conduct analyses and simulations in two empirical case networks. In section 2 above, the importance of flexible asset management was discussed. In this study, we apply the Flexible Asset Management model (FAM-model) first introduced by Marttonen, Viskari and Kärri (2011; 2012). The model concerns the factors of the return on investment (*ROI*) from the asset management perspective. The starting point of the model is the basic definition of the *ROI* (profits divided with capital invested). The parameters of the *ROI* and the FAM-model are specified in Figure 1. From the managerial perspective, the company profits are produced with certain fixed and current assets. Of current assets, we focus on operational working capital, and thus on inventories, accounts receivable and accounts payable. The cycle times are used to measure working capital, as they are easier to grasp than monetary sums. From the financial perspective, the *ROI* is linked to the return on equity. The value of the return on equity, on the other hand, depends on the capital structure of the company, as well as on the interest rate of debt.

Figure 1 Components of relative profitability



Mathematically, the interrelations in the FAM-model can be presented as in Equation 1 (Marttonen, Viskari and Kärri, 2012). Both fixed assets (*FA%, B*) and current assets (*CCC, r*) are thus taken into account.

$$ROI = \frac{EBITDA\% - \left(FA\% * \frac{1}{B-1}\right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%} = \frac{i_D * D + i_E * E}{D + E}, \quad (1)$$

Where
- *ROI* is the return on investment,
- *EBITDA%* is the ratio of the profit margin to the net sales,
- *FA%* is the ratio of fixed assets to the net sales,
- *B* is the average depreciation time (in years) of fixed assets,
- *CCC* is the cycle time of operational working capital,

r	is the residual term, consisting of current assets (except inventories and accounts receivable, which are included in the *CCC*) and current liabilities (except accounts payable, which are included in the *CCC*),
i_D	is the interest rate of debt,
D	is the amount of long-term debt in the company,
i_E	is the return on equity, and
E	is the amount of equity in the company.

As Figure 1 shows, the cycle time of operational working capital (*CCC*) consists of the cycle times of inventories, accounts receivable, and accounts payable. This is also presented in Equation 2.

$$CCC = DIO + DSO - DPO \quad (2),$$

where	*DIO*	is the cycle time of inventories,
	DSO	is the cycle time of accounts receivable, and
	DPO	is the cycle time of accounts payable.

3.2 Case description

Next, we introduce the industrial maintenance networks studied in this paper (Figure 2). Both networks include three companies: the maintenance buyer (customer), the equipment provider, and the maintenance service company. Both networks are real, meaning that the service providers are actually in charge of at least some part of the customer company's maintenance activities.

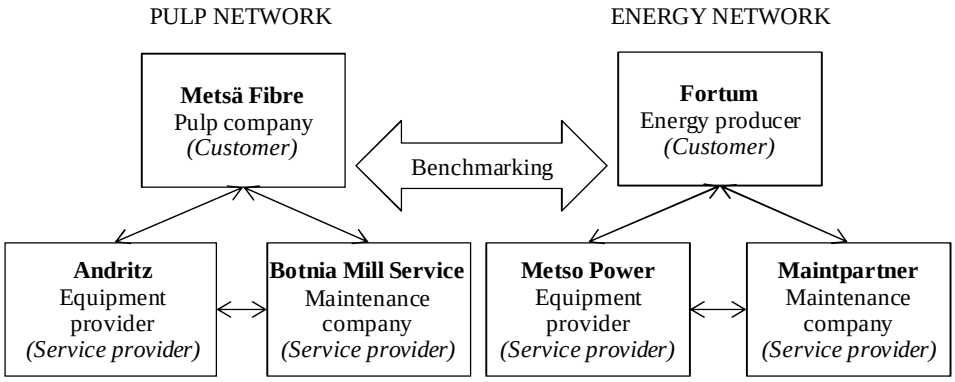
The pulp network includes the pulp company Metsä Fibre, the maintenance company Botnia Mill Service, which is owned by the customer Metsä Fibre, and the equipment provider, Andritz, which is a metal company known worldwide, delivering machinery for paper and pulp companies.

The energy network operates in the energy sector. Fortum is a large producer of power and heat in northern Europe. Maintpartner delivers comprehensive maintenance solutions for its customers. In Finland, the main customers of Maintpartner are from energy, metal, chemical and food industry. Metso Power is an international provider of technology and services in the energy industry.

These particular networks were chosen for this study on the basis of the maintenance companies. Although the outsourcing of industrial maintenance can be considered to be at an advanced level in Finland, the maintenance service industry is still developing. Mergers and acquisitions have taken place, and there are not many large providers of comprehensive industrial maintenance services available for research. Of this small group of companies (Botnia Mill Service, Efora, Empower, Konecranes Service, Maintpartner), the financial statements of Botnia Mill Service and Maintpartner were considered the most comparable. Efora was not incorporated until 2009. The financial statement of Empower describes not only the industrial maintenance business, but also energy industry. Konecranes Service represents both service providers and equipment manufacturers, which may influence its financial statements. Thus Botnia Mill Service and Maintpartner were chosen.

Botnia Mill Service has only one main customer: Metsä Fibre. Of the equipment providers, Andritz was selected because it has advanced co-operation with both Metsä Fibre and Botnia Mill Service. For the energy network, Fortum was chosen to present the energy industry. Forest industry represents the established knowhow of Finnish companies in international markets. Energy industry, on the other hand, is receiving more and more attention. In the near future, the energy industry will make major investments, and its importance will increase. Fortum is the best company to study in this context, as Maintpartner was separated from Fortum Service in 2006, when Maintpartner started business as an individual company. Metso Power was chosen as the service provider of this network, because several comprehensive delivery projects between Metso and Fortum have been announced recently.

Figure 2 Description of the case networks



4 Analysis of the maintenance networks

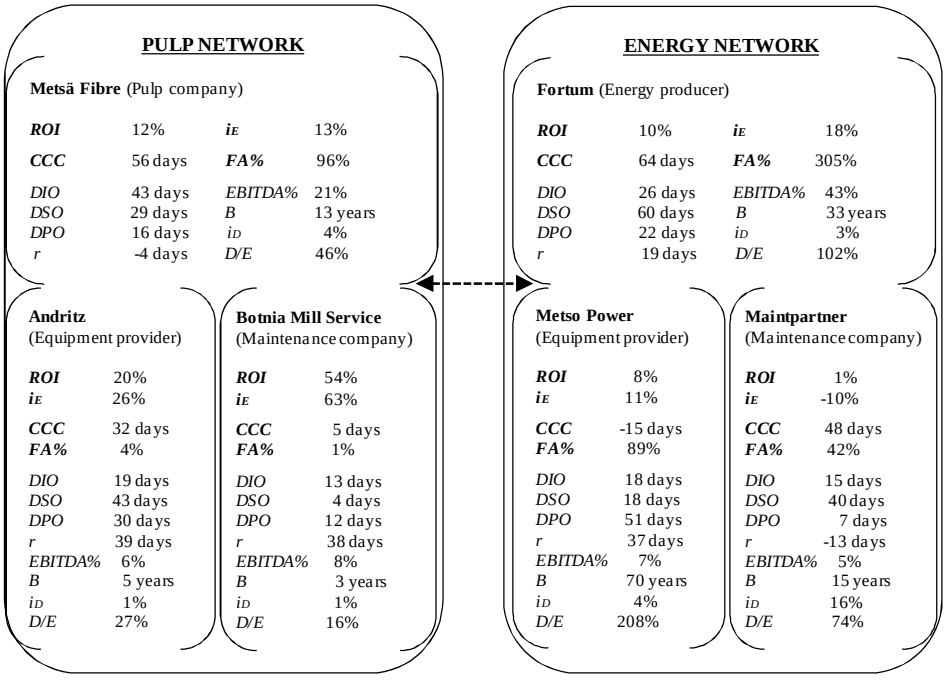
4.1 Data of the case networks

The financial statements of the case network companies were studied to collect the required elements of profitability and asset management. Table 1 shows the development of the *ROI* and the return on equity in the case companies during 2006-2010. Figure 3 shows the average values of the elements for each case company in the inspection period 2006-2010. The information given in this figure is analyzed in the next subsections by inspecting the differences between the two networks. In section 5, simulations are conducted to demonstrate different asset management practices in these networks.

Table 1 Development of the *ROI* and the i_E in the case network companies

		2006	2007	2008	2009	2010
Metsä Fibre	*ROI*	12%	10%	10%	-14%	45%
	i_E	15%	13%	11%	-29%	55%
Fortum	*ROI*	10%	12%	11%	10%	9%
	i_E	16%	19%	19%	18%	17%
Andritz	*ROI*	14%	13%	31%	24%	21%
	i_E	18%	16%	37%	30%	26%
Metso Power	*ROI*	5%	5%	7%	7%	13%
	i_E	7%	7%	14%	17%	11%
Botnia Mill Service	*ROI*	32%	70%	56%	59%	54%
	i_E	34%	73%	62%	70%	74%
Maintpartner	*ROI*	6%	1%	5%	-7%	0%
	i_E	5%	-12%	-9%	-27%	-7%

Figure 3 Average data of the case networks from 2006 to 2010



4.2 Comparing the customer companies of the case networks

Both customer companies are quite similar as regards profitability and asset management. Figure 3 shows that Metsä Fibre has a slightly better *ROI* than Fortum. However, when profitability is set against net sales instead of invested capital, we can see that the *EBITDA%* of Fortum is remarkably high, much higher than that of Metsä Fibre. Fortum carries heavy fixed assets (*FA%* over 300%), consisting mostly of various tangible assets and investments. The high amount of fixed assets thus decreases the *ROI* of Fortum. The

return on equity is better in Fortum (18%) than in Metsä Fibre (13%). This is mostly caused by the financial leverage reached by Fortum through a higher debt-to-equity ratio.

From Table 1 it can be concluded that the development has been more constant for Fortum than for Metsä Fibre. The financial crisis has created a clear drop in the *ROI* of Metsä Fibre. By studying our data we can conclude that the main reason for this has been a drop in the *EBITDA%*. In Metsä Fibre the net sales has decreased by 44%, and the *EBITDA* 89% from 2008 to 2009. For Fortum, the corresponding decreases are 4% for the net sales and 8% for the *EBITDA*. This reflects the cyclical nature of the pulp industry, compared with the energy industry. This is mostly caused by the severe variation in the market price of pulp. Nevertheless, already in 2010 the *ROI* of Metsä Fibre clearly surpassed the *ROI* of Fortum.

4.3 Comparing the equipment providers of the case networks

Next, the two equipment providing companies of the case networks, Andritz and Metso Power, are compared. There are clearly more differences between the equipment providers than between the customer companies. Figure 3 shows that the *EBITDA%* of Metso Power is slightly higher than that of Andritz. However, the *FA%* is tremendously greater for Metso Power (89%) than for Andritz (4%). The high amount of fixed assets causes the *ROI* of Metso Power to drop clearly below the *ROI* of Andritz.

Andritz has a clearly better return on equity (26%) than Metso Power (11%). The interest rate of debt of Andtriz is exceptionally low (1%), which increases the i_E. Metso Power, on the other hand, has a high debt-to-equity ratio. However, the financial leverage of this debt is not exploited fully, since the interest rate of debt of Metso Power is quite close to its *ROI*.

The working capital management of the two equipment providers is compared next. It can be seen in Figure 3 that Metso Power has a negative cycle time of working capital (-15 days), while for Andritz the cycle time is clearly positive (32 days). Compared with Andritz, Metso Power has a shorter cycle time of accounts receivable and a longer cycle time of accounts payable. Thus Metso Power controls its contracts and payment terms in a more profitable way.

In Table 1 it can be seen that the *ROI* of Andritz has decreased from 2008 to 2010, but the *ROI* of Metso Power has actually increased. This can be related to industry-specific differences; Metso Power provides equipment for the energy industry, where the demand stays quite stable even during financial crises. On the other hand, the clientele of Andritz is more diverse, including for example pulp and paper, metal, and separation industries in addition to the energy industry.

4.4 Comparing the maintenance companies of the case networks

Now we move on to analyse the differences between the two maintenance companies. When profitability and asset management are studied, the maintenance companies are very different from each other. Botnia Mill Service is more profitable than Maintpartner. The *ROI* of Botnia Mill Service (54%) is tremendously higher than the *ROI* of Maintpartner (1%). Also the *EBITDA%* of Botnia Mill Service (8%) is higher than the *EBITDA%* of Maintpartner (5%). Botnia Mill Service also has a much shorter cycle time of working capital and a lower fixed asset ratio than Maintpartner.

Table 1 shows that the difference between the profitability of the maintenance service companies is systematic; Botnia Mill Service has been highly profitable throughout the research period, while the *ROI* of Maintpartner has remained near to zero or even negative. The main reasons behind this difference are profits, fixed assets, and operational working capital.

In addition to the *ROI*, Botnia Mill Service has a tremendously better return on equity than Maintpartner: the i_E of Botnia Mill Service is 63%, while the i_E of Maintpartner is -10%. This is caused by the large difference in the *ROI*, but also the distinction between the interest rates of debt (1% in Botnia Mill Service, 16% in Maintpartner). Finally, Maintpartner has much higher debt-to-equity ratio than Botnia Mill Service. Since the *ROI* of Maintpartner is lower than its i_D, the financial leverage has turned into a disadvantage, causing the i_E to decrease.

As Figure 3 indicates, the *CCC* has been on average ten times longer for Maintpartner than for Botnia Mill Service. This has been mostly caused by the cycle time of accounts receivable, *DSO*. However, the *CCC* of Botnia Mill Service has increased from 2006 to 2010, while the *CCC* of Maintpartner has decreased. In 2010, the *CCC* of Maintpartner (13 days) was actually shorter than the *CCC* of Botnia Mill Service (18 days).

4.5 Comparing the case networks

On the network level, it can be concluded that in the pulp network, the *ROI*-values are better and the *FA%* and average depreciation times smaller, compared with the energy network. Thus the pulp network manages its assets in a more profitable way, and each company in the network has been profitable. It seems that the pulp network is more uniform as regards profitability. In the energy network, the customer company, Fortum, is much more profitable than the other two network members. The energy network, on the other hand, seems to be relying on the stability of the energy industry. It can be concluded on the basis of Table 1 that the development has been more constant for the energy network than for the pulp network. The energy network could still improve its profitability through benchmarking the asset management practices from the pulp network.

We also noticed that the energy network bears explicitly more debt than the pulp network. However, since the relative profitability is not always very high in the energy network, the financial leverage goes unexploited. In the pulp network, on the other hand, the *ROI* has remained high enough, clearly higher than the i_D. Nevertheless, the companies of the pulp network have relatively low debt-to-equity ratios, which causes the i_E to remain quite close to the *ROI* and not rise much higher. This kind of cautious incurring of debt is of course justified in the pulp network, as the industry is cyclical and quite unpredictable by nature.

5 Simulating flexible asset management practices in the network level

5.1 The presumptions used in the simulation

Here the observations discussed above are transformed into simulations. The simulations are conducted in order to find out how rationalizing asset management practices in the network level would impact profitability. To do this, two different situations have been constructed: one for each case network. In this subsection the presumptions used in these

situations are briefly introduced, and in the following subsections the actual simulations are conducted.

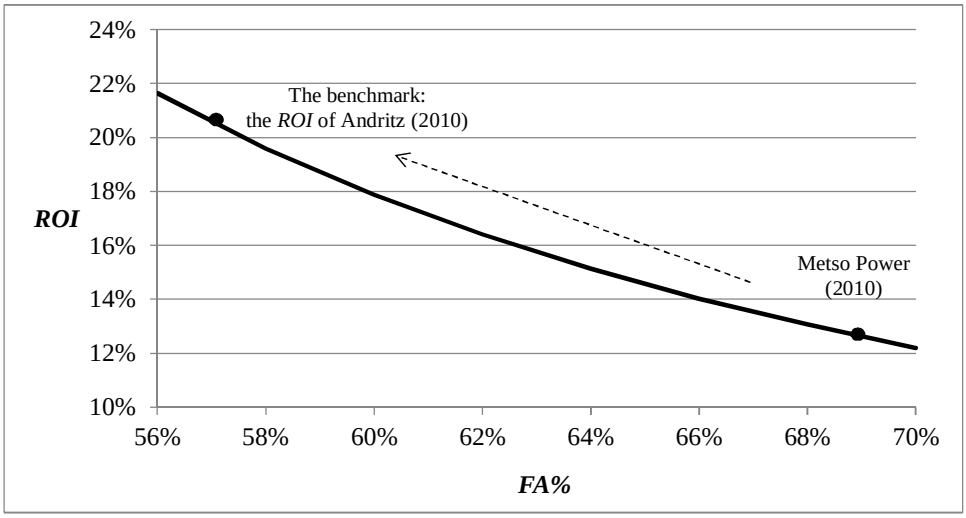
The simulation for the energy network deals with the unequality of the network as regards profitability. In the previous section we concluded that Fortum is much more profitable than the other two members of the energy network, and that Metso Power and Maintpartner could improve their profitability by benchmarking the asset management practices of the pulp network. Thus, the problem to be addressed through simulation is: how could Metso Power and Maintpartner improve their profitability through asset management, and what would this change mean for Fortum?

On the other hand, the pulp network seems to manage its assets quite effectively. The most interesting remark about this network is the cyclical nature of the industry. Thus this is what the simulation will focus on: if a downturn causes an extensive collapse in the net sales of the network, how should the network manage its assets? The dilemma of the pulp network is addressed in section 5.3, while section 5.2 discusses asset management in the energy network.

5.2 Simulation for the energy network

First let us examine the situation of the energy network equipment provider, Metso Power. Here we analyze how Metso Power could increase its *ROI* of 2010 (13%) to match the *ROI* of Andritz in 2010 (21%) through decreasing the amount of fixed assets. Since the *CCC* of Metso Power is already negative, it would not be realistic to reach for a better *ROI* through changes in working capital management. Thus only the fixed assets of Metso Power are taken into the simulation. Figure 4 shows how Metso Power could reach the *ROI*-level of Andritz. The dot on the right specifies the situation of Metso Power in 2010, and the dot on the left shows how the *FA%* should change in order to reach the target *ROI*. It can be seen that by decreasing its *FA%* from 69% to 57%, Metso Power would reach the *ROI* of Andritz. This can be considered a realistic and achievable goal. This increase in the *ROI* from 13% to 21% would also lead to an increase in the i_E: the i_E of Metso Power would increase from 11% to 20%.

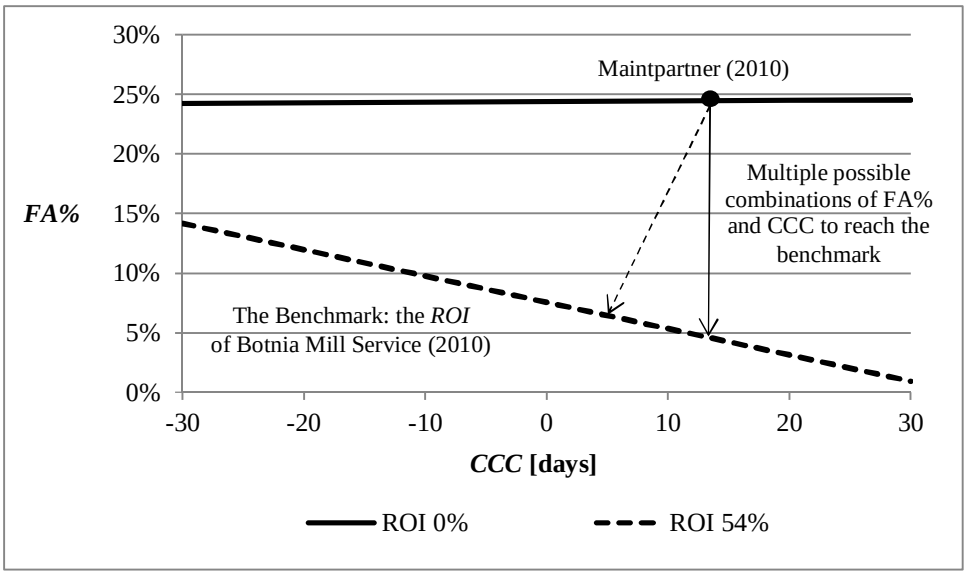
Figure 4 The *FA%* that would lead Metso Power to the target *ROI*



Now the discussion moves on to the maintenance company of the energy network, Maintpartner. We analyze how Maintpartner could reach the 2010 *ROI*-level of Botnia Mill Service, 54%. The starting point is the 2010 *ROI* of Maintpartner, 0%. Here we concentrate on achieving the target *ROI* with better asset management. Figure 5 shows which combinations of the *FA%* and the *CCC* would result in the *ROI* of 0% (the upper curve) and the *ROI* of 54% (the lower curve). The other elements of the FAM-model have been set constant at the actual 2010 level of Maintpartner. The dot in the figure specifies the actual situation of Maintpartner in 2010. The dash line illustrates the possible combinations of the *FA%* and the *CCC* which would lead Maintpartner into the *ROI*-level of Botnia Mill Service.

It can be seen in Figure 5 that Maintpartner could reach the *ROI* of Botnia Mill Service through decreasing the *FA%* from 25% to 5%. This is a challenging goal, but not an impossible one. Reaching the goal could be made slightly easier if the decrease of fixed assets was combined with an improvement in working capital management. For Maintpartner in its present state, the impact of the *CCC* on profitability is insignificant. This is caused by the level of the *FA%*, as well as the other parameters of the FAM-model. However, if Maintpartner could decrease its *CCC* from 13 days to 5 days, a decrease of the *FA%* from 25% to 7% would be sufficient to reach the *ROI* of Botnia Mill Service. These changes in asset management would lead to an extensive increase in the return on equity: the i_E of Maintpartner would increase from -7% to 75%.

Figure 5 The combinations of the *FA%* and the *CCC* that would lead Maintpartner into the target *ROI*



Concluding from the analysis above, Metso Power would need to decrease its *FA%* from 69% to 57%. This means a 34 M€ decrease in the fixed assets of Metso Power. In addition, the *FA%* of Maintpartner would have to decrease from 25% to 7%, meaning a 6 M€ decrease in its fixed assets. The operational working capital of Maintpartner in 2010 consisted of inventories only. The decrease in the *CCC* of Maintpartner from 13 days to 5

days requires a 2 M€ decrease in its inventories. Assuming that the operations could not be advanced to this extent, these items should be transferred from the balance sheet of these companies to the balance sheet of their network partner, Fortum, for example.

Since Fortum carries a heavy balance sheet, the changes described above would not have much impact on it. The *FA%* of Fortum would increase from 288% to 289%, and its *CCC* would increase from 52 days to 53 days. The *ROI* of Fortum would remain at 9%, and its i_E would not go down from 17%. Table 2 shows the main figures of the energy network companies in the actual situation of 2010, as well as in the possible situation according to our simulation.

Table 2 The effects of the simulated changes to the energy network companies

The actual situation			
	Fortum	**Metso Power**	**Maintpartner**
FA%	288%	69%	25%
CCC	52 days	-68 days	13 days
ROI	9%	13%	0%
i_E	17%	11%	-7%
The possible situation according to the simulation			
	Fortum	**Metso Power**	**Maintpartner**
FA%	289%	57%	7%
CCC	53 days	-68 days	5 days
ROI	9%	21%	54%
i_E	17%	20%	75%

It can be concluded that through this kind of mutual asset management on the network level, the profitability figures of Metso Power and Maintpartner would become more appealing. The effect of these simulated arrangements can be assumed to be quite extensive at the stock market, since the return on equity would improve in these companies, alluring more investors. Mutual asset management would be reasonable on the network level also because the interest rate of debt is lower for Fortum that for the other two network companies. Thus Fortum can carry assets for a lower price. Fortum would benefit from this arrangement due to an increase in the financial leverage, but mutual asset management should also be included as one part of the maintenance contract negotiations between the companies. The value of the arrangement should be identified for each network member, as these asset ownership services must be priced correctly.

5.3 Simulation for the pulp network

Companies should have a long-term target level for their *ROI*. In case of an extensive decrease in the net sales, the amount of fixed assets and working capital should be reduced respectively. In this simulation, the net sales of the pulp network will suddenly decrease by 50%. In our case network, all three companies are involved in the forest industry to such an extent that a collapse in the net sales of the industry would concern them all. All the network partners would have to adjust the amount of their assets, so transferring items from one network member to another is not a solution in this case. Of course the cycle times of accounts receivable and accounts payable could be minimized inside the pulp network, but aside from that, the inventories and fixed assets should be transferred outside this network.

Halving the amount of fixed assets and working capital through rearrangements could succeed in Andritz and especially Botnia Mill Service, as they operate with light balance sheets. On the other hand, Metsä Fibre would have a hard time rearranging its assets. Metsä Fibre represents the forest industry, which is capital-intensive and has traditionally pursued economies of scale rather than flexibility. Metsä Fibre should thus act proactively, and modify the flexibility of its assets through for example leasing and outsourcing arrangements. This way, the risk caused by inflexible assets could at least be downsized.

We concentrate on Metsä Fibre in this simulation, due to its heavy assets. The starting point for the simulation is Metsä Fibre in 2010, having a *FA%* of 42%, a *CCC* of 44 days, a *ROI* of 45% and a i_E of 55%. In Table 3 these figures are presented in five different situations. In each of these situations the net sales decreases by 50%. The amount of fixed assets and/or working capital decreases by 0%, 15%, or 30%. For simplicity, we have made an assumption about the average depreciation time and the operating margin ratio staying unchanged.

Table 3 Return on investment and return on equity in Metsä Fibre in different situations. The reference values of Metsä Fibre are a *FA%* of 42%, a *CCC* of 44 days, a *ROI* of 45% and a i_E of 55%.

Asset flexibility as net sales decreases by 50%	***FA%***	***CCC***	***ROI***	i_E
Fixed assets and working capital stay unchanged	84%	87 days	20%	23%
Fixed assets and working capital decrease by 15%	72%	74 days	25%	30%
Working capital decreases by 30%, fixed assets by 15%	72%	61 days	26%	31%
Fixed assets decrease by 30%, working capital by 15%	59%	74 days	30%	36%
Fixed assets and working capital decrease by 30%	59%	61 days	31%	37%

Judging from Table 3, the profitability of Metsä Fibre would decrease by more than 50% if both the fixed assets and working capital stayed unchanged while the net sales collapsed. It would thus be crucial to achieve at least some asset flexibility. If the fixed assets and working capital could be decreased by just 15%, the profitability would be clearly better. On the other hand, if the decrease of fixed assets and working capital could be extended to 30%, the profitability would be significantly better, measured through either the *ROI* or the i_E. It should be noted that most of the resources should be allocated to making the fixed assets more flexible. It can be seen in Table 3 that as regards

profitability, the changes in the amount of fixed assets are clearly more important than the adjustments in the amount of working capital. This is reasonable, as the amount of fixed assets is relatively high in Metsä Fibre.

6 Conclusions

This paper has addressed the profitability of the companies in two case maintenance networks. We have studied how the networks could improve their profitability through flexible asset management practices. We conclude that the energy network features extensive differences between company profitabilities. As a result, the network could gain additional value by using mutual asset management. Thus the other two network members should transfer some of their assets to the balance sheet of the network customer, Fortum. In our second case network, the pulp network, the profitability is more uniform between the companies. The cyclical nature of the pulp industry causes substantial challenges for the flexibility of the companies' balance sheets. It can be concluded that the pulp network should focus on making their assets, especially fixed assets, more flexible.

We have two main theoretical implications in this paper. The first implication concerns introducing a method to study flexible asset management in networks with financial statement data, analytical modeling and simulations. Our second theoretical implication is about integrating the management of fixed assets and working capital. Usually these two aspects have been studied separately, even though they are complementary from the asset management perspective.

The most important managerial implication in this paper is the ability of flexible asset management practices to improve profitability. We have simulated how the profitability can be influenced through reorganizing the ownership of the network's assets, and through increasing the flexibility of the company's balance sheet. All in all, based on our results, the companies should manage their balance sheets actively. It can also be valuable to organize flexible asset management on the network level: the different features of the companies can create potential for collaboration.

One of the research limitations of this article is using financial statement data. Although useful in many respects, the information gathered from financial statements can sometimes be imperfect. For example, exact simulations of working capital management cannot be conducted, as financial statement data does not take into account the other customer and supplier relationships of the case companies.

We have provided the case networks with suggestions about applying mutual asset management and increasing asset flexibility. However, the scope of this paper is on the strategic level. Converting these suggestions into operational action plans is thus left for further research. It would be very important to study for example how the reorganizing of assets between companies could be taken into account in maintenance contract negotiations and pricing. This way, academics would take yet another step closer to the optimization of collaboration in maintenance networks.

References

Ahonen, T., Reunanen, M., Pajari, O., Ojanen, V. and Lanne, M. (2010) 'Maintenance communities – a new model for the networked delivery of maintenance services', *International Journal of Business Innovation and Research*, Vol. 4, No. 6, pp. 560–583.

Allee, V. (2008) 'Value network analysis and value conversion of tangible and intangible assets', *Journal of Intellectual Capital*, Vol. 9, No. 1, pp. 5–24.

Aoudia, M., Belmokhtar, O. and Zwingelstein, G. (2008) 'Economic impact of maintenance management ineffectiveness of an oil and gas company', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 3, pp. 237–261.

Chiou, J., Cheng, L. and Wu, H. (2006) 'The determinants of working capital', *The Journal of American Academy of Business*, Vol. 1, No. 10, pp. 149–155.

Gibson, V. (2000) 'Property portfolio dynamics: the flexible management of inflexible assets', *Facilities*, Vol. 18, No. 3, pp. 150–154.

Grosse-Ruyken, P.T., Wagner, S. and Jönke, R. (2011) 'What is the right cash conversion cycle for your supply chain?', *International Journal of Services and Operations Management*, Vol. 10, No. 1, pp. 13–29.

Hatinen, L., Pirttilä, M., Viskari, S. and Kärri, T. (2012) 'The investment logics of Finnish industrial maintenance service providers', *International Journal of Strategic Engineering Asset Management*, Vol. 1, No. 1, pp. 33–48.

Hilletofth, P. and Ujvari, S. (2010) 'Agent-based decision support for maintenance service provider', *International Journal of Services Sciences*, Vol. 3, No. 2/3, pp. 194–215.

Hui, E. and Tsang, A. (2006) 'The inter-organizational relationship in a multi-contractor business network', *Journal of Quality in Maintenance Engineering*, Vol. 12, No. 3, pp. 252–266.

Komonen, K. (2010) 'Asset management in the industrial sector: background and conceptual approach', *Maintworld*, Vol. 2, No. 1, pp. 16–19.

Kumar, R., Markeset, T. and Kumar, U. (2006) 'Implementation and execution of industrial service strategy. A case study from the oil and gas industry', *Journal of Quality in Maintenance Engineering*, Vol. 12, No. 2, pp. 105–117.

Kärri, T. (2007) *Timing of capacity change: models for capital intensive industry*, Dissertation for the degree of Doctor of Science, Lappeenranta University of Technology, Lappeenranta, Finland.

Levery, M. (1998) 'Outsourcing maintenance – a question of strategy', *Engineering Management Journal*, Vol. 8, No. 1, pp. 34–40.

Lin, S., Gao, J., Koronios, A. and Chanana, V. (2007) 'Developing a data quality framework for asset management in engineering organisations', *International Journal of Information Quality*, Vol. 1, No. 1, pp. 100–126.

Markeset, T. and Kumar, U. (2005) 'Product support strategy: conventional versus functional products', *Journal of Quality in Maintenance Engineering*, Vol. 11, No. 1, pp. 53–67.

Marttonen, S., Sinkkonen, T., Tynninen, L. and Kärri, T. (2011) 'Objective cost model for networks of industrial maintenance services', in proceeding of *Maintenance Performance Measurement and Management*, Luleå, Sweden, 13–15 December, pp. 131–139.

Marttonen, S., Viskari, S. and Kärri, T. (2011) 'Modeling the impact of working capital management on the profitability in industrial maintenance business', *Sixth Annual World Congress on Engineering Asset Management (WCEAM)*, Cincinnati, Ohio, USA, 2–5 October.

Marttonen, S., Viskari, S. and Kärri, T. (2012) 'Connecting the managerial and owner's view of flexible asset management in industrial maintenance companies', *Seventeenth International Working Seminar on Production Economics*, Innsbruck, Austria, 20–24 February.

Navarro, P. (2009) 'Recession-proofing your organization', *MIT Sloan Management Review*, Vol. 50, No. 3, pp. 45–51.

Ojanen, V., Hatinen, L., Kärri, T., Kässi, T. and Tuominen, M. (2012) 'Flexible investment planning and collaborative maintenance management', In: Van der Lei, T., Herder, P. and Wijnia, Y. (Eds.) (2012) *The state of the art in Europe from a life cycle perspective*, Springer.

Ojanen, V., Kolehmainen, J., Ahonen, T. and Tuominen, M. (2010) 'Developing collaborative relationship between industrial service providers and their client: the case of industrial maintenance management', in proceeding of *PICMET '10*, Phuket, Thailand, 18–22 July.

Olsson, U. and Espling, U. (2004) 'Part I. A framework of partnering for infrastructure maintenance', *Journal of Quality in Maintenance Engineering*, Vol. 10, No. 4, pp. 234–247.

Paguio, R. (2010) 'CRM technology: can adoption increase service quality and perceived value in maintenance services?', *International Journal of Services Sciences*, Vol. 3, No. 2–3, pp. 250–268.

Panesar, S.S. and Markeset, T. (2008) 'Development of a framework for industrial service innovation management and coordination', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 2, pp. 177–193.

Pintelon, L., Pinjala, S.K. and Vereecke, A. (2006) 'Evaluating the effectiveness of maintenance strategies', *Journal of Quality in Maintenance Engineering*, Vol 12, No. 1, pp. 7–20.

Protopappa-Sieke, M. and Seifert, R. (2011) 'Interrelating operational and financial performance measurements in a multiproduct inventory system', *International Journal of Services and Operations Management*, Vol. 10, No. 3, pp. 328–347.

Sawhney, R., Kannan, S. and Li, X. (2009) 'Developing a value stream map to evaluate breakdown maintenance operations', *International Journal of Industrial and Systems Engineering*, Vol. 4, No. 3, pp. 229–240.

Sun, H., Yam, R. and Wai-Keung, N. (2003) 'The implementation and evaluation of total productive maintenance (TPM) - an action case study in a Hong Kong manufacturing company', *International Journal of Advanced Manufacturing Technology*, Vol. 22, No. 3–4, pp. 224–228.

Talha, M., Christopher, S.B. and Kamalavalli, A.L. (2010) 'Sensitivity of profitability to working capital management: a study of Indian corporate hospitals', *International Journal of Managerial and Financial Accounting*, Vol. 2, No. 3, pp. 213–227.

Tam, A. and Price, J. (2008) 'A maintenance prioritization approach to maximise return on investment subject to time and budget constraints', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 3, pp. 272–289.

Tenhunen, J. (2006) *Management accounting in networks. Application possibilities and companies' needs*, Dissertation for the degree of Doctor of Science, Lappeenranta University of Technology, Lappeenranta, Finland *(in Finnish).*

Viskari, S., Lukkari, E. and Kärri, T. (2011) 'State of working capital management research: bibliometric study', *Middle Eastern Finance and Economics*, Vol. 5, No. 14, pp. 99–108.

Waeyenbergh, G. and Pintelon, L. (2002) 'A framework for maintenance concept development', *International Journal of Production Economics*, Vol. 77, No. 3, pp. 299–313.

Xia, B.-Z., Liu, J., Yu, D.-J. and Zhou, A.-M. (2011) 'A study on ally searching in maintenance alliance based on relation web model', *International Journal of Industrial and Systems Engineering*, Vol. 9, No. 4, pp. 412–433.

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'The missing link between maintenance contracts and flexible asset management'

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The missing link between maintenance contracts and flexible asset management

Salla Marttonen*, Sari Viskari and Timo Kärri

Department of Industrial Management,
Lappeenranta University of Technology,
P.O. Box 20, FIN-53851 Lappeenranta, Finland
E-mail: salla.marttonen@lut.fi
E-mail: sari.viskari@lut.fi
E-mail: timo.karri@lut.fi
*Corresponding author

Abstract: The paper shows how additional value can be created in maintenance collaboration through integrating the features of flexible asset management into maintenance contracts. We expand the traditional typology of maintenance contracts and introduce a new contract type, flexible asset management contracts. Also value sharing in the new contract type is discussed. Our logic for sharing the value is based on reaching for win-win situations in industrial maintenance collaboration. Finally, we present scenarios which prove that significant financial benefit can be achieved through adopting these novel contracts. In the dynamic and challenging operating conditions of the present, companies should actively search for this kind of possibilities for closer collaboration with their customers and suppliers.

Keywords: maintenance; contracts; flexible asset management; fixed assets; working capital; typology; value sharing; pricing; win-win; customer; service provider; procurement management.

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Biographical notes: Salla Marttonen is a doctoral student in the Department of Industrial Management at Lappeenranta University of Technology, Finland. She received her MSc (Tech) in Industrial Management in 2010 and after that she has worked in academia. Her research interests include capital, capacity and cost management. Her doctoral studies are related to costs and profitability of industrial maintenance business.

Sari Viskari is a doctoral student in the Department of Industrial Management at Lappeenranta University of Technology, Finland. She received her MSc (Tech) in Industrial Management in 2006 and after that she has worked in the private sector as well as in academic world. Her research interests include capital, capacity and cost management. Her doctoral studies are related to financial supply chain management and accounting in networks, more specifically measuring and management of working capital.

Timo Kärri is a Professor (acting) in the Department of Industrial Management at Lappeenranta University of Technology, Finland. He received his DSc (Tech) in Industrial Management in 2007. His dissertation considered timing of capacity changes in capital intensive industries, and his research interests include capital, capacity and cost management.

1 Introduction

This paper addresses combining the traditional understanding of maintenance contracts with flexible asset management thinking. Competition has become tight and globalised, and the number of outsourcings has increased. This has enhanced the collaboration between customer and supplier companies (Kroes and Ghosh, 2009; Yazici, 2012). Industrial maintenance service providers are forced to pursue higher profits for themselves and additional benefits for their customers. Therefore, maintenance companies are searching for novel contracts and services to offer (Martin, 1997; Wang, 2010). Companies can improve their performance through sharing more information with their supply chain partners (see e.g., Fantazy et al., 2011; Magnan et al., 2011). At the same time, companies must increase their adaptability in order to survive in the ever-increasing dynamism of the operating conditions (More and Babu, 2011). This dynamism can be managed through strategic partnerships (Raut et al., 2012). One way of accomplishing these partnerships and hence adaptability is through flexible asset management (Gibson, 2000; Marttonen et al., 2011; Navarro, 2009; Ojanen et al., 2012; Sawhney et al., 2009).

Extensive collaboration in maintenance networks calls for new models and methods (Ahonen et al., 2010). So far, flexible asset management has not been considered from the maintenance contract perspective. By adopting this view, additional asset management services can be attached to the actual maintenance contract. The value sharing of these additional services has not been studied before, either.

The goal of this study is to demonstrate the creation of additional value in maintenance collaboration by combining the research areas of flexible asset management and maintenance contracts. Our research questions are the following:

- How can the principles of flexible asset management influence the traditional understanding of the typology of maintenance contracts?
- What are the strengths and weaknesses of flexible asset management contracts compared with traditional contract types?
- How should the value be shared in flexible asset management contracts in order to reach win-win situations in maintenance collaboration?

Our contribution to the existing literature is expanding the traditional typology of maintenance contracts. We also discuss the benefits of contracts with flexible asset management services, and present how the value of the additional services of these contracts can be shared in favour of win-win situations. The value sharing of the actual maintenance work is not addressed.

The structure of the paper is as follows. After the introduction, Section 2 discusses the literature of maintenance contracts and flexible asset management. In Section 3, the research setting is presented. Next, a novel typology of maintenance contracts is introduced in Section 4. In Section 5, we address the matter of value sharing in flexible asset management contracts. Section 6 offers scenarios on flexible asset management contracts in case companies, and summarises how companies can exploit the link between maintenance contracts and flexible asset management. The article ends with conclusions.

2 Literature review

2.1 Maintenance contracts

The tightened competition and the emergence of outsourcings have caused many companies to increase collaboration with their customers and suppliers (Kroes and Ghosh, 2009; Yazici, 2012). Maintenance service-providing companies are looking for new types of contracts to improve their profitability and provide additional benefits for their customers (Martin, 1997). Wang (2010) states that service providers can pursue higher profits by sharing the customer's risks. We point out that previous literature considers mostly the perspective of the customer, while optimisation from the service provider's point of view is unusual. Previous research shows that inter-organisational information sharing improves the performance in supply chains (e.g. Fantazy et al., 2011; Magnan et al., 2011). Holmström et al. (2010) state that information sharing enables new forms of collaboration – for example customers may outsource the ownership of physical assets.

We introduce a new type of maintenance contracts, the flexible asset management contract. Essentially, the theoretical foundations of this paper are in the traditional agency theory (see e.g., Grossman and Hart, 1983; Hart and Holmström, 1987). However, we do not discuss the agency theory in detail in this paper. Instead, we focus on a more specific topic, contracts in the maintenance business. Accordingly, our reasoning is based on the explicit typology of maintenance contracts presented by Martin (1997). This widely cited typology includes three contract types: work package contracts, performance contracts, and facilitator contracts, also called lease contracts. In work package contracts, the service provider simply performs the tasks given by the customer. In performance contracts the service provider is typically also responsible for maintenance planning and organisation. The service company then agrees to provide the customer with a specific level of asset availability. Compared to work package contracts, performance contracts are more complex and require more trust between the contracting companies. The final contract type in Martin's typology, the lease contract, means that the service provider owns the assets to be maintained. Thus the customer pays for using the assets, and the service provider is tied to their ownership. From the perspective of flexible asset management, this means inherent inflexibility. For example, the main benefit of lease contracts is usually seen to be the chance of decreasing the risks of the customer (e.g., Pongpech et al., 2006), although this may happen at the expense of the service provider.

The viewpoint introduced for example by Teece (1988) assumes that each contracting party acts opportunistically. Of course, there is always a risk that opportunism incurs surprising losses for one or both of the companies (Vining and Globerman, 1999). As a solution, de Jong and Smit (2012) have introduced collaborative contracts, in which the objectives of the contracting companies are congruent. By implementing flexible asset management contracts, these ideal collaborative contracts can be made more approachable.

The liabilities in maintenance contracts have been discussed in previous literature. For example, the issue of who accounts for the success of maintenance in outsourcing situations has been studied (e.g., Hui and Tsang, 2006; Levery, 1998). Multiple research gaps can be found in the traditional contract typologies, however. This is also acknowledged by Ahonen et al. (2010), who claim that novel tools are needed to promote the increasing collaboration in maintenance service networks. This point, although on a

more general level, is also recognised by MacCarthy and Jayarathne (2012). Markeset and Kumar (2005) state that it has become more common for the service provider, not the customer, to own the physical assets. What remains quite unexplored, however, are the profitability impacts of the assets being included in the service provider's balance sheet. Panesar and Markeset (2008) state that the conditions of the customer-service provider relationship must encourage the service provider to improve the performance of the customer actively. In general, the existing maintenance contract types have not succeeded in doing that. Jackson and Pascual (2008) have introduced a model for maintenance service pricing, but models for sharing the value of the accessory flexible asset management services in maintenance contracts do not exist. This is where we contribute to the discussion.

2.2 Flexible asset management

Today, dynamism is an essential part of doing business. In order to remain profitable, companies should somehow adapt to different operating conditions (More and Babu, 2011). Raut et al. (2012) emphasise the role of strategic partnerships in controlling dynamism. One way of advancing this is flexible asset management (Gibson, 2000; Navarro, 2009), where the amount of assets in a company's balance sheet should follow the progression of changing demand. Considering a broader discussion, the importance of asset management for company profitability has been identified by several researchers (e.g., Aoudia et al., 2008; Lin et al., 2007; Tam and Price, 2008). Sawhney et al. (2009) point out that flexible asset management is also significant in striving for a lean business philosophy. Companies have also recognised the importance of flexible asset management: in an international survey conducted by the European Federation of National Maintenance Societies (2011), 67% of the respondents thought that the flexibility of production assets is either significant or very significant.

Previous literature has studied how to make fixed assets more flexible (e.g., Kärri, 2007). In fact, flexible asset management has traditionally mostly concerned fixed assets (Komonen, 2010) and long-term capital (Chiou et al., 2006). However, also current assets should be taken into account, for example by managing the company's operational working capital. This is defined as inventories plus accounts receivable less accounts payable. In the maintenance business, the main drivers of working capital are spare part stocks and payment terms. Ojanen et al. (2012) highlight the importance of working capital in flexible asset management. Working capital management can have a significant impact on both company profitability and liquidity (Protopappa-Sieke and Seifert, 2011; Talha et al., 2010). Grosse-Ruyken et al. (2011) and Randall and Farris (2009) emphasise the importance of managing working capital together with the supply chain partners. In inter-organisational maintenance collaboration, the role of working capital management is particularly important, as the amount of fixed assets is generally low in maintenance service companies (Marttonen et al., 2011, 2012). So far, working capital management has not been addressed very often in previous academic literature (Viskari et al., 2011).

In order to make the principles of flexible asset management more explicit, we present the flexible asset management model (the FAM-model) first introduced by Marttonen et al. (2012). The FAM-model combines aspects of asset management, profitability and financing. The model has been created through modifying the conventional formulas of the return on investment and the cost of capital. We use this model in our scenarios in Section 6. The FAM-model can be presented as:

$$ROI = \frac{EBITDA\% - \left(FA\% * \frac{1}{B-1} \right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%} = \frac{i_D * D + i_E * E}{D + E}, \quad (1)$$

where

ROI	is the company's return on investment
EBITDA%	is the proportion of the profit margin to the net sales
FA%	is the proportion of the fixed assets to the net sales
B	is the average depreciation time in years
CCC	is the cycle time of operational working capital in days
r	is the residual which consists of other current assets and other current liabilities
i_D	is the interest rate of company debt financing
i_E	is the company return on equity
D	is the amount of long-term debt in the company balance sheet
E	is the amount of equity in the company balance sheet.

The FAM-model perceives the ROI as a function of both fixed (*FA%*, *B*) and current asset management (*CCC*, *r*). In addition, from the perspective of the return on equity, the model can be presented as

$$i_E = \frac{EBITDA\% - \left(FA\% * \frac{1}{B-1} \right)}{\frac{CCC}{365} + \frac{r}{365} + FA\%} * \left(1 + \frac{D}{E} \right) - i_D * \frac{D}{E}. \quad (2)$$

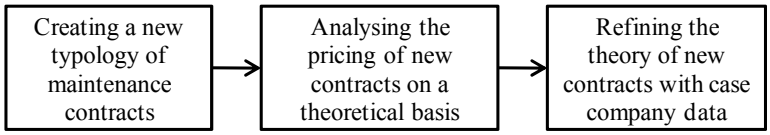
In equation (2) the principle of financial leverage is evident: by increasing the share of debt in its balance sheet, a company can improve its return on equity. Financial leverage, as well as the FAM-model, will be readdressed in the following sections.

3 Research setting

The new type of maintenance contracts, flexible asset management contracts introduced in this study are based on previous literature. We also address the logic for value sharing in these new contracts. It should be noted that the value sharing of the maintenance work itself is not discussed in this paper. Instead, we focus on sharing the value of the additional services of flexible asset management contracts. First, we introduce a theory of value sharing in the contracts, and then the theory is refined through a case study. Dubois and Araujo (2007) state that case research contributes extensively to the research of purchasing and supply management, and according to Yin (2009), case research contributes to situations where 'how' or 'why' questions are studied, and when a deep

understanding is needed of a certain phenomenon. These conditions are fulfilled in our research to a great extent. The research stages of the paper are presented in Figure 1.

Figure 1 The exploratory phasing of the paper



The case companies chosen for this study were Metsä Fibre Oy and Botnia Mill Service Oy. Metsä Fibre is a well-known Finnish producer of pulp. Botnia Mill Service, on the other hand, provides industrial maintenance services almost exclusively for Metsä Fibre. Botnia Mill Service has been founded from the internal maintenance department of Metsä Fibre, and it is also partially owned by its customer. This means that the collaboration between these two companies is close and long-term. Hence, it is particularly justified to study the introduction of a very collaborative contract type between these companies, compared to average customer-service provider relationships. In addition, Metsä Fibre represents the pulp industry, which is capital intensive. Asset management collaboration with a service company that carries a light balance sheet can be assumed to be fruitful.

The case companies were studied through their financial statement data. The financial statements of year 2010 were used, as data from more recent years was not available. Using data from just one year can be considered reasonable, as we show how the new maintenance contract type can have an impact on the current profitability of the case companies. In 2010, Metsä Fibre had a net sales of €1,365 M, and a balance sheet total of €996 M. In Botnia Mill Service, the net sales were €54 M and the balance sheet total €20 M. The data of the case companies was used to create two different scenarios, which illuminate the sharing of the value of the additional services related to the flexible asset management contracts.

4 Combining flexible asset management and maintenance contracts

Here we extend the typology of maintenance contracts by combining flexible asset management thinking with the typology of maintenance contracts presented by Martin (1997). We have incorporated some characteristics of flexible asset management thinking into the new contract type. These are:

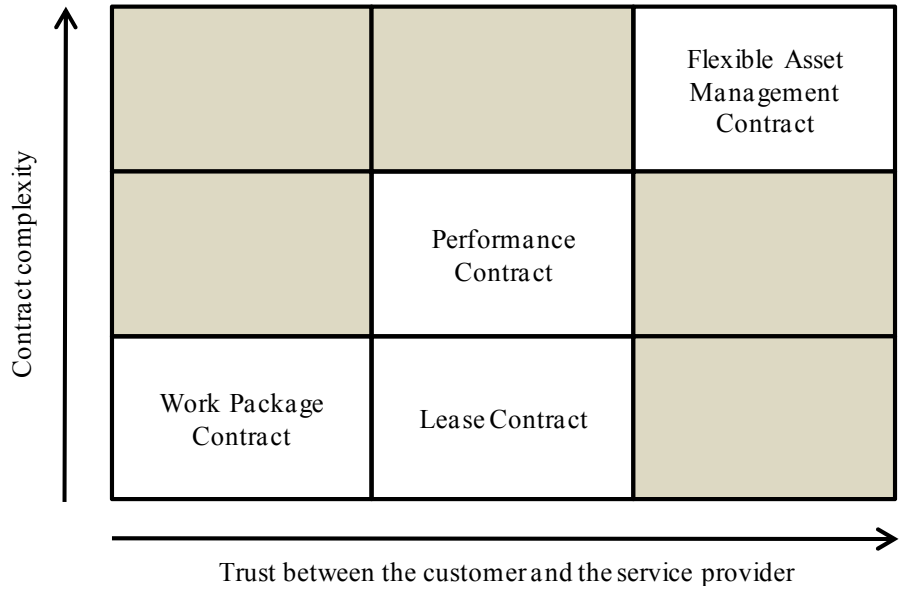
- ownership of the fixed assets that the contract concerns
- ownership of the spare part stocks related to the contract
- the impact of the payment terms on the profitability of the contract
- the impact of financial leverage on the profitability of the contract.

The first two points about the ownership of assets and spare parts have already been discussed in the literature in the connection of pursuance of lease contracts. However, lease contracts tend to determine the service provider as the owner of the assets and spare parts. In our typology we strive for more flexibility, and thus in flexible asset management contracts the ownership can also be shared between the customer and the

service provider. The third point concerns payment terms, which are present also in all traditional contract types. However, we would like to highlight the potential importance of the payment term decisions in the profitability of the contract. After all, operating with short payment times is a significant part of all lean business models. Finally, the impact of financial leverage should not be neglected when creating maintenance contracts. Gaining financial leverage can boost the profitability of the contract. For example, if a company chooses to carry additional assets in its balance sheet, financing these assets with debt can improve the company's return on equity.

The characteristics discussed above are the main features of flexible asset management contracts. The relation of the flexible asset management contract to the traditional contract types is presented in Figure 2. The dimensions used in Figure 2 are the amount of trust required from the customer-service provider relationship, and the complexity of the contract. Here we assume that the complexity of the contract type has a positive correlation with the costs incurred by creating and maintaining the contract.

Figure 2 The novel typology of maintenance contracts (see online version for colours)



An increase in the complexity of the contract type creates an increase in the potential benefits to be reached through the contract; in work package contracts the benefit is caused by the ability of the service provider to execute maintenance work tasks in a more cost-effective way, compared to the customer. In typical performance contracts the potential benefit is extended to include also the superior ability of the service provider to conduct maintenance planning and organising. In lease contracts the customer is usually released from the risk of owning the assets. However, we argue that the potential benefits of the lease contract are actually quite low. This is because the benefits can be great for the customer, but not so great for the service provider. In lease contracts the risks induced by the ownership of the assets are simply transferred from the customer to the service provider, which is not the optimal solution, at least from the point of view of maintenance collaboration.

In order to maximise the collaboration benefit and to create a win-win situation, the risks should be balanced between the partners in flexible asset management contracts. We can conclude that, compared to traditional maintenance contracts, flexible asset management contracts call for more trust between the contracting parties. In addition, due to different terms of ownership, they are more complex, and hence more costly than the other three contract types presented in Figure 2. On the other hand, also the potential benefits are higher in flexible asset management contracts than in other types of contracts. This new type of maintenance contracts can create additional value for both the customers and the service providers through additional services, like asset ownership. Before making profit, however, the value created by the contract has to be shared between the contracting partners.

5 Value sharing in flexible asset management contracts

Here we address sharing the value created by the additional flexible asset management services discussed in the previous sections. The first challenge in the value sharing of a flexible asset management contract is fixed asset ownership. In the FAM-model [equation (1)] it can be seen that the amount of fixed assets compared with the amount of company net sales (the *FA*%) has an impact on the *ROI*. Depending on the other parameters, as well as the initial level of the *FA*%, the change of the *ROI* caused by adjusting the *FA*% varies across companies. In order to share the value of the flexible asset management contracts, we need the variable $\Delta ROI_{FA\%}$, defined as

$$\Delta ROI_{FA\%} = ROI\left(FA\%_2\right) - ROI\left(FA\%_1\right), \tag{3}$$

where

$\Delta ROI_{FA\%}$ is the change of the *ROI* caused by an adjustment in the amount of fixed assets

$ROI(FA\%_2)$ is the *ROI* calculated with the adjusted *FA*%

$ROI(FA\%_1)$ is the *ROI* calculated with the initial *FA*%.

In order to examine the impact of the *FA*% on the profitability in monetary terms, we must take the amount of invested capital into account. In the *ROI*, this invested capital consists of long-term debt and equity. The monetary change implies how much the profits should change for the company to end up on the same level of the $ROI(FA\%_2)$, even though the amount of fixed assets remained unchanged.

When asset ownership is shifted from one company to another, it is possible that profitability decreases for the company that takes the asset into its balance sheet (company A), while profitability increases for the firm that gives up the asset (company B). In this situation, a fair value sharing calls for pricing this 'asset ownership service'. The price should be set somewhere between the losses of company A and the profits of company B. This way, both companies should gain from the arrangement. This logic of value sharing is presented in equation (4).

$$-\Delta ROI_A * \left(D_A + E_A\right) < p < \Delta ROI_B * \left(D_B + E_B\right), \tag{4}$$

where

p is the price charged by company A from company B for taking the ownership of the asset

ΔROI_A is the decrease of the ROI caused by the increased fixed assets in company A

ΔROI_B is the increase of the ROI caused by the decreased fixed assets in company B

D_A is the amount of long-term debt in company A

D_B is the amount of long-term debt in company B

E_A is the amount of equity in company A

E_B is the amount of equity in company B.

Depending on the context, the scale of the segment for an agreeable service price described by equation (4) can vary substantially. The larger the segment, the more untapped financial benefit is included in taking the asset ownership arrangements as a part of the maintenance contract. It is of course possible that an agreeable price does not exist, meaning that there is no value to be shared. This is the case when the decreased profits of company A are greater than the increased profits of company B, or when the profits decrease for both companies. When an agreeable service price cannot be detected, this service of asset ownership should be left out of the contract. It is also possible that both companies will reach an increase in their profitability through shifting assets from company B to company A. In this case the role of the service price is to share the profits between the two companies, using a logic which the companies have agreed on.

Now we move on to discuss value sharing of spare part stock ownership and payment term alterations. These two aspects can be addressed together, as they both impact on the cycle time of operational working capital, the *CCC*, in the FAM-model [equation (1)]. The logic of sharing the value remains the same as above in the discussion about asset ownership. Once again we start by defining the impact of the agreement on the company *ROI*:

$$\Delta ROI_{CCC} = ROI\left(CCC_2\right) - ROI\left(CCC_1\right), \tag{5}$$

where

ΔROI_{CCC} is the change of the *ROI* caused by an adjustment in the cycle time of operational working capital

$ROI(CCC_2)$ is the *ROI* calculated with the adjusted *CCC*

$ROI(CCC_1)$ is the *ROI* calculated with the initial *CCC*.

From this point on, the process of sharing the value is not unlike the process described for asset ownership agreements. Equation (4) is also suitable for pricing spare part stock ownership and payment term alterations. Again, the size of the segment for an agreeable service price determines the amount of potential financial benefits present in including the spare parts and payment terms in the maintenance contract.

Finally, we discuss using financial leverage to improve the profitability of a maintenance contract. In the previous paragraphs the profitability changes were analysed through the *ROI*. However, the impacts of the financial leverage are better to explicate through the return on equity, i_E. When a company accepts additional assets, spare part

stocks, or disadvantageous payment terms in its balance sheet, the financing of these items has to be organised. Presented simply, additional balance sheet items can be financed with either debt or equity financing. When deciding whether to use equity or debt, the impact of financial leverage on contract profitability should be studied.

For the sake of simplicity, this analysis focuses on the financial leverage of company A, the company that takes additional items to its balance sheet. The financial leverage of company B is left for further research, since adjusting the company financing would be more complicated when giving balance sheet items away. In order to include the impact of financial leverage in the logic of sharing value, we introduce variable Δi_{EA}:

$$\Delta i_{EA} = i_{EA2} - i_{EA1}, \tag{6}$$

where

Δi_{EA} is the change of the i_E caused by an adjustment in the capital structure of the company

i_{EA2} is the i_E calculated with the adjusted capital structure

i_{EA1} is the i_E calculated with the initial capital structure.

Equation (4) must now be altered to take the monetary impact of the financial leverage into account. This can be done by including the Δi_{EA} as well as the amount of equity in company A in the equation:

$$-\Delta ROI_A * (D_A + E_A) + \Delta i_{EA} * E_A < p < \Delta ROI_B * (D_B + E_B). \tag{7}$$

Equation (7) concludes our theoretical reasoning about sharing the value of additional flexible asset management services. Next we demonstrate the benefits of these contracts through a case study.

6 Findings of the case study

6.1 Scenarios on flexible asset management contracts

In this subsection, we illuminate how the case companies could benefit from adopting flexible asset management contracts. Figure 3 summarises the data collected from the financial statements of the case companies.

Figure 3 Case company data used in the scenarios

Metsä Fibre				**Botnia Mill Service**			
EBITDA%	33%			*EBITDA%*	10%		
FA%	42%			*FA%*	1%		
B	9 years	*ROI*	44%	*B*	2 years	*ROI*	52%
CCC	44 days			*CCC*	18 days		
r	30 days			*r*	45 days		
i_D	7%			i_D	0%		
D	178,677,000€	i_E	54%	*D*	2,689,000€	i_E	71%
E	671,042,000€			*E*	6,970,000€		

This subsection consists of two scenarios: a scenario of fixed assets and a scenario of working capital. The first scenario is about fixed asset ownership and financial leverage. Let us assume that Botnia Mill Service wishes to transfer a fixed, physical asset of €200,000 from its balance sheet to the ownership of Metsä Fibre. Thus, Botnia Mill Service represents company B discussed in the previous section, and Metsä Fibre stands for company A. Straight-line depreciations of ten years have been hypothesised. Table 1 shows the *ROI*-levels of the two companies before and after the fixed asset transfer, the following change in profitability, and the change in monetary terms. It can be concluded that transferring the fixed asset has profit potential: the profitability of Metsä Fibre would decrease with the extent equivalent to a drop of €1 M in profits. Botnia Mill Service, on the other hand, would increase its profitability with nearly €2 M. Thus, despite the initial losses of Metsä Fibre, there is enough value to be shared to reach a win-win situation. The net benefit is €899,294 (€1,938,492–€1,039,198).

Table 1 Scenario on shifting fixed asset ownership

	Metsä Fibre	*Botnia Mill Service*
$ROI(FA\%_1)$	44.02%	51.52%
$ROI(FA\%_2)$	43.89%	71.59%
$\Delta ROI_{FA\%}$	–0.12 percentage points	20.07 percentage points
$\Delta ROI_{FA\%} * (D + E)$	–€1,039,198	€1,938,492

Now we incorporate financial leverage to the simulation. Table 2 presents the return on equity of Metsä Fibre before and after the transfer of the fixed asset, as well as the change in both percentage points and monetary terms. The two columns show the situation when Metsä Fibre chooses to finance the asset with either debt or equity. It can be seen that the impact of financial leverage must not be neglected: in monetary terms the return on equity of Metsä Fibre would increase by over €70,000 when using debt financing. Due to the heavy balance sheet of Metsä Fibre, even a small modification in the Δi_E, expressed in percentage points, causes extensive changes in the $\Delta i_E * E$, expressed in monetary terms. It would definitely be advisable to finance the fixed asset with debt. Of course, this only holds when the profitability of Metsä Fibre is high enough to enable financial leverage instead of disadvantage.

Table 2 Financial leverage of Metsä Fibre in the fixed asset scenario

	Using debt financing	*Using equity financing*
i_{E1}	53.6896%	53.6896%
i_{E2}	53.7006%	53.6867%
Δi_E	0.011 percentage points	–0.003 percentage points
$\Delta i_E * E$	€73,585	€–19,587

Adding up Tables 1 and 2, the losses of Metsä Fibre would be €965,613 (€1,039,198–€73,585) after taking financial leverage into account. According to equation (3), this is also the lowest agreeable price to be set for this particular service of asset ownership. On the other hand, the increase in the profitability of Botnia Mill Service equals additional profits of €1,938,492. This is thus the highest agreeable price for the service. The net benefits to be shared between the contracting companies

equal the difference between the highest and the lowest agreeable price: €972,879 (€1,938,492–€965,613).

Our second scenario is about working capital management. It involves transferring spare part stocks from one company to another, adjusting payment terms, and using financial leverage in the process. We assume that the spare part stocks and payment terms are transferred in such a way that a sum of €3,300,000 is taken off from the balance sheet of Botnia Mill Service (company B), and added to the balance sheet of Metsä Fibre (company A). This would change the CCCs of the two companies, and thus also the profitability. Table 3 shows the results of the working capital scenario, concluding that the arrangement would result in a monetary loss of nearly €2,400,000 for Metsä Fibre, but a monetary benefit of almost €2,600,000 for Botnia Mill Service. This means that a win-win situation can be created through collaboration. The net benefit equals €212,740 (€2,581,943–€2,369,203).

Table 3 Scenario on working capital management

	Metsä Fibre	*Botnia Mill Service*
$ROI(CCC_1)$	44.02%	51.52%
$ROI(CCC_2)$	43.74%	78.25%
ΔROI_{CCC}	–0.28 percentage points	26.73 percentage points
$\Delta ROI_{CCC} * (D + E)$	–€2,369,203	€2,581,943

In Table 4, the impact of financial leverage of Metsä Fibre on the contract profitability is presented. The benefit of using debt financing is over €1,200,000 for Metsä Fibre, which thus improves the profitability of the arrangement substantially. Again, using debt instead of equity is highly advisable.

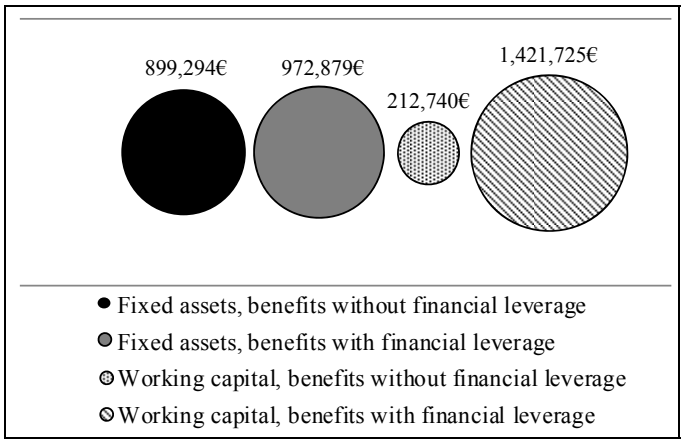
Table 4 Financial leverage of Metsä Fibre in the working capital scenario

	Using debt financing	*Using equity financing*
i_{E1}	53.49%	53.49%
i_{E2}	53.67%	53.44%
Δi_E	0.18 percentage points	–0.05 percentage points
$\Delta i_E * E$	€1,208,985	–€320,339

After including the impact of financial leverage into the analysis, the losses of Metsä Fibre, expressed in monetary terms, are €1,160,218 (€2,369,203–€1,208,985). According to our logic of value sharing, this is the minimum price to be set for this particular service of owning spare part stocks and adopting the altered payment terms. The benefits for Botnia Mill Service are €2,581,943, which is also the maximum price for this additional service. The net benefits created through this kind of collaboration equal €1,421,725 (€2,581,943–€1,160,218).

Our scenarios are concluded with Figure 4, in which the net benefits are presented for each of the two scenarios before and after taking the impact of financial leverage into account.

Figure 4 Comparing the benefits of the two scenarios of flexible asset management services



When the impact of financial leverage is taken into account, the working capital management scenario seems more preferable for our case companies. However, the amount of capital to be shifted between the companies has been presumed to be €200,000 in the fixed asset scenario, and €3,300,000 in the working capital management scenario. Thus the large amount of capital has increased the role of financial leverage in the working capital scenario. It can be seen in Figure 4 that the benefits of the working capital scenario are moderate without the financial leverage, compared with the fixed asset scenario. In fact, if the working capital scenario was conducted with the same amount of capital transferred between the companies than in the fixed asset scenario (€200,000), an agreeable price would not be found at all. Thus, the value of this scenario depends on the large amount of capital to be transferred, which of course increases the risks of the contract.

The fixed asset scenario, on the other hand, shows that including flexible management of fixed assets into the contract can create value even when the amount of capital to be transferred is quite small. The proportional impact of financial leverage is minor.

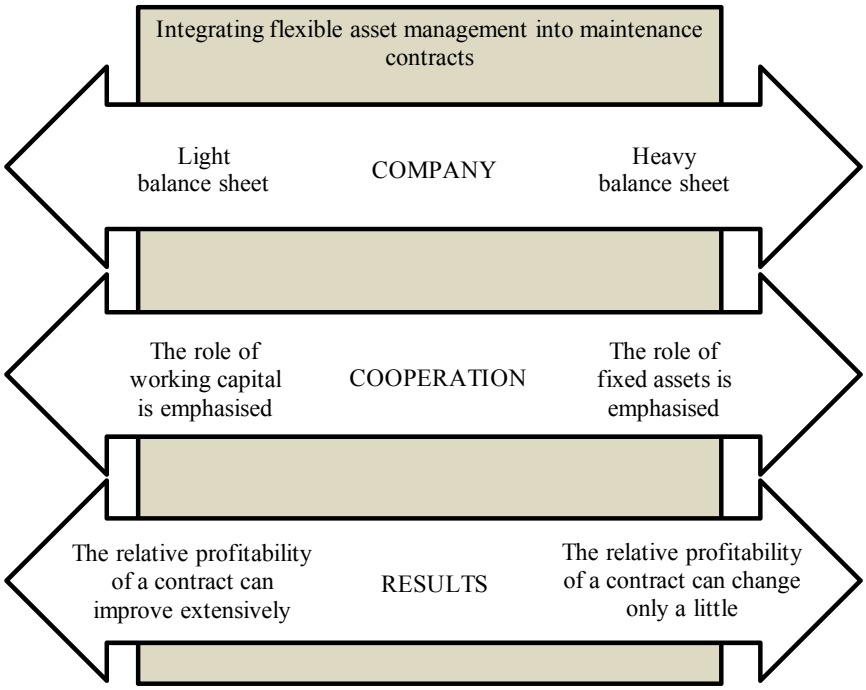
6.2 Exploiting flexible asset management contracts

The lessons learned from the case study are summarised next. Now it is time to examine how different companies can profit from a link between maintenance contracts and flexible asset management. Figure 5 shows a framework of how companies with a light or heavy balance sheet should create asset management collaboration to maximise their relative profitability.

Maintenance service buyers usually carry heavy assets, compared with service providing companies. A specific monetary sum affects the relative profitability of these companies differently. As a result, transferring assets from the balance sheet of a service provider to the balance sheet of a customer creates a lot of additional value. On the other hand, transferring assets from a customer to the light balance sheet of a service provider often destroys value instead of creating it. It would thus be crucial for customer companies to be open-minded to extensive collaboration, instead of just advancing their own benefit in the short term. As we have shown, win-win situations can emerge from

applying flexible asset management contracts, despite the ostensible losses incurred for the maintenance customer.

Figure 5 Framework of how different companies should exploit flexible asset management in their maintenance contracts to gain value (see online version for colours)



In general, the amount of fixed assets influences the relative profitability more than the amount of working capital. Thus, flexible management of fixed assets should be a priority. However, it needs to be noted that working capital management should not be neglected. Its influence on profitability depends on multiple parameters of a company. The role of working capital is emphasised in companies which carry light fixed assets, for example in many service providing companies.

Companies carrying heavy balance sheets need extensive transfers in order to alter their relative profitability either through an actual contract or financial leverage. High-value transfers increase the risks of the contract, and decrease its attractiveness. The impact of these increased risks on the contract profitability should be measured, but this issue is here left for further research.

7 Conclusions

We have contributed to the literature by introducing a new maintenance contract type, flexible asset management contracts. Compared to traditional contract types, these contracts have higher potential benefits, and a better potential to create win-win situations. It would be important for maintenance service providers and their customers to

utilise these contracts: maintenance collaboration is developing rapidly, but so far the decision makers have lacked tools to manage non-traditional forms of collaboration.

Through proper pricing, flexible asset management contracts can create significant financial benefits for both contracting parties. These contracts consider not just the perspective of customer companies, but also that of service providers. This is quite exceptional, as previous literature has mostly focused on the customer's viewpoint. Instead of analysing the maintenance work itself, we have concentrated on the value sharing of the little studied issues of fixed asset and spare part ownership.

We have learned that compared to working capital management, fixed asset management has a greater impact on profitability. Thus, the first step for company managers is to analyse how much value could be created by transferring fixed assets to and from their balance sheets. After that, value creation through working capital management should be addressed.

Our first research limitation is about using financial statement data and creating fictitious scenarios. Not many companies are ready to unveil their experiences with highly collaborative contracts. Thus researching these contracts with authentic case data must be left for further research at the moment. We have also studied the contracts with only one pair of case companies. This was justified, as including more companies would have exceeded the scope of the article. Nevertheless, it is important to conduct future research on contracts with a more extensive group of companies. This way, the necessity of the contracts can be truly examined. The final research limitation concerns the scope of this article. Some essential issues were left for further research to keep the scope suitable. These issues include studying the financial leverage of the company extracting an asset from its balance sheet. We suggest that future research should include applying flexible asset management contracts with more than two contracting parties. The maintenance collaboration of today can involve three or more companies, which complicates the logic of value sharing to some extent. Also the higher risks and costs of creating and maintaining flexible asset management contracts, compared with traditional contract types, should be studied further. This way the profitability of these contracts can be estimated more precisely. We emphasise that to prosper in the future, companies should actively search for novel ways of collaborating with their partners.

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References

Ahonen, T., Reunanen, M., Pajari, O., Ojanen, V. and Lanne, M. (2010) 'Maintenance communities – a new model for the networked delivery of maintenance services', *International Journal of Business Innovation and Research*, Vol. 4, No. 6, pp.560–583.

Aoudia, M., Belmokhtar, O. and Zwingelstein, G. (2008) 'Economic impact of maintenance management ineffectiveness of an oil and gas company', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 3, pp.237–261.

Chiou, J., Cheng, L. and Wu, H. (2006) 'The determinants of working capital', *The Journal of American Academy of Business*, Vol. 1, No. 10, pp.149–155.

de Jong, A. and Smit, K. (2012) 'Collaborative contracts for inter-organisational quality systems', *Journal of Quality in Maintenance Engineering*, Vol. 18, No. 2, pp.171–182.

Dubois, A. and Araujo, L. (2007) 'Case research in purchasing and supply management: opportunities and challenges', *Journal of Purchasing & Supply Management*, Vol. 13, No. 3, pp.170–181.

European Federation of National Maintenance Societies (2011) *Intermediate Results of the Asset Management Survey for All National Maintenance Societies* [online] http://e-lomake.fi/raportti/efnms_2011_survey (accessed 18 July 2012).

Fantazy, K.A., Kumar, V. and Kumar, U. (2011) 'The impact of information sharing on supply chain performance: an empirical study', *International Journal of Procurement Management*, Vol. 4, No. 3, pp.274–296.

Gibson, V. (2000) 'Property portfolio dynamics: the flexible management of inflexible assets', *Facilities*, Vol. 18, No. 3, pp.150–154.

Grosse-Ruyken, P.T., Wagner, S. and Jönke, R. (2011) 'What is the right cash conversion cycle for your supply chain?', *International Journal of Services and Operations Management*, Vol. 10, No. 1, pp.13–29.

Grossman, S. and Hart, O. (1983) 'An analysis of the principal-agent problem', *Econometrica*, Vol. 51, No. 1, pp.7–45.

Hart, O. and Holmström, B. (1987) 'The theory of contracts. Part I', in Bewley, T. (Ed.): *Advances in Economic Theory, Fifth World Congress*, pp.71–155, Cambridge University Press, Cambridge.

Holmström, J., Brax, S. and Ala-Risku, T. (2010) 'Comparing provider-customer constellations of visibility-based service', *Journal of Service Management*, Vol. 21, No. 5, pp.675–692.

Hui, E. and Tsang, A. (2006) 'The inter-organizational relationship in a multi-contractor business network', *Journal of Quality in Maintenance Engineering*, Vol. 12, No. 3, pp.252–266.

Jackson, C. and Pascual, R. (2008) 'Optimal maintenance service contract negotiation with aging equipment', *European Journal of Operational Research*, Vol. 189, No. 2, pp.387–398.

Kärri, T. (2007) *Timing of Capacity Change: Models for Capital Intensive Industry*, Dissertation for the degree of Doctor of Science (Tech.), Lappeenranta University of Technology, Lappeenranta, Finland.

Komonen, K. (2010) 'Asset management in the industrial sector: background and conceptual approach', *Maintworld*, Vol. 2, No. 1, pp.16–19.

Kroes, J. and Ghosh, S. (2009) 'A framework and scale development for assessing supply chain outsourcing alignment with competitive priorities', *International Journal of Procurement Management*, Vol. 2, No. 1, pp.1–24.

Levery, M. (1998) 'Outsourcing maintenance – a question of strategy', *Engineering Management Journal*, Vol. 8, No. 1, pp.34–40.

Lin, S., Jing, G., Koronios, A. and Chanana, V. (2007) 'Developing a data quality framework for asset management in engineering organisations', *International Journal of Information Quality*, Vol. 1, No. 1, pp.100–126.

MacCarthy, B.L. and Jayarathne, P.G.S.A. (2012) 'Sustainable collaborative supply networks in the international clothing industry: a comparative analysis of two retailers', *Production Planning & Control*, Vol. 23, No. 4, pp.252–268.

Magnan, G.M., Fawcett, A.M. and Fawcett, S.E. (2011) 'Supply chain success: key initiatives differentiating high- and low-performing firms', *International Journal of Procurement Management*, Vol. 4, No. 2, pp.181–202.

Markeset, T. and Kumar, U. (2005) 'Product support strategy: conventional versus functional products', *Journal of Quality in Maintenance Engineering*, Vol. 11, No. 1, pp.53–67.

Martin, H.H. (1997) 'Contracting out maintenance and a plan for future research', *Journal of Quality in Maintenance Engineering*, Vol. 3, No. 2, pp.81–90.

Marttonen, S., Viskari, S. and Kärri, T. (2011) 'Modeling the impact of working capital management on the profitability in industrial maintenance business', Paper presented at the *6th Annual World Congress on Engineering Asset Management (WCEAM)*, 2–5 October 2011, Cincinnati, USA.

Marttonen, S., Viskari, S. and Kärri, T. (2012) 'Connecting the managerial and owner's view of flexible asset management in industrial maintenance companies', Paper presented at the *17th International Working Seminar on Production Economics*, 20–24 February 2012, Innsbruck, Austria.

More, D. and Babu, A.S. (2011) 'Managing supply chain flexibility using an integrated approach of classifying, structuring and impact assessment', *International Journal of Services and Operations Management*, Vol. 8, No. 1, pp.46–75.

Navarro, P. (2009) 'Recession-proofing your organization', *MIT Sloan Management Review*, Vol. 50, No. 3, pp.45–51.

Ojanen, V., Hatinen, L., Kärri, T., Kässi, T. and Tuominen, M. (2012) 'Flexible investment planning and collaborative maintenance management', in Van der Lei, T. et al. (Eds.): *The State of the Art in Europe from a Life Cycle Perspective*, pp.65–77, Springer, Dordrecht.

Panesar, S.S. and Markeset, T. (2008) 'Industrial service innovation through improved contractual relationship', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 3, pp.290–305.

Pongpech, J., Murthy, D.N.P. and Boondiskulchock, R. (2006) 'Maintenance strategies for used equipment under lease', *Journal of Quality in Maintenance Engineering*, Vol. 12, No. 1, pp.52–67.

Protopappa-Sieke, M. and Seifert, R. (2011) 'Interrelating operational and financial performance measurements in a multiproduct inventory system', *International Journal of Services and Operations Management*, Vol. 10, No. 3, pp.328–347.

Randall, W.S. and Farris II, M.T. (2009) 'Supply chain financing: using cash-to-cash variables to strengthen the supply chain', *International Journal of Physical Distribution and Logistics Management*, Vol. 39, No. 8, pp.669–689.

Raut, R.D., Bhasin, H.V. and Kamble, S.S. (2012) 'Analysing the effect of uncertain environmental factors on supplier-buyer strategic partnership (SBSP) by using structural equation model (SEM)', *International Journal of Procurement Management*, Vol. 5, No. 2, pp.202–228.

Sawhney, R., Kannan, S. and Li, X. (2009) 'Developing a value stream map to evaluate breakdown maintenance operations', *International Journal of Industrial and Systems Engineering*, Vol. 4, No. 3, pp.229–240.

Talha, M., Christopher, S.B. and Kamalavalli, A.L. (2010) 'Sensitivity of profitability to working capital management: a study of Indian corporate hospitals', *International Journal of Managerial and Financial Accounting*, Vol. 2, No. 3, pp.213–227.

Tam, A. and Price, J. (2008) 'A maintenance prioritization approach to maximise return on investment subject to time and budget constraints', *Journal of Quality in Maintenance Engineering*, Vol. 14, No. 3, pp.272–289.

Teece, D.J. (1988) 'Capturing value from technological innovation: integration, strategic partnering, and licensing decisions', *Interfaces*, Vol. 18, No. 3, pp.46–61.

Vining, A. and Globerman, S. (1999) 'A conceptual framework for understanding the outsourcing decision', *European Management Journal*, Vol. 17, No. 6, pp.645–654.

Viskari, S., Lukkari, E. and Kärri, T. (2011) 'State of working capital management research: bibliometric study', *Middle Eastern Finance and Economics*, Vol. 5, No. 14, pp.99–108.

Wang, W. (2010) 'A model for maintenance service contract design, negotiation and optimization', *European Journal of Operational Research*, Vol. 201, No. 1, pp.239–246.

Yazici, H. (2012) 'Buyer perceptions on the buyer-supplier collaborative relationship and performance: a service example', *International Journal of Services and Operations Management*, Vol. 12, No. 2, pp.165–187.

Yin, R.K. (2009) *Case Study Research – Design and Methods*, 4th ed., Sage Publications, Thousand Oaks.

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