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THE ROLE OF FORECAST DATA AS A RISK REDUCING MEASURE

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ABSTRACT : *In order to realise just-in-time concepts in supply chains, customers usually have to provide information about their required materials to their suppliers. Now the problem arises what forecast data the customer should report to his suppliers when the future demand of his outlet isn't exactly known. This demand usually is subject to a probability distribution. Without any restrictions, the customer will always report those forecast data that correspond to the possible maximum demand of his outlet in order to keep flexibility. This information won't be useful to the supplier. Therefore, the customer usually is engaged to purchase, within certain limitation periods, that quantity of parts he reported. Otherwise he has to do an adjustment payment. This paper analyses what forecast data the customer should report, which amount the supplier should take into consideration in light of the customer's intentions and what release order quantity the customer should realise having previously reported the forecast data.*

KEY WORDS : *Risk reduction, Risk Measures, Forecast Data, Supply Chain Management, Customer Supplier Relationship Management*

1. PROBLEM

Supply networks are "loose" conjunctions of legally independent enterprises linked by the relationships between customers and suppliers. (cf. Cooper and Ellram 1993, p. 13 et sqq.; Brueckner et al. 2005, p. 316; Harrison 2005, p. 4.) The aim of those networks is to improve the material flow in the value chain and to achieve synergetic effects by coordinated activities. (cf. McGovern et al. 1999, p. 152 et sqq.) There exist several concepts that aim for a closer cooperation of the network participants. E.g. within the Vendor Management Inventory VMI a supplier is managing the stock of his customer. The advantage is that the supplier is getting immediate sales information but he is taking nearly the whole risk of out-of-stock costs. This situation is only realistic if the customer is a predominant partner. Otherwise, the supplier won't accept taking the whole risk. Further more, not only sales information of the past but also forecast data of the customer would be valuable information to the supplier. Only in case, the supplier is able to produce just-in-time the sales information are sufficient. But then, more restrictive assumptions must hold like light spreading sales volumes, short lead times and low setup costs. Regarding the Continuous Planning Forecasting and Replenishment CPFR for example the supply chain partners are collaborating by forecasting and planning together. Then, the risk of forecasting is often shared by the partners equally. Such a tight relation between partners often cannot be realised because the information needed are very sensitive and competitors in the same supply network may benefit from these information. (cf. Hallier 1999, p. 57)

Therefore, one of the most popular concepts consists in systematically sharing (forecast) data concerning the estimated quantity of materials that is required within the following periods (cf. Grünewald 1991, p. 218 et sqq.) in order to eliminate information asymmetries and uncertainties. (cf. Fiala 2005, p. 419; Simon 1989, p. 457 et sqq.; Zäpfel and Piekarz 1996, p. 21.)

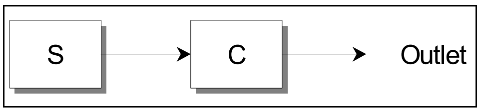

Figure 1: Underlying Network Structure

The following analysis underscores a simple network structure (see Figure 1) with two enterprises, one supplier S and one customer C, the latter of which has to face uncertainties in his outlet. (cf. Tsay et al. 2002, p. 304) We will discuss how the costumer should determinate the forecast data and which impact the provision of forecast data has on the supplier's planning. Furthermore, the customer's decision on the effectively required quantity should be surveyed, if he reported certain forecast data to the supplier. In contrast to some other papers, we will focus on both sides (cf. Eppen and Iyer 1997), the released quantity will not be limited (cf. Tsay 1999, Bassok and Anupindi 1995 and 1997) and there will be a penalty for making adjustments (cf. Tsay 1999, Milner and Rosenblatt 1997).

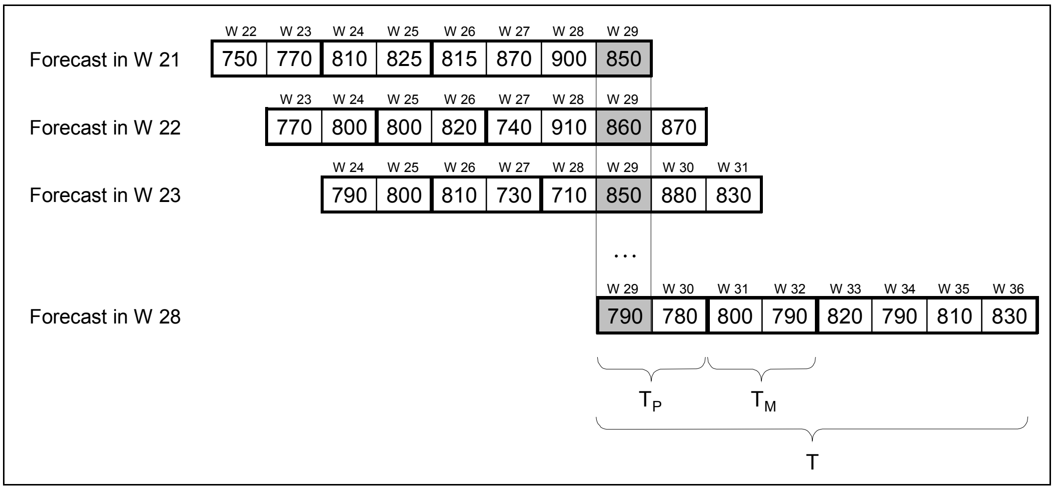

Figure 2: Typical planning horizon

In the underlying network structure, the supplier S delivers one product to the customer C, who operates on the outlet. The sales forecast of C's outlet is one parameter of his production plan. From this, he quantifies the future release orders of the preliminary product. He reports these forecast data to the supplier, who uses them to plan his production and supply activities. (cf. Lackes 1998, p. 293 et sqq.) The forecast covers a planning horizon T, separated in subperiods 1, 2,…,T. In case, the planning horizon T is lower than the supplier's planning horizon T_S, (scaling is assumed to be equal), S has to plan the periods T-T_s by himself. In line with revolving planning, C's sales forecast, which is getting more precise in shorter forecasting horizons, may cause modifications in the corresponding forecast data for specific periods in the later planning (see Figure 2). (cf. Zäpfel and Piekarz 1996, p. 22.)

Within the planning horizon, there are two concerted points in time T_M and T_P with $1 \leq T_P < T_M \leq T$, where modifications to forecast data are limited and cause compensation. Typically, these are the point of go-ahead for purchase of input materials (material release point T_M) and the point of production go-ahead (production go-ahead point T_P). (cf. Grünewald 1991, p. 218 et sqq.) Thus C has to bear the risk of reporting forecast data to S based on an uncertain sales forecast of his outlet. Because L is geared to C's sales forecast, his risk is minor. However, for S the risk of (possibly short term) modifications to the forecast data remains. (cf. Meyer et al. 1988, p. 41; Simon 1989, p. 456.) Although the customer takes one part of the commercial risk through compensation agreements, a certain part remains at the supplier, which he has to consider in his planning.

Below, the following problems shall be discussed:
1. Which forecast data should the customer C report to the supplier S in order to gain maximum flexibility with regard to his uncertain outlet?
2. Which quantity should the supplier S consider in his primary requirements planning, if he knows from experience that the forecast quantities reported by C tend to be too high, that they can be revised and that the effectively required quantity can differ from the reported forecast quantity?
3. Which quantity should the customer C effectively require when the point of demand is reached, bearing in mind his previously reported forecast data and the fact that his sales forecast has become more precise in the meantime?

2. DETERMINATION OF FORECAST DATA

The customer has to deal with the question of which quantity x_F of the preliminary product he should report to his supplier as forecast data. On the one hand, he wishes to gain certainty of supply concerning his preliminary product. On the other hand, he wants to avoid an adjustment payment and the supplier can prepare for this demand so that the supplier's planning situation is improved by the forecast data. This may lead to better purchase conditions for the customer. Aggregatively the customer doesn't precisely know the exact end customer demand. His expectations are more vague the more the the sales period lies in the future. (cf. Lackes 2004, p. 408.)

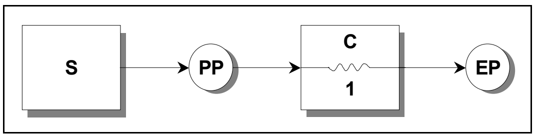

Figure 3: Cumulated gozintograph

For simplicity we assume w.l.o.g. that the (possibly accumulated) production coefficient between the preliminary product and the customer's end product is 1 (see Figure 3). This means that the ratio between the amount of the end product EP and the amount of the preliminary product PP is 1. Further more, we assume that the customer doesn't hold a stock for preliminary products as it can be seen in the automobile industry where just-in-time delivery of many component groups is state of the art. Instead, the customer always manufactures the end product using the total amount of preliminary products and then he only stores his end product.

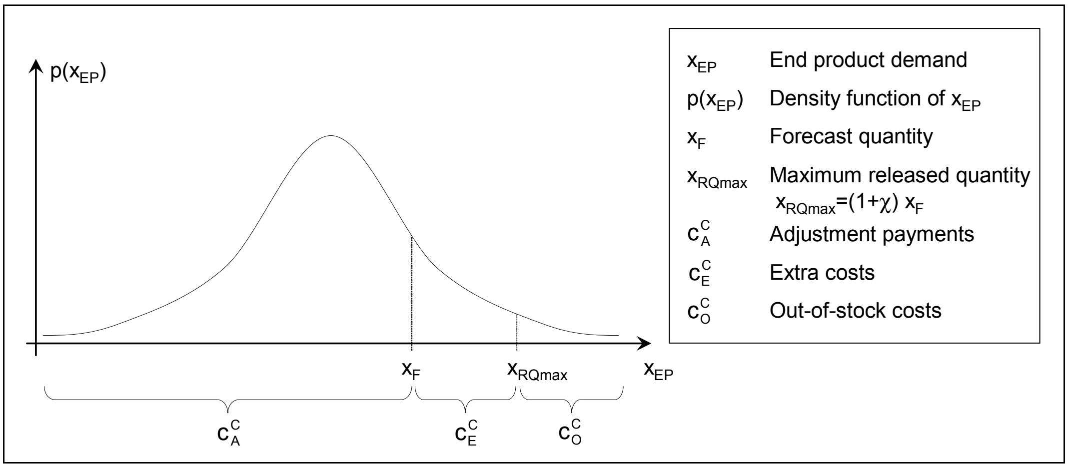

Figure 4: Cost components and density function of the end product demand x_{EP}

This assumption leads to the fact that customer C determines his end product demand and reports this demand as forecast data to his supplier S. That has barely an effect on the discussion because considering the customer's stock will only lead to a (nearly fix) discount of the end product demand when determining the forecast data.

The customer C has to face an uncertain demand of his end product on his outlet (cf. Tsay 1999, p. 1345). Being in a mass market the demand of a period isn't influenced by prior periods if we exclude saturation of the market. Historic market data will help in forecasting the total market demand and often we can assume a nearly constant market share but due to the unknown behaviour of all market members there is no causality between two demands of different periods.

Let $x_{EP,t}$ be the end product demand on C's outlet in a period $t = 1, \ldots, T$. Then for $x_{EP,t}$, which is a random variable with expectation $\mu_{EP,t}$ and standard deviation $\sigma_{EP,t}$, holds:

1. The random variables $x_{EP,t}$ are each independent.
2. $\frac{\sigma_{EP,t}}{\mu_{EP,t}} < \frac{\sigma_{EP,t+1}}{\mu_{EP,t+1}}$ i.e. the distribution of density function decreases in time.

Following categories of cost matter for C for the determination of forecast data for any period t = 1,…,T (see Figure 4): (cf. Corsten 2004, p. 446; Kilger 1986, p. 352; Reichmann 1997, p. 72 et sqq.)

– Out-of-stock costs c^C_O, in consequence of underestimated end customer demand and not accommodating demand, so for $x_{RQmax} \leq x_{EP}$.
– Adjustment payment c^C_A to supplier S due to released quantities of the preliminary product less than the reported forecast data, so for $x_{EP} < x_F$. (These costs can be differentiated after the forecast coverage relevant for t, see below.)
– Extra costs c^C_E for released quantities greater than the reported forecast data. Up to a certain maximum x_{RQmax}, this may be possible, so for $x_F \leq x_{EP} < x_{RQmax}$.

Since the released quantity is determined after the forecast data it is not included in the cost consideration. This indeed leads to the fact that the adjustment is not correctly calculated at all, because the choice of the released quantity as a degree of freedom is not considered. But as the released quantity, respectively its determinants are unknown at the time, the forecast data is determined, a simultaneous solution had to be used instead of a successive planning. (cf. Corsten 2004, p. 509 et sqq.)

If C's release order quantity is lower than the quantity of his forecast x_F, he has to do an adjustment payment to L. We assume this payment c^C_A to be lower than C's storage costs for the preliminary product. Thus, there is no inducement for C to do a release order that exceeds his demand just because of his prior forecast data. More over we assume C's out-of-stock costs c^C_O to be greater than the adjustment payment c^C_A, otherwise release orders greater than x_F, would not make any economic sense.

If the released quantity x_{RQ} is greater than the forecast quantity x_F because of a greater end product demand, additional needs can be satisfied up to a maximum released quantity x_{RQmax} for greater costs c^C_E (extra costs). The maximum released quantity x_{RQmax} is supposed to be dependent on reported forecast quantity x_F, which can be exceeded by the released quantity up to a certain percentage χ. This means $x_{RQmax} = (1+\chi)\cdot x_F$. Every additional end product demand cannot be satisfied and therefore leads to out-of-stock costs.

The determination of the "optimal" forecast quantity is a decision problem under risk because the cost function contains a non-deterministic element, respectively a random variable. (cf. Dinkelbach 1982, p. 57 et sqq.) Therefore we have to use a substitution model that reflects the risk affection of the decision-maker, in this case the authorised agent of C, in order to determine the concrete forecast quantity. If the customer C orientates the decision risk neutral to the expectation of these costs (cf. Dinkelbach 1982, p. 74 et sqq.; Schneeweiss 1967, p. 48 et sqq.), we get (for simplicity the period index t is left out):

$$
\begin{aligned}
C^C(x_F) = & \int_0^{x_F} c_A^C \cdot (x_F - x_{EP}) \cdot p(x_{EP}) \cdot dx_{EP} \\
& + \int_{x_F}^{x_{RQ\max}} c_E^C \cdot (x_{EP} - x_F) \cdot p(x_{EP}) \cdot dx_{EP} \\
& + \int_{x_{RQ\max}}^{\infty} c_O^C \cdot (x_{EP} - x_{RQ\max}) \cdot p(x_{EP}) \cdot dx_{EP}
\end{aligned}
\tag{1}
$$

This cost expectation has to be minimised and leads to the following conditional equation with density function p(x) and distribution function P(x):

$$
\begin{aligned}
0 = & c_A^C \cdot \left(P(x_F) - P(0)\right) \\
& + c_E^C \cdot \begin{pmatrix} P(x_F) - P((1+\chi) \cdot x_F) \\ + p((1+\chi) \cdot x_F) \cdot \chi \cdot (1+\chi) \cdot x_F \end{pmatrix} \\
& + c_O^C \cdot \left((1+\chi) \cdot P((1+\chi) \cdot x_F) - (1+\chi)\right)
\end{aligned}
\tag{2}
$$

The greater the out-of-stock costs c_O^C are the greater the difference between the expected sales volume of the end product $E(x_{EP})$ and the optimal forecast quantity. This means that the customer C reports forecast data too high compared to the sales forecast of his outlet. (cf. Grünewald 1991, p. 219) If we assume the customer C to avoid risk, which is very realistic, this effect is enhanced. Then the minimum of the cost expectation is no longer the only decision criteria but additionally the standard deviation or rather the variance of the costs. (cf. Dinkelbach 1982, p. 84 et sqq.)

Adjustment payments act oppositely to out-of-stock costs. The lower the payment is in relation to the out-of-stock costs, the greater the forecast data are. This effect can be observed in sensitive outlets where sales orders will be lost if a fast delivery is impossible. In this case, the customer C safeguards himself by reporting very high forecast data (compared to the expectation). The possibility of obtaining more preliminary products than those reported provides some *a posteriori* room for manoeuvre to the customer C. This leads to more "realistic" forecast data because the customer C won't have to build a safety stock a priori by reporting relatively high forecast data.

3. SUPPLIER'S USE OF FORECAST DATA

From practical experience, the supplier S knows that most times the forecast data are too high because the customer C wants to gain a certain potential of flexibility. If S discovers a bias and knows about the correct value he has to correct the forecast data by using this bias. (cf. Kakouros et. al. 2002). But in most cases the correct bias is unknown. Hence S has to think about a "subjective" correction factor concerning the customer's forecast data.

In analogy to our considerations about the customer's sales forecast, the released quantity x_{RQ} is a random variable whose probability distribution has the expectation μ_{RQ} and the standard deviation σ_{RQ}. (see Figure 5) Because the forecast data $x_{F,t}$, with t = 1, …, T, build a time-dependent data vector, we can assume:

1. Every $x_{F,t}$ is a value of the random variable $x_{RQ,t}$ from the estimated distribution with expectation $\mu_{RQ,t}$ and standard deviation $\sigma_{RQ,t}$.
2. $x_{F,t} = \mu_{RQ,t} + \alpha \cdot \sigma_{RQ,t}$
3. $\alpha_t < \alpha_{t+1}$ i.e. the forecast data differ not so much from the expectation if the planning period is short.
4. $\frac{\sigma_{RQ,t}}{\mu_{RQ,t}} < \frac{\sigma_{RQ,t+1}}{\mu_{RQ,t+1}}$ i.e. distribution of density function decreases in time.
5. The random variables $x_{RQ,t}$ are each independent.

Now the supplier S has to deal with the problem of how to handle these forecast data within his material requirements planning and job order planning. Concretely he has to decide which quantity $x_{P,t}$ he should provide to the customer C because of the reported forecast data. This equals the customer independent requirements in the material requirements planning. The concrete quantity to be produced is calculated later in consideration of disposable inventory using methods and data (storage costs etc.) of lot-sizing. (cf. Corsten 2004, p. 452 et sqq.; Fandel et al. 2006, p. 308) Taking into account the reported forecast data and a probability distribution about the future released quantity the following cost and revenue components are relevant (cf. Corsten 2004, p. 446; Kilger 1986, p. 352; Reichmann 1997, p. 397) to optimising S's primary requirements quantity $x_{P,t}$ (for simplicity, the period index t is again left out):

Cost components:

- Storage costs c_S^S for quantities not purchased by C, so for $x_P > x_{RQ}$.
- Out-of-stock costs c_O^S occurring in case C wants to purchase more than S had planned, so for $x_P \leq x_{RQ} \leq x_F$.

Revenue components:

- Adjustment payment c_A^C C has to pay in case the released quantity is lower than the forecast quantity resp. the primary requirements quantity, so for $x_F \geq x_{RQ}$ resp. $x_P > x_{RQ}$.
- Extra revenue c_E^C generated for released quantities greater than x_F, so for $x_F < x_{RQ} \leq (1+\chi) \cdot x_{RQ}$.

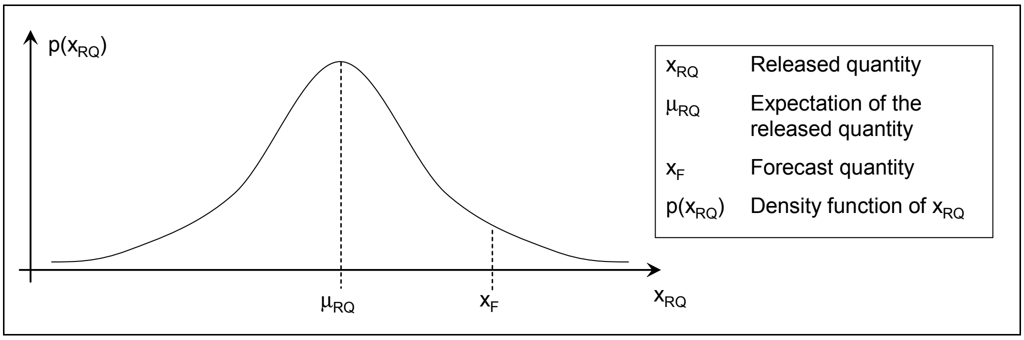

Figure 5: Density function of the released quantity x_{RQ}

Adjustment payments by the customer C have to be considered as far as the regarded period lies within the agreed release period. This compensation is calculated as the product of the agreed adjustment payment per unit of the release period that is reached and the difference between the primary requirements quantity and the released quantity. The more the release period lies in the future the lower is the piece compensation $c^{C}_{A,R}$ for this period R ($c^{C}_{A,R} > c^{C}_{A,R+1}$). Extra revenue only occurs in case the customer C is able to purchase more than he reported before. This is only relevant when the supplier S can provide this quantity. As an incentive for C to purchase a quantity $x_{RQ} > x_F$ the extra revenue c^{C}_{E} has to be lower than the out-of-stock costs c^{C}_{O}, which the customer C has to bear in mind.

However, even if the released quantity is greater than the primary requirements quantity, it may be covered under certain circumstances. This may happen because, due to the supplier's lot-sizing (cf. Fandel et al. 1994, p. 156), a greater released quantity may be provided than the primary requirements quantity suggests. But within successive planning – as we have here – the lot-sizing and job order planning is done after the primary requirements planning (cf. Lackes 2004, p. 407; Zäpfel and Piekarz 1996, p. 33 et sqq.).

To determine the cost optimal primary requirements quantity we have to distinguish whether the primary requirement quantity is lower or greater than x_F. In case $x_P \leq x_F$, no additional revenue can be generated. (see Figure 6). Storage costs and adjustment payments can be summarised such that the latter seem to be a reduction of the storage costs, so effectively $c^{S}_{S} - c^{C}_{A,R}$. For simplicity, the period index R will be omitted in the following. In case $x_P > x_F$, additional revenue can be generated (see Figure 7). Out-of-stock costs do not appear and adjustment payments only occur up to x_F, not up to x_P as in the first case. If we are again geared to the expectation of costs, as a risk neutral decision maker would do, we get the following cost functions:

$x_P \leq x_F$: (3a)

$$C^{S}_{F}(x_P) = \int_{0}^{x_P} (x_P - x_{RQ}) \cdot (c^{S}_{S} - c^{C}_{A}) \cdot p(x_{RQ}) \cdot dx_{RQ} + \int_{x_P}^{x_F} (x_{RQ} - x_P) \cdot c^{S}_{O} \cdot p(x_{RQ}) \cdot dx_{RQ}$$

$x_P > x_F$: (3b)

$$C^{S}_{F}(x_P) = \int_{0}^{x_P} (x_P - x_{RQ}) \cdot c^{S}_{S} \cdot p(x_{RQ}) \cdot dx_{RQ} - \int_{0}^{x_F} (x_F - x_{RQ}) \cdot c^{C}_{A} \cdot p(x_{RQ}) \cdot dx_{RQ} - \int_{x_F}^{x_P} (x_{RQ} - x_F) \cdot c^{C}_{E} \cdot p(x_{RQ}) \cdot dx_{RQ}$$

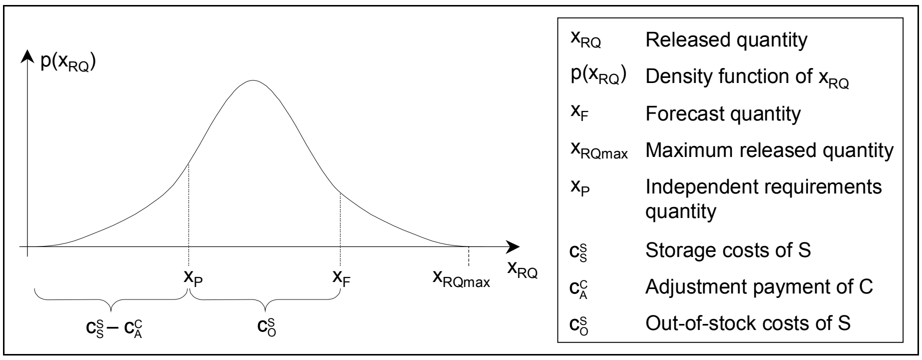

Figure 6: Cost and revenue components and density function of the released quantity x_{RQ} of the preliminary product for $x_P \leq x_F$

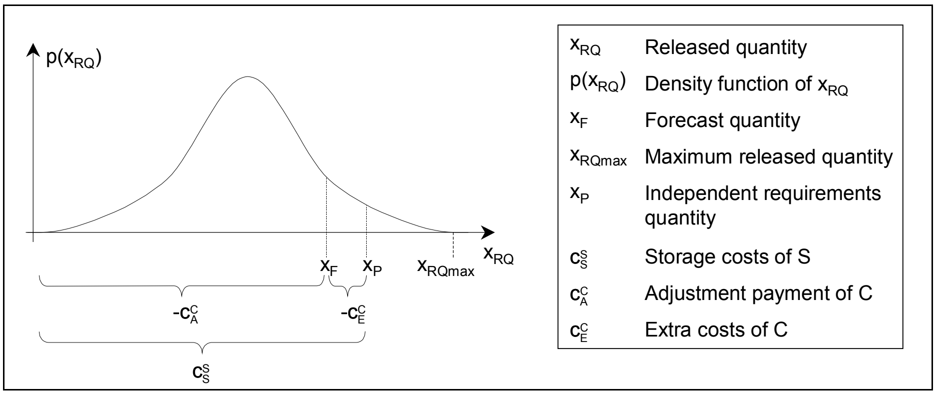

Figure 7: Cost and revenue components and density function of the released quantity x_{RQ} of the preliminary product for $x_P > x_F$

At this we suppose that supplier S only gets adjustment payments in case the released quantity is lower than the primary requirements quantity and it does not extend this difference. This implies that the supplier S doesn't hide information about his scheduled primary requirements quantity x_P, otherwise he may possibly get greater adjustment payments at an altitude of $x_F - x_{RQ}$. Hiding these information about x_P is quite easy for the supplier S because this origin information is not visible in warehouse stock and job order planning. But in the sense of a trustful co-operation in a supply network, we assume that hiding this information won't take place. The minimisation of the cost function $C_F^S(x_P)$ results in:

$$P(x_P) = \frac{P(0)\cdot\left(c_S^S - c_A^C\right) + P(x_F)\cdot c_O^S}{c_S^S + c_O^S - c_A^C} \qquad (4a)$$

$$0 = c_S^S \cdot \left(P(x_P) - P(0)\right) - c_E^C \cdot \left(p(x_P)\cdot(x_P - x_F)\right) \qquad (4b)$$

The customer C and the supplier S have to negotiate the adjustment payments c_A^C for lower released quantities. The greater they are, the more cautious the customer C will calculate his forecast data to avoid them. The intention is to guarantee the supplier S a kind of indemnity for additional costs caused because he relied on the forecast data and provided according quantities of the preliminary product. Hence it is reasonable to orientate the adjustment payments to the supplier's additional storage costs. If the supplier S succeeds in completely shifting the storage costs to C ($c_S^S - c_A^C = 0$), then this affects that he doesn't schedule less than the forecast data. Thus, the supplier S eliminates the risk of shortfalls and according out-of-stock costs, as the customer has to bear storage costs if he purchases less than the forecast data. But it is also conceivable that because of his market power, the customer C enforces very low adjustment payments (0 in the extreme) in comparison to the supplier's storage costs. Then, the customer C doesn't have to fear any consequencies and will tend to report forecast data near his maximum distribution expectation. Furthermore, the supplier S beholds this forecast data as very invalid and amends them down. In the extreme, this information is completely useless to him.

4. DETERMINATION OF THE RELEASED QUANTITY

4.1. Overview

When reaching the preliminary product's release point, which is depending on its estimated transport time and the lead time of the end product, the customer C has to ask himself which quantity of the preliminary product he should really purchase. From his point of view, the situation is characterised as follows: On the one hand, he has already reported forecast data to the supplier – within revolving planning at different points in time possibly different quantities for the same period – and on the other hand, he meanwhile gained more precise information about his real end product demand. With reporting the forecast data the customer C accepted certain purchase respectively adjustment commitments. These have to be considered in the actual decision on the released quantity. In the following, we assume that out of the series of reported forecast data concerning a certain demand period one representative (possibly the most actual value or a weighted average value) x_F is chosen.

We can subdivide the situation on the customer's outlet into the two following cases:

1. The end product demand is completely known, this means that the release order of the preliminary product can be done after the customer C knows his end product demand.
2. The end product demand is not completely known and is subject to a probability distribution, whose statistical spread is lower than it was by the time the forecast data has been determined and reported. (cf. Lackes 2004, p. 408.) This means that compared to case 1 the customer C is in the less comfortable situation that he has to make a decision about the release order without knowing his own end product demand.

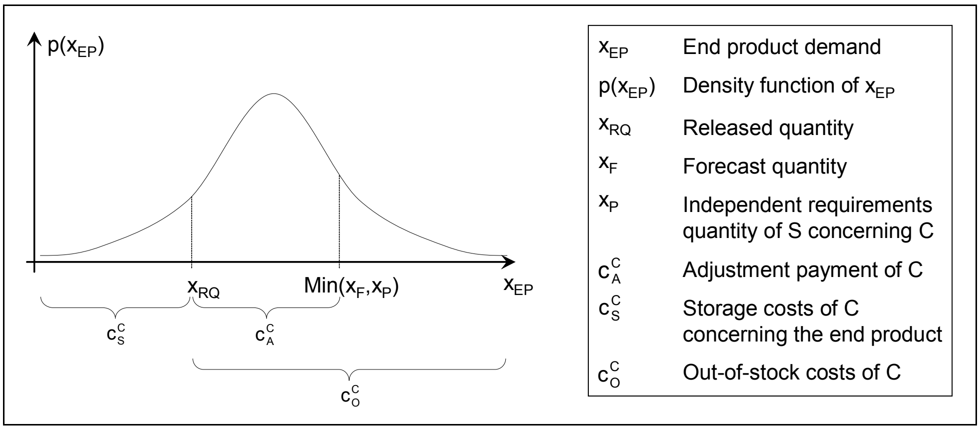

Figure 8: Cost components and density function of the end product demand x_{EP} for $x_{RQ} \leq x_F$

4.2. Certain end product demand

In the first case all determinants for the calculation of the optimum released quantity are known. If the forecast data x_F is lower than the demand quantity x_{EP}, the demand quantity is purchased, if the extra costs for quantities greater than the forecast data are lower than the out-of-stock costs. Otherwise, the forecast quantity is purchased. If the forecast data x_F is greater than the demand quantity x_{EP}, the demand quantity is purchased if the storage costs for the end product are greater than the adjustment payment. (This de facto means that the supplier has to store the preliminary product.) Else, the forecast quantity is purchased, directly used to manufacture the end product and therefore stored in the end product stock. Thus we get the following conditional equations:

$$x_F \leq x_{EP}: \quad x_{RQ} = \begin{cases} x_{EP} & \text{for } c_E^C \leq c_O^C \\ x_F & \text{for } c_E^C > c_O^C \end{cases}$$
$$x_F > x_{EP}: \quad x_{RQ} = \begin{cases} x_{EP} & \text{for } c_S^C > c_A^C \\ x_F & \text{for } c_S^K \leq c_A^C \end{cases} \qquad (5)$$

4.3. Uncertain end product demand

In case the exact demand of the end product is unknown the demand quantity x_{EP} is subject to a probability distribution, which in general spreads less than the distribution used earlier to specify x_F. We need the following four cost components to determine – the assumptions made in earlier chapters may still hold – the cost optimal released quantity of the preliminary product (see Figure 8 and Figure 9):

– Storage costs c_S^C for the end product in case the released quantity x_{RQ} of the preliminary product and thus (because of the assumed cumulated production coefficient of 1) the quantity of the manufactured units of the end product is greater than the demand, thus for $x_{EP} \leq x_{RQ}$.
– Out-of-stock costs c_O^C for the demand of the end product not supplied on the outlet, thus for $x_{RQ} \leq x_{EP}$.
– Adjustment payment c_A^C for quantities of the preliminary product which are not purchased although the reported forecast quantity was greater, thus for $x_{RQ} < x_F$.
– Extra costs c_E^C for quantities of the preliminary product, purchased although the reported forecast data were lower, thus for $x_F < x_{RQ}$.

When optimising the released quantity adjustment payment and extra costs exclude each other. Adjustment payment only appears if the released quantity x_{RQ} is lower than the forecast data (see Figure 8). Extra costs instead only occur if the released quantity is greater than the forecast data (see Figure 9). So we first have to calculate the cost optimum for both cases and afterwards determine the general optimum from this.
Due to the assumptions made in previous chapters, adjustment payment only accrues for released quantities lower than x_F, but never above the supplier's scheduled quantity x_P. This means that it results from the difference between the minimum of x_P and x_F and the chosen released quantity x_{RQ}.

$$\text{Adjustment payment} = c_A^C \cdot \left(\text{Min}(x_P, x_F) - x_{RQ}\right) \qquad (6)$$

Instead the additional payment is only based on the forecast data. Depending on the released quantity x_{RQ} of the preliminary product we get the following functions of the cost expectation:

$x_{RQ} \leq x_F$: (7a)

$$C_{RQ}^C(x_{RQ}) = \int_0^{x_{RQ}} (x_{RQ} - x_{EP}) \cdot c_S^C \cdot p(x_{EP}) \cdot dx_{EP}$$
$$+ \int_{x_{RQ}}^{\text{Min}(x_P, x_F)} \left(\text{Min}(x_P, x_F) - x_{RQ}\right) \cdot c_A^C \cdot p(x_{EP}) \cdot dx_{EP}$$
$$+ \int_{x_{RQ}}^{\infty} (x_{EP} - x_{RQ}) \cdot c_O^C \cdot p(x_{EP}) \cdot dx_{EP}$$

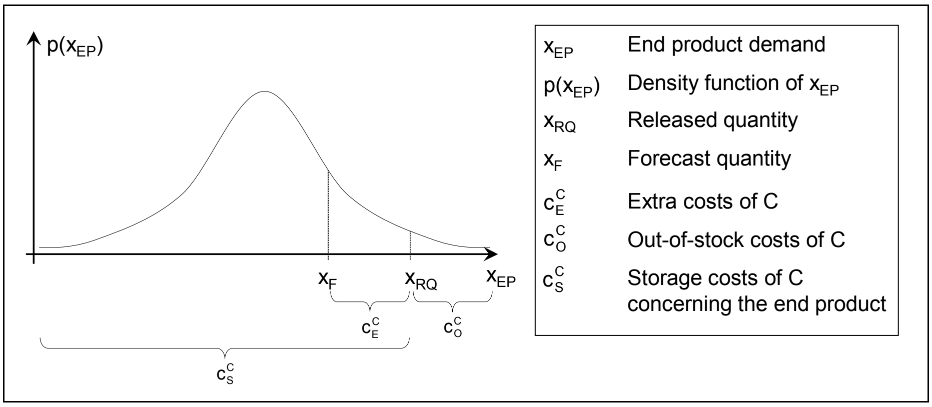

Figure 9: Cost components and density function of the end product demand x_{EP} for $x_{RQ} > x_F$

$x_{RQ} > x_F$: (7b)

$$C^C_{RQ}(x_{RQ}) = \int_0^{x_{RQ}} (x_{RQ} - x_{EP}) \cdot c^C_S \cdot p(x_{EP}) \cdot dx_{EP} + \int_{x_F}^{x_{RQ}} (x_{RQ} - x_F) \cdot c^C_E \cdot p(x_{EP}) \cdot dx_{EP} + \int_{x_{RQ}}^{\infty} (x_{EP} - x_{RQ}) \cdot c^C_O \cdot p(x_{EP}) \cdot dx_{EP}$$

These two functions have to be minimised according to the released quantity x_{RQ} such that we get the following conditional equations:

$x_{RQ} \leq x_F$: (8a)

$$0 = c^C_S \cdot (P(x_{RQ}) - P(0)) + c^C_A \cdot \begin{pmatrix} P(x_{RQ}) - P(\mathrm{Min}(x_P, x_F)) \\ + p(x_{RQ}) \cdot (x_{RQ} - \mathrm{Min}(x_P, x_F)) \end{pmatrix} + c^C_O \cdot (P(x_{RQ}) - 1)$$

$x_{RQ} > x_F$: (8b)

$$0 = c^C_S \cdot (P(x_{RQ}) - P(0)) + c^C_E \cdot (P(x_{RQ}) - P(x_F) + p(x_{RQ}) \cdot (x_{RQ} - x_F)) + c^C_O \cdot (P(x_{RQ}) - 1)$$

For each of the two values of x_{RQ} calculated with the equations (8a) and (8b) we have to determine the costs afterwards. That x_{RQ} that leads to lower estimated costs is the cost optimal released quantity.

5. RESULTS

From all this it follows that additional information between the supply network participants about their dispositions reduces uncertainty. (cf. Lackes 2004, p. 410 et sqq.) Within this paper we examined three decisions occurring in supply networks. First of all, this was the determination of forecast data under the condition that the demand of the customer's outlet is uncertain. Therefore, we developed a conditional equation, which calculates the optimum forecast data assuming a risk neutral decision maker. Secondly, we determined the optimum primary requirements quantity, if the supplier acts risk neutral and the customer provides forecast data. Finally, we described the optimum released quantity the customer should choose bearing in mind that he previously reported some forecast data and that the information about his outlet has become more precise. The participant's risk preferences can easily be modified.

We have pointed out that providing forecast data is useful to the supplier and therefore benefits the whole supply network. Without forecast data the supplier would have to face similar uncertainties as the customer on his outlet and therefore build his own risk-absorbing stock. Because the supplier does not take the forecast data as deterministic values but modifies them from his experience, the situation in the whole supply network improves again. The supplier's modifications act risk-reducing as the supplier's specific situation is included into his consideration of the forecast data. If not, the uncertainties on the customer's outlet would uncontrollable take effect on the supplier.

Room for improvement results from the fact that the customer doesn't only report some forecast data but also the whole estimating of his outlet, i.e. the distribution function of the end customer demand. In this case the supplier doesn't need to speculate which value of the distribution function the customer has chosen as forecast data. Instead he can orientate to the risk information on the end customer outlet. Doing so, several changes in the contract between C and S may occur: If S knows about the outlet demand S's out-of-stock costs c^S_O will increase because he cannot fulfil the demand despite his knowledge about the distribution function. The adjustment payment c^C_A will also increase because know S knows about the correct outlet demand and carries half the risk. Therefore, C has to pay for when he wants to gain more flexibility.

A further risk reduction and further potential of economisation can be achieved by not only reporting data about the estimated demand – against the direction of material flow – but also reporting data about possible supply shortfalls in upstream areas of production – corresponding to the material flow (similar to the concept of message-based production planning). (cf. Lackes 1995, p. 442 et sqq.) Through this, we could achieve that the follow-up costs evoked by one's own decisions but arising externally among other participants of the network, can be included into one's own disposition.

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