Decision Support for Negotiations of Flexibility Contracts

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Abstract
Supply contracts are a medium for coordinating materials and information flows in supply chains aiming at reducing uncertainties, order variances, delivery lead times, and inventory risks with increased fill rates. Practitioners were always up-front involved in designing and negotiating clauses of so called quantity flexibility contracts. Meanwhile researchers have proved the advantage of such contracts with the limitation of restricted feasibility on operational level, mainly due to a lack of understanding the possible and needed reconciliations of forecast updating and their overall short-term consequences. This paper presents a model supporting contract design and operational decision making regarding cost optimal order bundling strategies on supplier’s side in a stochastic or quasi-deterministic make-to-order environment. We hypothesize that firm, agreed upon flexibilities and a tangible, efficient display of market risks will enable both parties gaining higher levels of transparency regarding their order balance as well as cost structure and hence encourage user’s acceptance.

Keywords
Flexibility Contracts, Supply Chain Management, Materials Management

1 Introduction
Over the last decade producing companies have faced a number of challenges in their highly unpredictable and competitive market environment. The challenges arise mainly from competition-induced shortening of product lifecycles, a growing number and complexity of product variants as well as from an increasing volatility in market demands. In particular industries, dealing with high market uncertainties and offering much shorter delivery times to their customers than their suppliers are able to accomplish, are endangered by business risks caused by high inventory levels, stockouts and obsolescence. It became widespread to install so called basic agreements granting volume flexibilities for certain timeframes (e.g. replenishment lead times) or certain volumes (e.g. customer optimal lot sizes) for flexible timeframes. A recently conducted survey among 51 Swiss companies from the industry sector proves that these basic agreements are a common vehicle, whereby it is still more widespread for procurement than for sales activities [Schnetzler et al. 2006]. Furthermore one has to remark that granted volume flexibilities appear in the same frequency as agreed upon time flexibilities, not depending on the direction within the logistics chain, nor from the production strategy, such as make-to-stock or make-to-order. But the study highlights, that companies applying these contracts still lack appropriate decision support in the cost optimal assignment of purchasing materials to order frequencies as well as in gathering transparency and estimating costs for required flexibilities [Schnetzler et al. 2006].
Considering this background a methodology has been elaborated aiming at bridging the above mentioned performance gap and providing comprehensive decision support. A scenario tool enables a definition of dependent demand for different flexibility corridors. In order to build-up a comprehensible framework for suppliers and buyers likewise, a deterministic demand model is being introduced that offers inherently volume and time flexibility according to time. In a next step, the arising question of cost optimal order bundling and processing as well as the determination of the ideal stocking levels in a quasi-deterministic production environment is being addressed. In a last step performance indicators, such as logistics costs per part for different flexibility corridors, are being calculated enabling a transparent splitting of market risks among partners in the supply chain.
The explanation of the methodology with focus on a detailed description of the demand model and the software-supported decision support system is furthermore enriched by an illustrative example of appliance in a company from the high-tech-sector. The case study provides some facts and figures displaying economic impacts of different settings of presented elaborated type of contract.
2 Literature Review

Supply contracts as medium for reducing risks and uncertainties in supply chains gained high importance for researchers and practitioners likewise. See Tsay et al. [Tsay et al. 1999] for an extensive and substantial review of contracting clauses applied in industry and examined by researchers. Wang [Wang 2002] offers a generalized framework of supply contracts taking into account many clauses described in Tsay et al., such as pricing, minimum purchase commitment or buyback issues.

The focus of following investigations comprise the limitation of supply contracts incorporating boundaries for buyers’ orderable quantities in regard to time. In contrast to agreed upon price-sensitive e.g. return policies between buyers and suppliers often seen in manufacturer-distributor relationships [Pasternack 1985], [Kandel [1996], and [Emmons & Gilbert 1998] embedded also in minimum purchasing commitments [Monahan 1984], [Sadrian & Yoon 1984], [Lee & Rosenblatt 1986], [Anupindi & Akella 1993], [Anupindi & Bassok 1998], and [Webster & Wenig 2000], so called quantity flexibility contracts provide flexibility with no explicit penalty for exercise, but rather use constraints as a way to motivate appropriate order behaviour [Tsay 1996]. The mechanism of such quantity flexibility contracts allow the buyer to cancel a predefined contingent with no additional costs; the costs of the oddment is what induces more careful ordering. These contracts are frame contracts that are in the best interest of both parties. The buyer profits from lower prices and a higher fill rate from the supplier, whereby the supplier in turn can depend on a minimum blanket order quantity and gains advantages of increased planning capabilities. These types of contracts are preferably applicable when the buyer has some reliable long-term-planning for the products to be purchased. His supplier evaluation criteria then not only comprise lowest prices, but also the criteria of delivery reliability and short delivery times [Schönsleben 2004].

Only a few instances of such contracts are formally documented in the academic literature, and even then the details of specific terms are available only in limited resource. See [Tsay 1999] for an overview of applied quantity flexibility contracts in automotive, electronics or energy industry. The research in that special field can be segmented into two general categories: those that focus primarily on the buyer’s decision problem, followed by those that consider both parties.

Bassok and Anupindi [Bassok & Anupindi 1995] are one of the first authors who considered forecasting and purchasing behaviour in a rolling-horizon scheme. The buyer initially forecasts month-by-month demand over an entire year and then may revise each month’s purchase once within defined percentage bounds. They also have analyzed a single product contract where the supplier offers discounts for a guaranteed total minimum quantity commitment [Bassok & Anupindi 1997] Bassok and other authors provide decision support to buyers by very efficient heuristics that determine allowable flexibility corridors depending on a price and observed or expected variability [Bassok et al. 1997]. Moinzadeh and Nahmias have studied a model in which the buyer makes a firm commitment to purchase a certain minimum quantity at regular time intervals [Moinzadeh & Nahmias 2000]. Li & Kouvelis study in a deterministic demand model the dependencies of installed time-flexibilities on evolution of cost figures. The buyer may observe stochastic price or exchange rate fluctuations and may decide dynamically when to buy [Li & Kouvelis 1999]. A drawback of all above approaches is that the supplier’s behaviour and capabilities for fulfilling negotiated arrangements is not emphatically considered.

Both parties, buyers and suppliers, are considered in various types of contract descriptions (e.g. see above return policy, buyback or minimum commitment contracts) and decision processes affected by the double marginalization phenomenon. See [Tsay 1999] for a considerable authors list. Recent studies contain investigations of applying flexibility options for buyer-supplier-systems. The buyer can be forced during a two-period timetable to buy evaluated options for calls (buyings) in the second period, after he made firm orders for the first period [Barnes-Schuster et al. 2002]. This approach was extended by establishing put-options (not buying) [Cheng et al. 2002] and also for longer periods [Vial & Delft 2002].

Considerations of sharable profits and an evaluation of efficiency among partners in the supply chain in a quantity flexibility environment has been done by [Tsay 1996], [Tsay & Lovejoy 1999]. Their presented supply contract is somewhat similar to the one presented here. The main differences are that they are concerned with a multi echelon environment and that their single production stages face
stochastic demand starting from a distributor’s market interface in a short-term rolling-horizon scheme. Nodes in upstream direction have to cope with stochastic demand within assured flexibility corridors. Due to the many decision variables no closed analytical solution is available and can serve also as basis for operative planning. Their intention was more to study behaviour of the supply chain and to have statistical evidence about performance indicators’ development. One of the main findings was that these types of contracts reduce the bullwhip-effect, but can cause radical changes in procurement practices and often have to cope with organizational resistance. This is mainly due to a lack of understanding how much flexibility is actually needed for each rolling horizon-period. The difficulty lies in an appropriate description of how much flexibility is actually and in future available for the purchasers. Single supplier’s preferences are possible to be mapped, but explicitly no integrated product view with an explosion of bill of materials has been applied. Thereby, the individual replenishment lead times of supplier’s purchased materials and their effect on the whole product availability to customer is neglected in their rolling-horizon scheme.

In summary, it can be ascertained that none of above approaches copes from a supplier’s view with settings in quantity and time flexibility contract negotiations. In addition, realistic behaviour should be enabled by taking into account one’s suppliers order policy which in case of not only customer specific materials is surely depending on his other customers. For obtaining this objective and in order to provide advice for operational planning, the real demand is being simplified by implying quasi-deterministic demand and applying prominent Materials Requirements Planning (MRP)-techniques. Quasi-deterministic demand planning is characterized by utilization of stochastic methods or customer given forecasts to determine independent demand and deterministic methods to determine corresponding dependent demand [Schönsleben 2004]. Outside these later defined quasi-deterministic timeframes stochastic demand may occur. By predefining possible case scenarios disemboguing into correlative contracts, the risks of high storage or obsolescence costs on supplier’s side can be easily evaluated and serve as decision basis.

The customer oriented approach was chosen, not only to support suppliers, but also in order to map quantity flexibility contracts’ nature: The disciplinary action to customer for ordering in an appropriate way and for showing real cost consequences of allowed flexibilities transparently and efficiently. It has to be ensured that also the buyer is given decision support regarding his allowable order quantities in future. These displays seem also to be crucial, in particular when customer and supplier share an open-book philosophy meaning that customers gather transparency of supplier’s cost structures. Overall, our paper differs from most of the existing literature in the following ways:

- Contract modelling is supplier related and customer oriented.
- Product and product families with their bill of material are a contractual object.
- Consideration of products’ containing materials’ different replenishment lead times.
- Consideration of time flexibilities enabling customer’s order delays.
- Advices for parametrization of the Enterprise-Resource-Planning (ERP)-system regarding materials’ order policies at the suppliers’ side.

After the identification of the need for action, the demand and data model as well as the rough decision structure will be presented in the next section. An appliance of the software tool for decision support in the high-tech sector will be shown in the case study of the penultimate section.
3 Model and decision structure

Firstly, the rough structure of the methodology will be presented aiming at illustrating the appliance and data requirements. Figure 1 shows the data model with all relevant input and output data as well as the outline of the intermediate calculation algorithm.

![Data view on software-tool](image)

All relevant data from the in-use ERP-system need to be loaded via a standardized ODBC (OpenDataBase-Connectivity)-Interface into a separate database. These data comprise material specific master data, such as replenishment lead times and prices, a summarized bill of materials, and all other products’ forecasted demand. All other products’ demand means the forecasted demand of those products not being part of the contract, but in future being delivered to the same or other customers. These data seems to be relevant, in order to map a realistic situation of the whole replenishment schedule of all materials. Different flexibility configurations are possible to be mapped directly by the user. A scenario wizard enables configuring demand scenarios, explained in more detail within the next section. The output data consists of two categories. On one hand a display of cost figures is being provided. Relevant costs are additional needed storage capacities, ordering costs and eventually occurring obsolescence risks. On the other hand advices for the parametrization of a demand based dispatching strategy are being provided, described in the section after the next.

3.1 Demand information flows and input data

Due to the fact that particularly in the electronics industry supplier’s replenishment lead times can show the triple or even quadruple of customers’ desired lead times, a high volatility in independent demand causes an even higher variance in supplier’s orders. Therefore, within supplier’s own replenishment and production lead times at least, in the following called planning timeframe, the quantity of customers’ order
volume shows a rigid or firm flexibility, expressed by a predefined forecasted baseline $b$ that can be purchased by the customer in $n$ predefined even lasting order intervals $t_i$ within the even planning timeframes $T$. The baselines’ altitudes $b$ have to be announced by the buyer a whole planning timeframe in advance. That might have firstly a deterrent effect to the buyer, but compensation or updating is offered by a later possible adjustment of the resulting cumulative ordering quantity of the next planning timeframe. The buyer profits from two deployable kinds of flexibility: volume and time.

Firstly the customer enjoys volume flexibility and is able to replenish according to following replenishment vector $r(T)=[r_1(T), r_2(T),...,]$ in which $r_1(T)$ represents the possible purchasing quantity for period $t_1$ within planning timeframe $T$. The other entries $r_i(T)$ describe possible purchasing quantities in future that show a higher variance the more they lie ahead. They are in turn described by the other flexibility vectors $\alpha(t)=[\alpha_n, \alpha_{n+1},...]$ and $\omega(t)=[\omega_n, \omega_{n+1},...]$ that enable a baseline variation in period $t_i$ by increasing baseline quantity to $r_i=b(1+\alpha_i)$ and decreasing the baseline quantity to $r_i=b(1-\omega_i)$ with $\alpha_i \geq 0$ and $0 \leq \omega_i \leq 1$.

Additionally the buyer is able to achieve a time related flexibility encouraging him possibly to delay according to an agreed upon replenishment value factor $0 \leq p_i \leq 1$ resulting in an even lower order volume $(1-p_i)r_i(T)\cdot r_i(1-\alpha).$ The corresponding remaining order volume $p_i\cdot r_i(T)\cdot r_i(1-\alpha)-p$ therefore might be delayed for a number of periods $d$ with $d \leq n$. This additional time flexibility offers even lower boundaries than from volume flexibility variations enabled by $\omega_i$. Nevertheless, after time period $d$ the buyer has to order earlier delayed volume. The sum of the minimal purchased and remaining quantity amounts to the minimum blanket order quantity. Thereby the minimum blanket order quantity $MinBO$ per planning timeframe specifies the minimal committed quantity from buyer’s side, and is only flexible regarding volume. Thus, it consists of:

$$MinBO = \sum_{i=1}^{n} b \cdot (1-\omega_i)$$  \hspace{1cm} (1)

and the maximum purchasing quantity $MaxPQ$ turns to

$$MaxPQ = \sum_{i=1}^{n} b \cdot (1+\alpha_i)$$  \hspace{1cm} (2)

On the other hand the lowest quantity to be purchased is limited by allowed delay factor $p$ and delay time $d$ and can result in order quantities much lower than $MinBO$. The minimum purchasing quantity $MinPQ$ is determinable by firstly delaying all orders with maximal allowed factor $p$ until time interval $d$ is reached and an afterwards backordering and delaying policy, described by equation (3).

$$MinPQ = \sum_{i=1}^{d} b \cdot (1-\omega_i) \cdot (1-p) + \sum_{k=d+1}^{n} b \cdot (1-\omega_k) \cdot (1-p) + b \cdot (1-\omega_{k-d}) \cdot p$$  \hspace{1cm} (3)

$MinPQ$ stands for a certain cash-income for the supplier within the planning timeframe $T$. The per planning timeframe remaining residual order quantity $R$ to be transferred to and compulsorily purchased within the next planning timeframe results to the difference between $MinOQ$ and $MinPQ$. Supplier’s insecurity regarding customer’s replenishment quantity is being dissolved after each $t_i$ when the buyer is able to place an order. Subsequently supplier’s material requirements planning needs to be adapted according to possible open orders and the resulting new demand situation. Fill rates from the supplier are always planned to fulfill $MaxPQ$ within the planning timeframe. In a first phase fill rates of the purchased materials from the supplier were assumed to amount 100%. Sensitivity analyses of stockout situations are also applicable and enhance these first results. But for contract negotiations towards customers we took supplier’s inbound logistics reliability for granted.

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Figure 2: Example of buyers’ flexibility within discrete planning timeframes $T_i$

Figure 2 shows exemplarily customers’ flexibility regarding volumes within discrete timeframes $T$ and possible order residuals $R$ that have to be purchased latest after period $d$ as mentioned above. It is quite easy to retrace in this deterministic timely forward oriented environment the main influencing factors on buyers’ quantity flexibility to be the committed baselines as well as the parameters $p$, $d$, $\alpha_i(t)$ and $\omega_i(t)$. Therefore his forecasting updating reconciliations tend to be obviously to him. The supplier might gain a more detailed view on his order situation. Figure 3 shows the cumulated figures $MinPQ$, $MinBO$ and $MaxPQ$ as well as their evolvement in order of time from a continuous view over three time intervals, where $d$ equals to $T$, and $p$ equals one, meaning that the customer might delay the whole amount of orders over the entire planning timeframe. The broad columns represent the cumulative figures that have to be purchased by the buyer, as shown above in figure 2.

Figure 3: Example of supplier’s continuous and discrete order situation within planning timeframe $T$
Due to the fact, that the buyer can delay order volumes over the whole planning timeframe, the residual quantity $R$ only amounts to the minimal volume commitments from period 2 and 3, indicated as areas four and seven. His minimum quantity to be purchased $\text{MinPQ}$ therefore is the first replenishment vector from the first period, indicated as area one. As mentioned, the agreed upon minimum blanket order $\text{MinBO}$ represents the sum of the residual $R$ and $\text{MinPQ}$. The maximum quantity to be purchased is accordingly the sum of highest replenishment vectors, and therefore the sum of all indicated areas.

Thus far we have simply formalized the demand and buyer’s replenishment flow and will explain in the following other necessary input data. In order to map a realistic situation firstly all products need to be exploded by a condensed multilevel bill of material or so called summarized bill of material. On one hand these products are exploded whose demand situation needs to be contracted and also those not being part of the contract. Existing forecasts of products not being object in the contract need also to be considered, due to the fact that the materials might be needed for both kinds of products. These information as well historical consumption and materials’ master records (e.g. price, replenishment lead times) serve as input for the calculation of order frequencies and quantities taking into account all costs for dispatching, such as ordering, inventory and obsolescence costs.

3.2 Calculation method and output data

The main question being addressed is the determination of the costs for providing flexibility and supplier’s optimal own replenishment schedule under certain restrictions. Buyers’ freedom in order placements was being addressed in the previous subchapter.

Decisive on costs is the amount of inventory and number of additional orders needed for fulfilling buyer’s desired flexibility for a selected case. One case hereby is the cost comparison of buyer’s purchasing behaviour with supplier’s agreed upon fill rate. Due to the fact, that fill rates of the purchased materials from the supplier were assumed to amount 100% (see last section) and loss of production is not a restriction in the model, supplier’s prepared quantities are $\text{MaxPQ}$, multiplied with the contractually agreed upon fill rate. Therefore, one case could be a “worst case”, meaning that the buyer draws on minimum purchasing quantities and thereby causes additional storage costs on supplier’s side, who is prepared for maximum purchasing quantities with a previously definable fill rate (best case). So, the additional costs for one case represent the difference of the overall costs for two different buyer’s order levels. The overall costs are being calculated by summing costs for ordering, storage and the costs for obsolescence on supplier’s side. The latter costs are calculated by comparison with the weeks of supply and the depreciation period of some materials. Stockout costs are not a subject to calculation. They are preparatory costs, provided by the supplier who needs to fulfill all possible cases of buyer’s order behaviour. Additional costs for ordering appear, when the supplier needs to purchase a material more often than expected (see below for detailed explanation of defining supplier’s replenishment schedule). Hence, the additional costs or risk on supplier’s side for a case $k$ are:

$$\text{Risk}_k = \text{additional costs}_k = \text{Costs}_{\text{Case}_k} - \text{Costs}_{\text{Best Case}}$$

(4)

The software tool is able also to consider distributions of order quantities. By dint of this approach, a probabilistic risk assessment can be applied, displaying the average risk, by allowing for any case $k$ an assignment of probability $s_k$ to Risk $R_k$. In Figure 5 an example of a normal distribution with the guaranteed order quantity (calculated as $\text{MaxPQ} \cdot \text{fill rate}$) and the corresponding probability of failure (i.e. complementary probability of fill rate) is shown. User-specific probability assignments are also applicable. In general, the average risk for $m$ cases hereby is:

$$\text{Average risk} = \frac{\sum_{k=1}^{m} R_k \cdot s_k}{m}$$

(5)
The preliminary lead time for installing these contracts amounts beside the negotiation phase at minimum the whole replenishment and production lead time. This time represents furthermore the weeks of supply for the maximum purchasing quantity of the first time period $T$.

In case of number of time intervals $n$ within a planning timeframe $T$ being exactly one, meaning that customer only dissolves order uncertainties after a whole planning timeframe, then the additional needed storage costs for provided volume flexibility are calculable by taking the sum of $\alpha_n$ and $\omega_n$ and multiplying them with cumulated baseline’s value and an interest rate per planning timeframe. Considering storage costs provoked by time flexibility consists of a similar manner by calculating necessary storing within maximum possible delaying time $d$.

If the supplier gains earlier information about customers’ order situation, then he might adjust the amount of necessary replenishment volumes and hence reduce his necessary inventory. Thus, the typical materials management decision to be taken is how much as well as when to order. The approach by calculating economic lot sizes and installing classical rules for order frequencies might be suboptimal by taking into account that a dissolution of uncertainty might lead to more cost optimal decisions.

The tool-supported algorithm calculates cost optimal (re-)ordering and bundling policies for the worst case, meaning that buyer’s order quantities amount to the minimum allowed purchasing quantity. If e.g. the optimal length of order cycle exceeds single time intervals $t_i$, then a consideration of more frequently appearing ordering costs or a lower overall inventory by dissolution of uncertainty has to be done. The more time intervals $t_i$ defined, the less risks of high storage might occur. An other cost driver is a display of one product’s ascending sorted materials’ replenishment lead times over their cumulated order value in a so called replenishment cost function. The more concave the devolution of the curve, the more dissolving of uncertainty plays a role for reducing risks.

By comparison of the overall costs, an afterward assignment per material is being provided. It is assumed that in buyer’s other ordering cases (not worst case), the initial proposed ordering policies for the worst case are only suboptimal regarding to ordering costs and not to storage costs. These heuristics must not lead to worse decisions, also due to the upcoming trend of electronically support dispatching, in turn resulting to negligible costs for ordering. These assumptions must have already been a subject to other quantity flexibility contract investigations [Bassok et al. 1997], [Tsay & Lovejoy 1999]. However, mainly three different applicable ordering policies can be assigned to supplier’s purchased materials.
Firstly the bundling timeframes are being optimized by applying the classical MRP-technique calculating backwards dependent demand and offering following bundling timeframes and order frequencies:

1. Order frequency according to single time intervals \( t_j \), mostly for more expensive customer specific materials or lumpy demand.
2. Order frequency and lot sizing resulting by consideration of demand during the optimal length of order cycles for more or less stationary consumption rates.

The first group will be dispatched on a demand basis by appliance of the lot-sizing technique using \( t_i \) as bundling timeframe. Materials of the second group now need to be subdivided into these that are dispatched on a demand basis and those that could be dispatched on a consumption basis.

Our approach represents an all costs considering heuristics. The basic idea is the determination of a critical number of issue quantities. This critical number will be determined on a basis of the classical Economic Order Quantities (EOQ), shown in equation (6):

\[
x_{opt} = \sqrt{\frac{2 \cdot AD \cdot CS}{p \cdot CU}}
\]  

The classical EOQ aims at determining economic reasonable batch sizes. The ordering quantity \( x_{opt} \) for each material balances materials’ specific costs for ordering and storage by above equation [Andler 1929]. \( AD \) represents an annual demand, in this case split up into half-year consumption and half-year demand in the future, in order to consider mid-term volatilities. \( CS \) are the material specific setup and ordering costs per procurement, \( CU \) marks the costs per unit, and \( p \) constitutes the material specific annual inventory interest rate, due to different handling, storage or quality insurance costs. Extensions of classical EOQ, taking into account stockouts [Churchmann 1961], discounts [Candea 1984], [Hartmann 2002], or obsolescence risks [Iliev & Jeck 2004] should be applied. For assigning materials to demand and consumption based dispatching firstly, a deviation factor \( d \) as ratio of average storage (half lot size in average on stock) and ordering costs (as ratio of annual demand and lot size multiplied with the costs for setup) for each material has to be determined, also in order to take deviations from EOQ into account.

\[
d = \frac{p \cdot CU}{2 \cdot CS} \cdot \frac{x^2}{AD}
\]  

In case of no necessary revision of the optimal batch sizes, the deviation factor \( d \) turns into 1. Based on optimal batch sizes \( x \), the annual costs per material for a potentially consumption based disposition have to be calculated and compared with the costs per material and year for a potentially demand based disposition assuming an average issue quantity \( \lambda \). The issue quantity \( \lambda \) serves as upper or lower bound, depending on the assignment question. Quantity \( \lambda \) represents the average issue quantity, above which a demand oriented and under which a consumption oriented dispatching strategy is surely more cost optimal. Its value is being compared with the real appeared demand \( \mu \) that is measured during a planning timeframe, whereby \( N \) represents the number of consumptions \( y_j \) for each material. The observed average issue quantity \( \mu \) herewith is:

\[
\mu = \frac{\sum_{j=1}^{N} y_j}{N} \quad ; \quad y_j > 0
\]  

Assuming more or less steady demand, the costs per material and year for a consumption based dispatching \( c_C \) amount to the sum of costs for ordering and storage:

\[
c_C = \frac{AD}{x} \cdot \left( \frac{CS}{x} + \frac{p \cdot CU}{2 \cdot AD} \cdot \frac{x}{AD} \right) = \frac{AD}{x} \cdot \frac{CS}{x} \cdot (1 + d)
\]
On the other hand, the annual costs $c_D$ for a demand based dispatching for each material are:

$$ c_D = \frac{CS}{\lambda} \cdot \frac{AD}{\lambda} \tag{10} $$

It is presumed that in case of demand based dispatching, a consumption takes more or less immediately place and that no storage of material is necessary. Limitations on this idealization might be demand forecast errors causing time periods with no consumption and thus resulting inventories. On the other hand, these effects are taken into account by the determination of safety stocks and not by the assignment to dispatching strategies.

The cost comparison and assignment step will be executed, in order to calculate the limit value of number of issue quantity $\lambda$, above which a demand oriented disposition is more cost optimal.

$$ c_D \leq c_C $$

$$ \Leftrightarrow \lambda \geq \frac{x}{\sqrt{1+d}} \tag{11} $$

For assignment, calculated $\lambda$ is being compared with the real measured average issue quantity $\mu$.

$\mu < \lambda \Rightarrow$ consumption based dispatching

$\mu \geq \lambda \Rightarrow$ demand based dispatching

An average higher consumption quantity stands for lumpy demand and serves as decision criteria for choosing dispatching strategies. Due to the fact, that ERP-systems cannot provide two different dispatching strategies for one material, the boundary for segmentation can be sharply formulated as mentioned above. Alternatively, the number of issue quantities can serve as decision heuristics by inserting equation (8) in (11). The critical number of issue quantities per material follows following expression:

$$ \lambda = \frac{\sum_{j=1}^{N} y_j}{N} = \frac{AD}{N} \geq \frac{x}{\sqrt{1+d}} $$

$$ \Leftrightarrow N \leq \frac{AD}{x} \sqrt{1+d} \Rightarrow demand\ based\ dispatching \tag{12} $$

If any material has been taken out of storage more often than $N$, seen in equation (12), then it is more cost optimal on a consumption basis.

By assigning materials to above dispatching rules, a cost and inventory risk optimal dispatching is guaranteed. The main benefit of this approach is besides a minimization of occurring market risks on supplier’s side, a precise and valuable advice for parametrizing the ERP-system and also for negotiations of release ordering to suppliers, that might also lead to negotiating contracts. By setting new parameters $p$, $d$, $\alpha(t_i)$ and $\omega(t_i)$, decisive answers to what-if-scenarios are being transparently given by evaluating parameter settings’ impact on all relevant costs. Implications on contractual agreements can thereby be discussed effectively and tangibly.
4 Case Study

To illustrate our methodology we want to present in the following an appliance of it in the high-tech-sector. The company is a so called Electronic Manufacturing Service (EMS-) Provider. Not only, but especially the EMS-industry copes with challenges of increasing replenishment lead times towards their suppliers and shorter claimed delivery lead times towards their customers as well as with highly insecure market environments arising from many product variants and volatile customer demand.

The example demonstrates the calculation of costs for provided flexibilities of one product to their customer. By different scenario configurations several cases were calculated. The treated product showed a convex replenishment cost function, meaning that the higher materials replenishment lead time accrues to be, the lower the purchasing costs per part tend to be. The planning timeframe was half a year with \( n=2 \), \( p=1 \), and variation of delay time \( d \) in months accounted up to \( n \) as well as the varied flexibility vector \( \alpha(t_i)=[0, 0.1u] \) and \( \omega(t_i)=[0, 0.1u] \) with \( u = 0, \ldots, 4 \).

The altitude of the baseline interestingly did not play a significant role. One could think, that the more, one material is built in different products, the more a baseline variation upwards (downwards) shows an increased (decreased) optimal length of order cycle and hence higher (lower) risks of storage and obsolescence. Due to the fact that the risk is always relative to the best case (see formula (4)), a baseline variation of up to 100% was not significant to costs. Of course, considering only customer specific materials, then baseline variations do not play a role. Figure 5 shows the additional surcharge costs per part for these thirty-five possible contract agreements.

![Figure 5: Costs for provided supply flexibility](image)

Furthermore, it was assumed that after one planning timeframe the finished goods inventory does not play a significant role. It is presumed to ask the customer to adjust his baseline according to too many in advanced produced products, also due to the transparency of inventories throughout the supply chain. The additional costs therefore indicate the costs for inventories within one planning timeframe. As it was expected, due to the convex replenishment cost function, the costs for delaying increased with declining gradient according to the delay time. In contrast the costs for provided volume flexibility increased with incremental gradient, due to more expensive materials needed to be stored in advance. However, the gradient would have been even higher, if an optimization of order policies, induced by dissolved uncertainties after \( t_i \), would not have been possible. The order bundling
strategies were as follows: 19% of the material needed to be ordered according to single time intervals \( t_j \) and circa a fourth of remaining 81% of all materials could be dispatched on a consumption basis. The main benefit of presented approach is that the company is able to offer a high fill rate with short lead times and an appropriate flexibility to his customer. The model served as decision support for both parties negotiating contract clauses with a mutual understanding of the cost consequences. Furthermore, buyer’s visibility over his order balance supports him tangible in placing future baselines and cumulative order volumes. Nevertheless an important success factor is constituted by an installed mutual controlling-process that has to be implemented at both sides, in order to measure one’s reliability in ordering and delivery.

5 Conclusions

Our approach for designing and evaluating volume flexibility contracts in supplier-buyer relationships represents a sample of in practice seen coordination policies. The main benefit of the method described is, that it is comprehensible for both parties and shows a strong customer orientation. Main enhancements to existing approaches comprise besides a qualified evaluation of inventory risks, advices for the parametrization of ERP-systems. The drawback of not allowing buyers to update their forecasts more flexible has been compensated by the possibility to offer a granted time flexibility to the customer which in turn leads to tangible order balances for both sides and an efficient controlling. This initial attempt to analyze shown kinds of contracts serve as basis for standardized contracts. The assumed limitation of deterministic demand shows high practicability and acceptance. Implementations in other industries or companies need to justify the potential for standardization.

Our work can be meaningful extended by building up different heuristics. One could be that replenishment cost functions, together will condensed bill of materials and contract clauses directly lead to approximately sufficient solutions for cost transparency. An other could comprise upper levels of baseline variations, above which new surcharges have to be taken into account. This would be due to very high variations and high volume flexibilities. An other reasonable heuristics could comprise a functional interrelation of number of updating order intervals and the flexibility parameters of the contract clauses. Additionally unutilized capacities or overloads in production with their effect on lead times, fill rates and costs could be investigated. Many questions are left unanswered, however and further research is needed.

6 References

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