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Simultaneous investment, operations, and financial planning in supply chains: A value-based optimization approach

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ABSTRACT

Asset utilization is a major mid-term lever to increase shareholder value creation. Since rough-cut planning of capacity (dis-)investments is performed at the long-term level, detailed timing of adjustments remains for the mid-term level. In combination with capacity control measures, capacity adjustment timing can be used to optimize asset utilization. This paper provides a corresponding framework for value-based performance and risk optimization in supply chains covering investment, operations, and financial planning simultaneously. We illustrate the benefits of the approach using a case-oriented example, and highlight the value of using flexible capacity options and postponing of capacity-related decisions in an uncertain environment.

1. Introduction

Since creating shareholder value is commonly considered the paramount business goal (Young and O'Byrne, 2001), frameworks for value-based management (VBM) are also discussed within the supply chain context (Walters, 1999; Lambert and Pohlen, 2001). Top-level performance metrics such as discounted Free Cash Flow (FCF) or Economic Value Added (EVA) and corresponding value driver trees to drill down the performance metric into operational levers are prevalent concepts of VBM (Rappaport, 1998). Risk implications are typically considered indirectly via risk-adjusted cost of capital (Kaplan and Atkinson, 1998). In contrast to the aforementioned explanatory frameworks, Lainez et al. (2009) and Hahn and Kuhn (2011b) provide model-driven approaches to value-based performance and risk management in supply chains. Whilst Lainez et al. (2009) focus on the long-term level of strategic network design for a planning period of 2–10 years, Hahn and Kuhn (2011b) cover the mid-term level of sales and operations planning with a planning period of 6–18 months (Fleischmann et al., 2008).

At the mid-term level, asset utilization is one of the major value drivers from a value-based planning perspective besides operating profit margin and operational cash flow (Walters, 1999). *Capacity (dis-)investments* in technical equipment and *capacity control* measures modifying supply and/or demand represent the two levers to manage asset utilization (Olhager et al., 2001; Buxey, 2003). Hahn and Kuhn (2011b) only focus on capacity control measures, and do not consider capacity (dis-)investments. Capacity adjustments can create additional value, but involve considerable risk potential due to costs of overcapacity or lost sales as well as physical degradation and depreciation (van Mieghem, 2003). Moreover, physical (dis-)investment decisions are inextricably interlinked with the corresponding financial decisions (Shapiro, 2007) and their impact on liquidity as well as overall value creation. An integrated approach to simultaneous investment, operations, and financial planning is therefore required that considers value-based implications.

Capacity adjustments and equipment replacement typically involve a planning period of several years depending on the average useful life of the machine, and NPV-based approaches are thus utilized to evaluate the investment decision (Luss, 1982). Corresponding decisions are considered together with decisions on facility locations at the long-term level of strategic network design (Goetschalckx and Fleischmann, 2008). However, decision models for strategic network design only provide support on *sizing* and *rough-cut timing* of capacity (dis-)investments due to their long-term perspective and aggregated (semi-)annual time buckets (Fleischmann et al., 2008). *Detailed timing* of capacity adjustments and equipment replacement remains for the mid-term level. Consequently, an integrated approach to capacity (dis-)investment timing and capacity control as part of sales and operations planning (S&OP) is required to manage asset utilization comprehensively. A corresponding unified framework has not yet been discussed, especially with respect to robust and risk-mitigating strategies in capacity (dis-)investment planning.

The aim of this paper is to develop a decision support framework for mid-term investment, operations, and financial planning in supply chains utilizing an integrated approach to value-based

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performance and risk optimization. We extend the paper of Hahn and Kuhn (2011b) to develop a comprehensive approach to capacity management taking into account related (dis-)investment and financing decisions from a value-based perspective. The remainder of this paper is structured as follows: Section 2 provides a literature review on the domains relevant for this research. In Sections 3 and 4, we outline the conceptual approach and describe a corresponding decision model. Section 5 highlights implications of the approach using a case-oriented example. We conclude the paper in Section 6 with a summary of the findings and an outlook for further research.

2. Literature review

Following the outline of the article, the literature review covers four domains relevant for the problem in focus: (i) value-based performance and risk optimization, (ii) integrated capacity (dis-)investment and financial planning, (iii) integrated capacity and operations planning in supply chains, and (iv) robust capacity planning under uncertainty.

Value-based performance and risk optimization. Concepts and metrics for supply chain performance management are widely discussed in the pertinent literature (Kleijnen and Smits, 2004; Gunasekaran et al., 2004; Cai et al., 2009). Corresponding frameworks such as the Supply Chain Operations Reference (SCOR) model have been genuinely developed for supply chain management (Supply Chain Council, 2010) or are adapted from general management literature such as the balanced scorecard and activity-based costing (Liberatore and Miller, 1998). However, the aforementioned frameworks have two major drawbacks from a decision support perspective (Cai et al., 2009): first, they cover a multitude of different metrics, but do not propose a paramount performance metric; second, they omit interdependencies and trade-offs between the metrics, and do not provide insight into cause-and-effect relationships. For example, the SCOR model covers five coequal but non-comprehensive as well as interdependent and partially conflicting top-level financial metrics. In contrast, value-based approaches apply one paramount and comprehensive performance metric (Young and O'Byrne, 2001) that can be used to consistently manage all (dis-)investment, operations, and financial decisions for value creation.

Value-based approaches in supply chain management have received increasing attention since the early work of Christopher and Ryals (1999) investigating supply chain strategy and its impact on shareholder value creation. Walters (1999) and Lambert and Pohlen (2001) develop EVA-based value driver trees to relate operational supply chain performance levers to overall value creation. In contrast to these explanatory frameworks, model-driven approaches to value-based performance and risk management in supply chains are provided in Lainez et al. (2009) and Hahn and Kuhn (2011b). Lainez et al. (2009) focus on the long-term level of strategic investment and financial management, optimizing shareholder value according to the discounted Free Cash Flow method. Option contracts are utilized to manage risk in supplier–customer relationships. Hahn and Kuhn (2011b) cover mid-term sales, operations, and working capital management and implement an EVA-based objective function. A direct approach to risk management is applied using downside risk-based metrics and scenario-based robust optimization methods. However, they do not consider aspects of capacity (dis-)investment timing to bridge the gap between the long-term and mid-term planning levels.

Integrated capacity (dis-)investment and financial planning. In an early paper, Luss (1982) provides a comprehensive literature survey on decision models for capacity expansion and equipment replacement. Recent literature reviews in this field covering a broad range of industries and different methodological approaches can be found in van Mieghem (2003), Wu et al. (2005), and Julka et al. (2007). More qualitative approaches to investment decision-making are described in Pirttilä and Sandström (1995), Olhager et al. (2001), and Ojala and Hallikas (2006). Pirttilä and Sandström (1995) integrate the capital budgeting process of a company with manufacturing strategy to comprehensively manage a portfolio of individual investment decisions. Olhager et al. (2001) provide a framework for long-term capacity (dis-)investment management linking manufacturing strategy and S&OP. Ojala and Hallikas (2006) investigate investment decisions under uncertainty and risk in buyer-dominating supplier networks. However, implications for integrated capacity (dis-)investment and financial management have not been discussed so far.

Capacity (dis-)investment planning covers four major decision problems: location, technology, sizing, and timing (Luss, 1982). Although capacity reductions involve the same considerations as capacity expansions (Olhager et al., 2001), disinvestment decisions are only covered marginally in respective models (Luss, 1982). Location, size, and timing of capacity expansions/reductions are typically included in decision models for strategic network design (Goetschalckx and Fleischmann, 2008). Aspects of technology selection and equipment replacement are covered separately from capacity adjustment planning (Li and Tirupati, 1994; Rajagopalan, 1998). However, considerations with respect to economies of scale and optimal operating value require an integrated approach (van Mieghem, 2003). Moreover, financial implications regarding accounting policies, capital budgeting, and costs of invested capital need to be considered (Julka et al., 2007). Majumdar and Chattopadhyay (1999) and Lavaja et al. (2006) develop decision models for integrated capacity (dis-)investment and financial planning in power systems as well as supply chains in the process industry. However, aspects of integrated capacity adjustment and financial planning at the mid-term level are not covered due to the long-term perspective.

Integrated capacity (dis-)investment and operations planning. Bradley and Arntzen (1999) and Rajagopalan and Swaminathan (2001) investigate integrated mid-term production and capacity expansion planning to analyze the trade-off between capacity and inventories for different demand patterns. Bradley and Arntzen (1999) implement EVA as a value-based performance metric and examine two case studies with seasonal demand patterns. However, they omit financial flows and their impact on economic value creation. Rajagopalan and Swaminathan (2001) analyze discrete capacity acquisitions in an environment with gradual demand growth resulting in excess capacity in the period subsequent to the investment. Bhutta et al. (2003) and Hsu and Li (2009) investigate integrated capacity and supply chain operations planning at the long-term level. Bhutta et al. (2003) consider a multi-national company and analyze exogenous factors such as exchange and tariff rates. Hsu and Li (2009) examine an example from the semiconductor industry and investigate optimal supply chain network design incorporating economies of scale. A unified approach for capacity adjustment and supply chain operations planning at a mid-term level covering both capacity adjustment and equipment replacement has not yet been discussed.

Robust capacity planning under uncertainty. A variety of papers discuss decision models for capacity planning under uncertainty. Eppen et al. (1989) and Paraskevopoulos et al. (1991) consider different levels of risk aversion and evaluate sensitivities to implement more robust solutions. Bok et al. (1998) and Aghezzaf (2005) present robust optimization approaches for capacity expansion and facility location planning in supply chains based on the robustness concepts of Mulvey et al. (1995). Barbaro