CR²M - An Approach for Capacity Control Considering Longterm Effects on the Value of a Customer for the Company

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Europäische Union
„Investition in Ihre Zukunft“
Europäischer Fonds für
regionale Entwicklung

in: Journal of Management Control 2 (2011) 22, p.187-204

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Abstract

In the last years, customer centricity has turned out to be a promising paradigm for maximizing corporate value by increasing value contributions from customers. In this context, the discipline of revenue management provides plenty of methods to optimize (predominantly short-term) cash-inflows from customers. However, the paradigm of a value-oriented management requires the integration of perspectives from revenue management and customer relationship management: When controlling scarce, inflexible capacity, the effects of the acceptance or denial of a customer request on the value of a customer for the enterprise have to be considered. Hence, this paper proposes a model for a customer lifetime value-oriented capacity control by allocating scarce resources to products for different customer segments combining methods from both revenue management and customer relationship management – termed CR^{2}M. The model presented in this paper at the same time allows a transparent calculation of opportunity costs caused by a short-term oriented control mechanism. In order to illustrate the applicability of the model, a company of the semiconductor industry serves as example.

Keywords

customer relationship management, customer value-oriented capacity control, revenue management, linear programming

1 Introduction

For a long time, most companies followed the paradigm of maximizing shareholder value by a short-term optimization of their operating profits and stock prices (Brealey et al. 2007; Keown et al. 2008). However, not only the financial crisis made obvious that such a short-term oriented strategy can destroy shareholder value: Empirical analyses show that companies pursuing a short-term strategy provide inferior results for the shareholders than companies that apply a long-term, customer-oriented strategy which puts the customer in the center of corporate strategy (Martin 2010). Thus, an evolution of the marketing paradigm from product and transaction centricity to customer relationship centricity has started several years ago. Customer centricity thereby marks the central point of the concept of customer relationship management (CRM). Its modern interpretation, the value-based CRM, pursues the goal “to build and manage a portfolio of customer relationships that maximizes corporate value“ (Gneiser 2010). In this context, the concept of customer lifetime value (CLV) often serves as assessment criterion in science and practice. The CLV is defined as a customer’s financial contribution to the value of a company (Heidemann et al. 2009). As many companies already have optimized their cash-outflows by cost cutting programs, customers’ cash-inflows are extremely relevant to attain a higher corporate value. Revenue management (RM) offers plenty of methods to optimize these revenues and cash-inflows, respectively (cf. Cross 1997; Klein and Steinhardt 2008; Talluri and van Ryzin 2005). However, these methods do not adequately consider the impact on the long-term value of a customer for the company (e.g., defection of a customer due to the denial of a request). Thus, in terms of a value-based management, suboptimal results may be the consequence. Accordingly, many scientists postulate an integration of RM and CRM (cf. Belobaba 2002; Dickinson 2001; Esse 2003; Hendler and Hendler 2004; Jonas 2001; Liebermann 2002; Metters et al. 2008; Noone et al. 2003; Shoemaker 2003). Nevertheless, to the best of our knowledge, up to now there is only one approach in RM considering both a customer and long-term oriented concept like the CLV (von Martens 2009; von Martens and Hilbert 2011). However, this approach is only applicable for a lost-for-good situation.

Thus, in this paper, we propose a new approach termed CR²M which constitutes a first step towards an integration of CRM and RM in more general situations. Thereby, capacity control as the most important component of RM is in the center of our discussion. Initially, methods for capacity control have been developed in the airline industry for controlling ticket sales by allocating contingents of capacity to the corresponding products offered. Nowadays, they are also applied for controlling sales processes in industries like make-to-order manufacturing or the process industry (Barut and Sridharan 2005; Defregger and Kuhn 2007; Hintsches et al. 2010; Kolisch and Zatta 2009; Spengler and Rehkopf 2005). In the model presented in this paper, the decision about the contingents of products for different customer segments is based on a traditional RM method which is enriched by the consideration of the long-term effects of the denial or acceptance of customers’ requests on the CLV. Furthermore, the model offers the flexibility to account for a company’s preferences according to its needs (e.g., solvency) by using individual weights.

The paper is structured as follows: In Section 2 we give an overview of the relevant literature in CRM and RM. In Section 3 – after specifying the background and assumptions of the model – we present the capacity control model combining aspects of RM and CRM. Subsequently, we discuss the model and identify questions for further research. Then, the model is applied to the case of a company from the semiconductor industry and the results of this application are discussed in Section 4. In Section 5, the paper ends with a conclusion.

2 Related literature in CRM and RM

Nowadays, customer relationships and the resulting value contributions are seen as central points in order to increase the value of a company and in the long run the shareholder value (Martin 2010). In the context of the evolution from a transaction-oriented to a customer-oriented thinking, customers meanwhile are seen as central assets of a company (Hogan et al. 2002; Kumar et al. 2004). Linked to this, the importance of CRM, which aims at managing customer relationships in a more efficient way, has increased since the 1990s (Ling and Yen 2001; Xu et al. 2002; Ngai 2005). In the context of value-based management, Gneiser (2010) presented the concept of value-based CRM. Value-based CRM aims to “build and manage a portfolio of customer relationships that maximizes corporate value” (Gneiser 2010). In value-based CRM, the value of a customer for the company is a central criterion when evaluating possible actions (Mengen and Mettler 2008, p. 30). This value of a customer, which is often operationalized by the CLV, measures the financial contribution of a customer in the course of his or her relationship with the company (Heidemann et al. 2009). The CLV can be calculated as the sum of the net present values of all estimated cash-flows from customers during the periods of their relationship with the company (Dwyer 1997, p. 7; Heiligenthal and Skiera 2007, p. 118). For calculating the CLV or respectively the customer equity which is defined as the sum of the CLV of all current and future customers (Blattberg and Deighton 1996; Rust et al. 2004), there are manifold approaches based, e.g., on financial concepts like the net present value (cf. Dwyer 1997; Berger and Nasr 1998; Blattberg et al. 2001), markov chains (cf. Morrison et al. 1982; Pfeifer and Carraway 2000; Ching et al. 2004) or option price models (for an overview cf. Kumar and George 2007). Meanwhile some models exist where the CLV or the customer equity are used as a criterion for decisions about customer-oriented actions (for an overview cf. Heidemann et al. 2009). Examples include determining the optimal customer portfolio in terms of strategic management of the target group (Buhl and Heinrich 2008), the allocation of (marketing) budget on new and existing customers (cf. Bitran and Mondschein 1996; Berger and Nasr-Bechwati 2001; Blattberg and Deighton 1996; Blattberg et al. 2001; Heiligenthal and Skiera 2007; Krafft and Albers 2000; Thomas et al. 2004), models for decision making regarding the instruments for handling the market (cf. Tirenni et al. 2007), but also the planning of investments in customer relationships (cf. Buhl et al. 2010). A classification of customers according to their CLV often builds the basis for such value-based investment decisions (Heidemann et al. 2009). To realize a better differentiation regarding customer segments with different value contributions, sociodemographic characteristics or behavioral patterns are often integrated into the process of segmentation.

While value-based CRM pursues the increase of a company's value by managing customer relationships on a long-term basis, RM rather provides methods for the management of short-term sales processes such that revenues are maximized. For industries that are characterized by selling a fixed capacity of perishable resources, RM offers a wide set of approaches for pricing and capacity control. With capacity control being the core of RM, the corresponding methods dynamically control the availability of a set of products, which are sold for a pre-determined price to different customer segments (Boyd and Bilegan 2003). By the way of contrast, dynamic pricing does not rely on the explicit definition of different products because the allocation of the available capacity is controlled by price adjustments only (Gönsch et al. 2009). Besides overbooking and the forecasting and modeling of customer demand, RM methods cover concepts for pricing and capacity control in either a single leg or a network scenario (for an overview see Boyd and Bilegan 2003; McGill and van Ryzin 1999). In the single leg case, only one resource is considered (e.g., a direct flight) whereas network problems allow products to access multiple resources (e.g., two or more connecting flights across a network).

While RM initially originates from the airline industry, by now, RM applications have found their way into other industries such as hotels and hospitality (Anderson and Xie 2010), the (car) rental industry (e.g., Geraghty and Johnson 1997; Savin et al. 2005), cargo services (e.g., Billings et al. 2003; Bartodziej et al. 2007), media (e.g., Kimms and Müller-Bungart 2007), or the manufacturing and process industry (e.g., Barut and Sridharan 2005; Defregger and Kuhn 2007; Hintsches et al. 2010; Kolisch and Zatta 2009; Spengler and Rehkopf 2005). Due to the large number of both application fields and developed methods, there is no universally accepted definition. Therefore, Kimms and Klein (2005) identify prerequisites for the application of RM methods in a business-to-customer context. Dietrich et al. (2008) analyze the requirements in a business-to-business environment. A widespread literature review regarding RM applications in various industries as well as problems and corresponding solution approaches is given by Chiang et al. (2007).

The relevance of an integrated view of CRM and RM has already been identified by several authors (e.g., Belobaba 2002; Dickinson 2001; Esse 2003; Hendler and Hendler 2004; Jonas 2001; Liebermann 2002; Metters et al. 2008; Noone et al. 2003; Shoemaker 2003). The relevant literature provides publications that examine issues at the interface of RM and customer acceptance. For example, Kimes (1994) and Phillips (2005, Chapter 12) examine the effects of different pricing and availability decisions regarding a customer's perception of fairness. Furthermore, there exist some contributions in which the customer acceptance is analyzed (empirically) dependent on particular factors – such as transparency and comprehensibility of the capacity control or the pricing mechanism (e.g., Kimes and Wirtz 2003a; 2003b; Wirtz and Kimes 2007; Wirtz et al. 2003; Choi and

Mattila 2004; 2005; 2006). However, in the field of RM, the existing optimization approaches usually consider CRM aspects only indirectly (e.g., fencing criteria in the context of customer segmentation). When taking a transaction-based view instead of a value-based one, especially the long-term implications of the provider's decisions on the value of both the customer and the firm are not addressed adequately. This can lead to the fact, that a high-revenue request of a customer with a low long-term potential is preferred to a request of a customer with a far higher long-term profitability. Thereby, corporate value is devastated.

A first concept for integrating aspects of CRM in an optimization model in the field of capacity control is the "customer value-based RM" approach developed by von Martens and Hilbert (von Martens 2009; von Martens and Hilbert 2011). In their model, the total value of a request – called "value-related revenue" – is defined as a convex combination of the short-term attainable revenue related to the requested product and the long-term CLV dependent on the segment the requesting customer belongs to. If a customer request is accepted, the "value-related revenue" is accounted completely in the objective function of the optimization model. In the case of denying a customer's request, both product-related revenue and the entire CLV are lost. Thus, by applying this approach, the company's relationship with the customer can only be considered in a lost-for-good setting, which in general does not characterize the relationship between a company and its customers adequately.

Despite having identified the integration of CRM and RM as an existing challenge, the analysis of the relevant literature shows that – to the best of our knowledge – there are no contributions in which the concept of a value-based business strategy is incorporated to its full extent into an optimization model for capacity control. In Section 3, we therefore introduce an optimization model that contributes to close this gap by integrating these two perspectives.

3 Modeling customer lifetime value-based capacity control

In the following, we present a capacity control model that integrates the management concepts of (value-based) CRM and RM. The basic idea of the model is to consider the expected implications of the provider's present decisions (i.e., accepting or denying a customer's current request) on the long-term value of the requesting customer. Thereby, the model allows for weighting the short-term outcome (in terms of the discounted contribution margin of the requested product) and the long-term effects (characterized as the monetary effects on the future cash flows generated from the requesting customer) according to the specific situation.

Pursuing the goal of maximizing the expected weighted sum of short- and long-term contribution, the decision regarding the acceptance or denial of a current request is a stochastic dynamic optimization problem: stochastic as a result of the uncertainty of future requests; dynamic, because the system state changes after every decision (Klein 2001). Although – if it is possible to estimate the probabilities and chronology of arriving requests for particular combinations of product and customer segment – a dynamic program can be formulated, in fact it is normally impossible to obtain an optimal solution within reasonable time due to the curse of dimensionality. Thus, alternative heuristic control approaches are applied. For this purpose, the stochastic dynamic program often is converted into a deterministic linear program by substituting the stochastic demand components by the expected value of the aggregated demand (Kimms and Klein 2005). In this paper, we present such an approach for capacity control considering the long-term effects on the customers' lifetime values.

In the following section, we present the general framework of the model as well as the underlying assumptions. The model itself is introduced in Section 3.2. Subsequently, we discuss the limitations of the model and outline further research directions in Section 3.3.

3.1 General framework and assumptions

The model presented in the following relates to the domain of capacity control in a network case where customers purchase bundles of resources in combination (e.g., connecting flights across a network). Accordingly, the provider has to dispose multiple perishable resources with fixed capacity (Talluri and van Ryzin 2005). These resources are required to meet the demand for different goods or services. The customer base can be separated into different customer segments, which differ regarding purchase behavior and their CLV, respectively. Due to the customer segments' heterogeneous purchase behavior, the company is capable of (indirectly) segmenting its customers through various fencing criteria, for example a 21-day advance purchase or a refundability option. In this context, differentiated prices can be charged by defining products that actually access the same resources by operationally or virtually modifying the underlying services. In the case considered here, the definition of fences (i.e., products) is generally based on the volume of a request and the purchase behavior of the requesting customer segment. Note that the sets of customer segments that purchase certain products must not necessarily be pairwise disjoint.

A product – to which a given price is assigned – is characterized by a fixed combination of different resources (Klein and Steinhardt 2008, p. 17) and the corresponding capacity consumption of each product is known. The provider's objective is to allocate the resources available for a single decision period (at whose end the accepted requests are fulfilled) in the context of a value-based perspective. Customer requests for the offered products arrive spread in time during a predefined booking period. Thus, within this booking period, the company faces stochastic demand for its fixed capacity available in the decision period. Therefore, price discrimination has to be extended by methods of capacity control in order to accept or deny particular requests. In the following, we present a model that allows for the determination of an optimal contingent for each combination of customer segment and product with respect to the capacity available in the decision period. The derivation of more sophisticated control policies is not intended in favor of the subsequently developed conceptual approach of capacity control. Here, the model is based on the following assumptions:

(A1) The decision maker is assumed to be risk-neutral, i.e., the decisions are taken based on the expected number of requests, the short-term attainable revenue, and the expected discounted long-term effects on the CLV dependent on whether a particular request is accepted or denied.

(A2) The expected values of the customer segment-specific effects of the availability decision on the CLV can be determined ex ante and are independent of the requested product.

(A3) Every customer requests a certain product at most once for the decision period. Thereby, the customers' requests are independent of the provider's control policy (i.e., the set of products offered at a certain point in time) and the number of requests can be forecasted for each combination of customer segment and product.

(A4) Products are only requested for the considered decision period. Thus, solely the capacity available in the decision period is relevant.

In order to reduce the requirements on forecasting, in (A2) it is assumed that the implications of accepting or denying a request on the CLV are independent of the requested product. This assumption is motivated by the fact that a certain customer segment is committed to a broadly homogeneous set of different products due to the applied fencing structure. Since there is no need to estimate the changes in CLV for each combination of product and customer segment, it is sufficient to determine the effects of accepting or denying a request depending on the requesting customer segment and its purchase history. Nevertheless, the model can be easily adjusted to the case of product-dependent changes in CLV.

In this context, optimal contingents can be determined by maximizing the sum of the short-term contribution margins and the (weighted) changes in long-term profitability that result from a feasible allocation.

3.2 Model description

In the following, a capacity control model for the determination of optimal contingents for the combinations of customer segments and products is presented where the uncertain demand is replaced by the expected demand according to assumption (A1). In RM, this approach is common practice and results in a deterministic linear programming model (DLP, see, e.g., Glover et al. 1982; Talluri and van Ryzin 1998; Bertsimas and Popescu 2003). For the formal presentation of the model, the notation described in Table 1 is used.

Notation	**Description**
$\gamma \in [0;1]$	parameter for weighting short-term versus long-term contributions of a customer
$\mathcal{I} = \{1, \dots, n\}$	set of products i
$\mathcal{K} = \{1, \dots q\}$	set of customer segments k
$\mathcal{S} = \{0, \dots, z\}$	set of the number of consecutive denials s („a customer's history"); the firm's relationship with the customer ends after z consecutive denials
$\mathcal{H} = \{1, \dots, m\}$	set of resources h
$d_{i,k}$	(discounted) short-term contribution margin in the case of accepting a request from a customer of segment k for product i
$\Delta CLV_k^{s,+}$ and $\Delta CLV_k^{s,-}$	long-term effects on the CLV of a customer from segment k with history s induced by accepting $(+)$ or denying (-) the corresponding request
C_h	capacity of resource h
$a_{h,i}$	number of capacity units of resource h required to fulfill one request for product i
A^h	set of all products accessing resource h
$D_{i,k,s}$	expected demand for product i from segment k with history s
E	minimal value of the cumulated short-term contribution margin
$v_{i,k}^{s,+}$ and $v_{i,k}^{s,-}$	total value contribution of a request in the case of acceptance or denial
$x_{i,k,s}$	decision variable: contingent to be allocated to product i requested by customers from segment k with history s

Table 1 Model notation

Due to the consideration of both short-term contribution and long-term changes of CLV, the total value contribution is given as follows:

Acceptance of a customer's request

$$v_{i,k}^{s,+} = d_{i,k} + \gamma\, \Delta CLV_k^{s,+}$$

Denial of a customer's request

$$v_{i,k}^{s,-} = 0 + \gamma \Delta CLV_k^{s,-}$$

In both cases, the total value contribution $v_{i,k}^{s,+}$ and $v_{i,k}^{s,-}$ consists of two terms: The former addresses short-term effects while the latter represents the long-term implications resulting from the provider's decision. Note that, in this context, the long-term changes in CLV ($\Delta CLV_k^{s,+}$ and $\Delta CLV_k^{s,-}$) do consequently not contain the contribution margin attainable in the short term. That means $\Delta CLV_k^{s,+}$ and $\Delta CLV_k^{s,-}$ represent the expected change of the present value of the profits generated from a customer in all periods that succeed the considered decision period. In the case of accepting a request, the total contribution is composed as follows: The first term characterizes the (discounted) contribution margin connected with the acceptance of the request. The contribution margin of product i, $d_{i,k}$, can vary for different customer segments k, e.g., depending on the distribution channel used by segment k. The second component of the total value contribution comprises the expected effects of the provider's availability decision (here: acceptance) on the (discounted) future cash flows related to the customer. Changes of the CLV can, for example, arise if the acceptance of a request increases the customer's loyalty towards the company which may lead to higher repurchase probabilities. Hence, to tie customers with high future potential, it even can be reasonable to accept a request with a negative short-term contribution. For ease of notation, we assume that the contribution margin of a denied request is equal to 0 since no revenue is generated and the firm's expenditures are usually negligible. Accordingly, the relevant total value contribution of denying availability can be stated as the change of the CLV weighted with γ. Because these CLV effects can be – especially if a customer's request is denied – strongly depend on the frequency of preceding denials, the number of consecutive denials s is considered in $\Delta CLV_k^{s,+}$ and $\Delta CLV_k^{s,-}$. The model thereby accounts for the circumstance that a customer's relationship with a company usually does not end after one denied request. Thus, the implications on the future customer behavior, which influences the lifetime value, are dependent on the customer's history s: For example, the future repurchase probabilities will successively decrease with the number of preceding denials s until the relationship finally ends after z consecutive denials. As a consequence, it is necessary to control the availability of products regarding the history of the customers and its influence on the CLV. Note that the lost-for-good scenario already addressed in literature (von Martens 2009; von Martens and Hilbert 2011) arises by setting $z = 1$ (i.e., the relationship ends after one denial), $\Delta CLV_k^{s,+} = 0$, and $(-\Delta CLV_k^{s,-})$ equal to the current lifetime value.

By varying the parameter γ within the interval $[0;1]$, the influence of the long-term potential (value-based CRM perspective) versus the short-term contribution (traditional RM perspective) can be weighted according to the decision maker's specific preferences. For $\gamma = 0$, the capacity is allocated according to traditional RM – however, a more fine-grained customer segmentation is applied. In contrast, the capacity rationing is carried out in terms of value-based CRM to its full extent for $\gamma = 1$ such that the change in CLV is considered entirely.

In order to determine optimal contingents for each combination of product and customer segment, the following linear optimization problem has to be resolved:

$$\max \sum_{i \in \mathcal{I}} \sum_{k \in \mathcal{K}} \sum_{s \in \mathcal{S}} v_{i,k}^{s,+} x_{i,k,s} + \sum_{i \in \mathcal{I}} \sum_{k \in \mathcal{K}} \sum_{s \in \mathcal{S}} v_{i,k}^{s,-} (D_{i,k,s} - x_{i,k,s}) \tag{1}$$

s.t.

$$\sum_{i \in A^h} \sum_{k \in \mathcal{K}} \sum_{s \in \mathcal{S}} a_{h,i} x_{i,k,s} \leq C_h \qquad \forall\, h \in \mathcal{H} \tag{2}$$

$$0 \leq x_{i,k,s} \leq D_{i,k,s} \qquad \forall\, i \in \mathcal{I}, k \in \mathcal{K}, s \in \mathcal{S} \tag{3}$$

$$\sum_{i \in \mathcal{I}} \sum_{k \in \mathcal{K}} \sum_{s \in \mathcal{S}} d_{i,k,s} x_{i,k,s} \geq E \tag{4}$$

$$x_{i,k,s} \text{ integer} \qquad \forall\, i \in \mathcal{I}, k \in \mathcal{K}, s \in \mathcal{S} \tag{5}$$

The objective function (1) is composed of two terms where the first one is related to the accepted customer requests (i.e., the contingents). The second term comprises all denied requests, which are the difference between expected demand and the provided contingents. Constraints (2) and (3) ensure that the available capacity is sufficient and the non-negative contingents for each combination of product and customer segment do not exceed the expected demand. Constraint (4) guarantees that the overall short-term attainable contribution margin does not fall below a given minimal amount E (e.g., due to liquidity requirements). Furthermore, the contingents need to be integer since requests often cannot be fulfilled partially (constraints (5)). However, even if the integer constraint is relaxed, for $C_h \in \mathbb{Z}\,\forall h$, $D_{i,k,s} \in \mathbb{Z}\,\forall i,k,s$, there exists an integer solution[1] in the case that the coefficient matrix of the system of inequalities (2)–(4) is totally unimodular (see Nemhauser and Wolsey 1999, Chapter III.1). Discarding constraint (4), this requirement is met if all $a_{h,i}$ take the values 1 or 0 (cf. Klein and Steinhardt 2008, p. 111). Without considering integrity, the dual problem can be analyzed which allows for determining opportunity costs in the context of a sensitivity analysis. To obtain an efficiently solvable model, constraints (5) are discarded in the following which is common practice in RM (e.g., de Boer et al. 2002).

For the purpose of further analyses, the objective function can be rearranged as follows:

$$\sum_{i\in\mathcal{I}}\sum_{k\in\mathcal{K}}\sum_{s\in\mathcal{S}}(d_{i,k}+\gamma\Delta CLV_k^{s,+})x_{i,k,s}+\sum_{i\in\mathcal{I}}\sum_{k\in\mathcal{K}}\sum_{s\in\mathcal{S}}\gamma\Delta CLV_k^{s,-}(D_{i,k,s}-x_{i,k,s})$$

$$=\sum_{i\in\mathcal{I}}\sum_{k\in\mathcal{K}}\sum_{s\in\mathcal{S}}d_{i,k}x_{i,k,s}+\gamma\sum_{i\in\mathcal{I}}\sum_{k\in\mathcal{K}}\sum_{s\in\mathcal{S}}\left(\Delta CLV_k^{s,+}-\Delta CLV_k^{s,-}\right)x_{i,k,s}$$

$$+\gamma\sum_{i\in\mathcal{I}}\sum_{k\in\mathcal{K}}\sum_{s\in\mathcal{S}}\Delta CLV_k^{s,-}D_{i,k,s}$$

Obviously, the third term of the objective function is a constant that can be ignored for optimization purposes. The first term describes – as known from the traditional transaction-based RM – the short-term attainable value contribution as product of the contribution margin and the corresponding contingent. The second summation represents the expected effects of the changes in the long-term lifetime values of the customers. This representation shows that it is sufficient to determine the expected difference between $\Delta CLV_k^{s,+}$ and $\Delta CLV_k^{s,-}$ for the practical application of the model. The described model can be solved with standard methods of linear programming.

With regard to a strictly value-based management approach, the long-term contributions should be considered entirely ($\gamma = 1$). However, for example due to a shortage of liquidity, a shorter-term orientation ($\gamma < 1$) can be temporarily reasonable. The value of the parameter γ describes whether the expected change of CLV carries as much weight as the short-term contribution margin ($\gamma = 1$) or if there is a reduction on the expected long-term value due to a higher preference of value contributions in the short term ($\gamma < 1$). Because of the (partial) negligence of long-term potential, the latter approach can cause a deterioration of the customer equity and thus the corporate value. The value of the parameter γ can be determined according to the estimation of a decision maker's degree of risk aversion in decision theory (see Bamberg et al. 2008; Klein and Scholl 2011). Beyond that, constraint (4) only should be taken into account by setting $E > -\infty$

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[1] Under the condition that there is an optimal solution for the linear program

if it is mandatory because fulfilling this restriction with equality[2] could possibly devastate long-term value.

If the integer constraints (5) are discarded, the marginal loss of long-term potential per monetary unit of liquidity required in the short term is given by the dual variable corresponding with constraint (4). This interpretation of the opportunity costs holds as long as the currently optimal basic feasible solution does not lose its optimality property (e.g., Domschke and Klein 2004).

If the integer constraints (5) are incorporated into the model, the limited validity of the corresponding dual problem has to be considered (see Nemhauser and Wolsey 1999, chapter II.3). The amount of lost long-term potential by choosing $\gamma < 1$ or $E > -\infty$ can be determined as follows: First, pursuing a long-term value-based management perspective, the model has to be solved with $\gamma = 1$ and $E \rightarrow -\infty$. Let $ZF^{*}_{1,-\infty}$ be the corresponding objective function value. Subsequently, the optimal capacity allocation computed for parameters $\gamma < 1$ or $E > -\infty$ has to be inserted into the objective function parameterized with $\gamma = 1$ and $E \rightarrow -\infty$. With $ZF^{*}_{\gamma,E}$ denoting the corresponding value of the objective function the overall loss of long-term value contribution can be stated by the difference $ZF^{*}_{1,-\infty} - ZF^{*}_{\gamma,E}$. This loss depends on both the choice of $\gamma < 1$ and the definition of a minimum cumulated short-term contribution margin ($E > -\infty$). Altogether, in terms of customer value-based RM, the model allows for a transparent and integrated consideration of short-term and long-term value contributions in the context of rationing scarce capacity.

3.3 Limitations of the model and future research directions

The capacity control model described in Section 3.2 represents a first step towards an integration of CRM an RM aspects in the sense of value-based management. In this context, the effects of the current capacity decisions on the lifetime value of the customers are considered. However, the model is based on some simplifying assumptions which lead to a number of limitations that have to be overcome by future research:

- It is assumed that the expected customer segment specific effects of accepting or denying a request can be determined ex ante by computing the point estimates $\Delta CLV_k^{s,+}$ and $\Delta CLV_k^{s,-}$. Taking a closer look and rearranging the objective function shows that it is sufficient to estimate the difference between the changes of the CLV in both cases which might be easier to do. Nevertheless, appropriate forecasting methods have to be developed.
- A further implicit assumption is that the CLV and its change respectively capture all relevant aspects of the value of a customer for the company in a monetary way. In general, there may exist further important aspects like customer loyalty (Krafft 2007) as well as other (indirect) components like the reference or information value of a customer (Braun and Cornelsen 2006; Cornelsen 2006). However, these aspects are often not directly linked to the

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[2] Considering integrity, the solution can be restricted even if both sides of constraint (4) are not equal.

cash-flows generated by the customers. Although some approaches to calculate the CLV also consider aspects like the retention rate of a customer which is influenced by his or her loyalty (e.g., Gupta et al. 2004; Reinartz and Kumar 2003), to the best of our knowledge, an approach for the calculation of the CLV providing an all-embracing consideration of these aspects is still missing.
- The decision maker is assumed to be risk-neutral. If this is not true, not only the expected values of the short- and long-term contributions, but also the variance of these cash flows has to be forecasted. Furthermore, the optimization model has to be extended to a stochastic one in order to be able to cope with uncertainty.
- Only one decision period is considered while not regarding inter-temporal dependencies between arriving requests (e.g., a customer requesting a product that accesses capacity in different decision periods). Again, this requires generalizing the optimization model.
- Finally, even if the provider faces excess demand for lower-value products and excess capacity of higher-value resources, the optimization model does not allow for the assignment of upgrades (e.g., Alstrup et al. 1986; Shumsky and Zhang 2009; Steinhardt and Gönsch 2011). Especially due to the fact that upgrades can influence customer behavior and the CLV, the integration of these options into the model is desirable.

4 Illustration of the model

In the following, we illustrate a possible application of our model for an exemplary company of the semiconductor industry. First of all, we describe the background and match it with the requirements of a CLV-oriented capacity control. Afterwards, we exemplarily apply the model (in a simplified form) and analyze the results for the following two cases: (1) considering aspects of the customer orientation versus (2) conducting a solely short-term oriented optimization. Furthermore, we analyze the results regarding the influence of the value selected for the parameter γ which represents the weight given to long-term effects on the lifetime values of the customers in the optimization model.

4.1 Background of the example

The semiconductor sector is characterized by a highly volatile demand situation. In the case of the company considered in this example, the customers are furthermore in a powerful situation as most of the company's divisions are actors in rather competitive markets where they depend on the demand of few customers with whom they predominantly maintain long-term relationships. The customers' requests thereby often occur ad hoc. At the same time, production capacities are limited and inflexible in the short run. Given this situation, for the decision on the acceptance or denial of a customer request and the induced allocation of production capacity the consideration of short-term as well as long-term effects in terms of a CLV-oriented capacity control is reasonable.

In our example, the company uses two types of machines: front-end (FE) and back-end (BE) production. The machine types offer the capacities C_{FE} and C_{BE}

which cannot be increased in the decision period. Furthermore, we assume that the company produces only two types of products: a premium product P and a basic product B. During the financial crisis, the degree of capacity utilization was very low. So, all customer requests could be served (i.e., $s = 0$ for all customer segments). Due to the subsequent boom, the number of customer requests has increased to such an extent that a CLV-oriented capacity control is needed, as one cannot serve all requests any longer. The company's customers can be clustered according to their request behavior in three exemplary segments. The first customer segment's price sensitivity is rather low. However, this customer segment purchases the relevant products also from other providers so that the change in CLV is not very high for both the acceptance as well as the denial of a request. In contrast, customer segment 3 is rather price sensitive. Due to a higher churn probability in the case of denying as well as a lock-in effect in the case of accepting a request, the changes in CLV are much higher for this segment. Customer segment 2 has an intermediate level of price sensitivity and changes of CLV compared to the other segments. In order to establish value-based management and customer orientation in the company's capacity control, the model for CLV-oriented capacity control should be used for allocating capacities.

4.2 Application of the model for customer lifetime value-based capacity control

Against the background described, we now apply the model introduced in Section 3 to our example from the semiconductor sector. Due to the fact that up to now all customer requests could have been served, the value of the parameter s is set to $s = 0$. Table 2 provides the further values for the input parameters of the model.

Segment	Prod.	d	ΔCLV^{+}	ΔCLV^{-}	ΔCLV	a_{FE}	a_{BE}	D
1	B	440	0	-40	40	1	0	5
1	P	550	0	-40	40	1	1	4
2	B	400	40	-70	110	1	0	3
2	P	500	40	-70	110	1	1	3
3	B	350	200	-100	300	1	0	3
3	P	480	200	-100	300	1	1	4

C_{FE}	C_{BE}
13	8

Table 2 Input values for the parameters in the model

First, the optimal contingents are determined without considering constraint (4) (i.e., $E \rightarrow -\infty$). The long-term as well as short-term components of the value contribution resulting from the optimal choice of contingents for a specific value of the parameter γ are provided in Table 3.

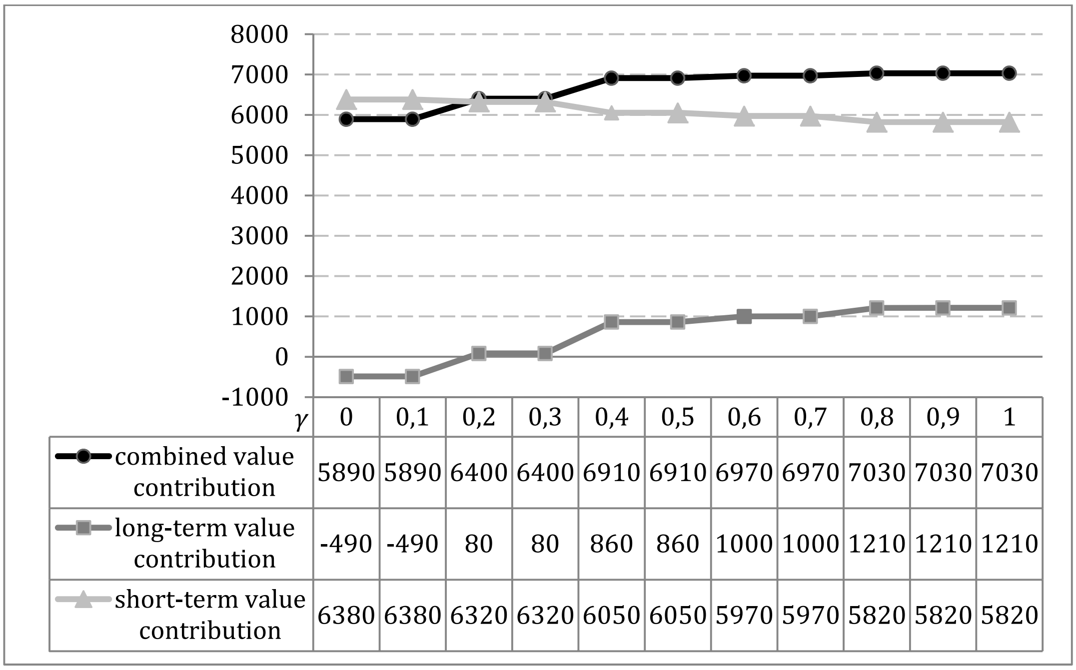
Parameter γ	**0**	**$0,1$**	**$0,2$**	**$0,3$**	**$0,4$**	**$0,5$**	**$0,6$**	**$0,7$**	**$0,8$**	**$0,9$**	**1**
Contingent $x_{B,1}$	5	5	5	5	2	2	0	0	0	0	0
Contingent $x_{P,1}$	4	4	4	4	4	4	4	4	1	1	1
Contingent $x_{B,2}$	0	0	0	0	0	0	2	2	2	2	2
Contingent $x_{P,2}$	3	3	0	0	0	0	0	0	3	3	3
Contingent $x_{B,3}$	0	0	0	0	3	3	3	3	3	3	3
Contingent $x_{P,3}$	1	1	4	4	4	4	4	4	4	4	4
Combined value contribution ($ZF^*_{\gamma=1,E\to-\infty}$)	5890	5890	6400	6400	6910	6910	6970	6970	7030	7030	7030
Long-term value contribution (cumulated change in CLV, $\gamma = 1$)	-490	-490	80	80	860	860	1000	1000	1210	1210	1210
Short-term value contribution	6380	6380	6320	6320	6050	6050	5970	5970	5820	5820	5820

Table 3 Long-term and short-term value contribution with $E \to -\infty$

For $\gamma = 1$ (i.e., a complete long-term orientation) the combined value contribution accumulates to 7030 monetary units (MU) with the following optimal contingents: $x_{B,1} = 0, x_{P,1} = 1, x_{B,2} = 2, x_{P,2} = 3, x_{B,3} = 3$ and $x_{P,3} = 4$. In this case, the expected demand from customer segment 3 is completely served by the capacity allocated to this segment. This is due to the fact that for this segment, the highest change in CLV is expected which overcompensates the lower short-term profit contribution. At the same time, these contingents lead to a short-term value contribution of 5820 MU. This is 560 MU less than the maximal possible short-term value of 6380 MU. However, this decrease of the short-term value contribution is overcompensated by a much higher long-term value contribution.

In case of an absolute short-term orientation (i.e., $\gamma = 0$) the combined value contribution accumulates to 5890 MU with the contingents $x_{B,1} = 5, x_{P,1} = 4, x_{B,2} = 0, x_{P,2} = 3, x_{B,3} = 0$ and $x_{P,3} = 1$. Compared to the optimal contingents for $\gamma = 1$, this choice leads to a decrease of 1140 MU. Altogether, the consideration of changes in the lifetime values of the customers when allocating capacities leads to an increase of the combined value contribution of 19 % in our example.

Figure 1 visualizes the evolution of short-term, long-term, and combined value contribution for different values of γ. The figure shows that in our example an increase in the long-term value contribution (positive change in CLV) goes along with a loss of value contribution attainable in the short run.



γ	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
● combined value contribution	5890	5890	6400	6400	6910	6910	6970	6970	7030	7030	7030
■ long-term value contribution	-490	-490	80	80	860	860	1000	1000	1210	1210	1210
▲ short-term value contribution	6380	6380	6320	6320	6050	6050	5970	5970	5820	5820	5820

Figure 1 Evolution of the long-term and short-term value contribution[3] for different values of γ ($E \rightarrow -\infty$)

If a short-term value contribution of at least 6050 MU is required, one gets the optimal contingents $x_{B,1} = 2, x_{P,1} = 4, x_{B,2} = 0, x_{P,2} = 0, x_{B,3} = 3$ and $x_{P,3} = 4$ for $\gamma = 1$. In order to fulfill this requirement, one must abandon in total 120 MU. So, the higher short-term value of 230 MU goes along with the loss of an increase in CLV of 350 MU.

Irrespective of the illustrated example, the consideration and weighting of short-term as well as long-term value contributions from customers is generally relevant if a company is confronted with requests of different value for its available, scarce capacity by customers from segments which react differently on the acceptance or denial of a request. Apart from the exceptional cases that the short-term value contributions of different combinations of product and customer segment are proportional to the long-term changes in the value of a customer, considerable differences regarding the optimal contingents for short-term $(\gamma = 0)$ or long-term oriented $(\gamma = 1)$ management can occur.

5 Conclusion

In this paper, we proposed an optimization model for allocating capacity to requests of different combinations of customer segments and products. Thereby, the model also considers the history of consecutive denials of requests from a customer (segment). Besides aspects from traditional RM allowing for the optimization of short-term revenues, long-term effects on the lifetime values of the customers influence the decision on the contingents. These effects can be weighted individually according to the preferences of a company. At the same

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[3] Calculated for $\gamma = 1$.

time, one can determine the long-term loss of customer equity and thus corporate value, which may result from a short-term oriented selection of the weighting factor. The optimal contingents for the different combinations of a product and a customer segment can then serve as the basis for further customer-oriented strategies. In summary, the model in this paper represents a first step towards an integration of CRM and RM by explicitly considering the trade-off between short-term value contributions of customers against their long-term potential when allocating capacities.

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