INFLUENCE OF RANDOM ORDERS ON THE BULLWHIP EFFECT

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ABSTRACT

Supply chains in industry have a very complex structure. The influence of many parameters is not known. Therefore the control of the orders, material flow and stock is rather difficult. In order to recognize the basic relationships between the parameters, a very simple model was set up. It consists of 4 identical stages. In all stages the stock is closed-loop controlled to a nominal stock. Therefore the only decision which can be made in the entire supply chain is the quantity of an order. In a first simulation run a suitable order strategy will be defined. Good results can be realized, if an order is splitted up in two: A customers order and a stock order. In a second run this strategy will be applied to orders, which contain a seasonal trend an a random part. It will be shown that the bullwhip effect can be minimized with the applied order strategy.

1 INTRODUCTION

Dynamic behavior of the material flow in a supply chain is influenced by the order policy of each particular company of a supply chain. Sometimes, these orders are affected by seasonal trends and random influences. In combination with not defined interaction of all companies the bullwhip effect occurs. It has been described first by (Forrester 1958). It is the increasing of a small variation in the requirements of a customer to an enormous oscillation with the manufacturer at the beginning of a supply chain. In many articles, this phenomenon is only described in general terms without a mathematical definition (i.e. Erlach 2010 and Dickmann 2007). It is questionable if the bullwhip effect can be avoided at all (Bretzke 2008). A mathematical justification for this thesis is not given in that paper.

To minimize the bullwhip effect, cooperation between all members in a supply chain is necessary. Basically, informations about i.e. orders of customers have to be provided to all subsuppliers in the supply chain. Most of the supply chains do not have this kind of cooperation. Therefore in the following examination the particular stages are acting independent.

A very simple model of a supply chain without any cooperation between the particular members has been published on the ECMS2013 (Barbey 2013). The target of this simulation was to develop strategies for a closed-loop control of each stage of a supply chain. These controlling strategies have been applied to a seasonal trend in this simple simulation model. (Barbey 2014).

This model will be used with a controlling strategy, which includes a kind of cooperation between the members of the supply chain (Barbey 2015). The model is designed in the following manner:

The model consists of four identical stages according fig. 1. The behavior of each stage is the same. The time to place an order is 1 time unit (TU). The time for delivery is 3 time units. Therefore the replenishment lead time to fill up the stock for one stage is the sum of both, 4 time units. If a customer places an order, the lead time for the entire supply chain is 16 time units to deliver the material from the very beginning to the end of the supply chain. To be able to fulfill a customers order within the minimum lead time of 4 TU each stage needs a stock. This model is designed according the simple Forrester model.

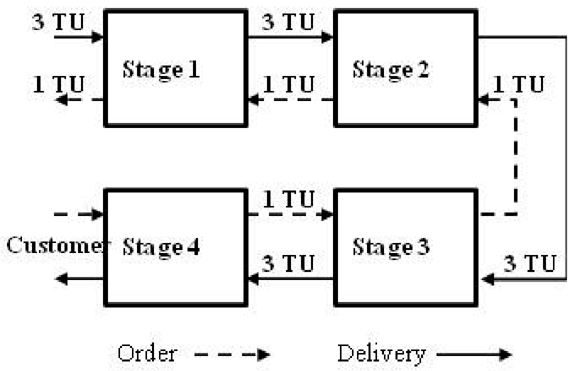

Figure 1: Model of a Supply chain
(TU= time unit)

The only decision, which can be made in this simulation, is to decide about the quantity of the order. This order has two tasks: It fulfills the predecessors order in the supply chain and compensates a difference in the own inventory. The applied controlling strategy for this decision will be described in chap. 2. The decision for an order has been taken each time unit. It is obvious that these parameters do not simulate a real supply chain. Normally the lead time to get material is much shorter than the time for the

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next order. However, this simulation demonstrates with this short order period the bullwhip effect in a more impressive manner.
To demonstrate the bullwhip effect clearly, all other influences like delay in delivery or empty stock have been eliminated.

2 APPLIED ORDER STRATEGY

The dynamic behavior of a supply chain and different order strategies have been discussed in several papers (Barbey 2013 and Barbey 2014).

The order strategy, which is applied in this examination, is described below. The best strategy to fulfill a customers order is:

Order in = order out

This strategy works perfect, if the orders are constant over time, or they have included only a random part. If there is any kind of trend, this strategy leads to a deviation of the stock from the nominal stock in each stage of the supply chain. To fill up the stock to the nominal stock an additional quantity has to be ordered. This additional order has nothing to do with a customers order, it is only related to the behavior of a particular stage of the supply chain. Therefore it should be handled as a second order, the "stock order". Now this stock order is independent from the customers order, i.e. in terms of the delivery time. The delivery time is only influenced by the decision how long the compensation of the stock will take. An example of this order strategy is given in fig. 2 and fig. 3.

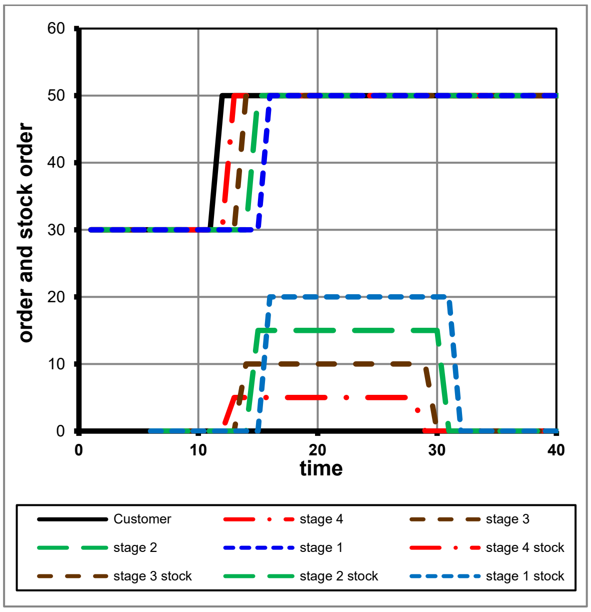

Figure 2: Order strategy of the closed-loop controller: Customers order and stock order with a compensation time of 16 time units

Fig. 2 shows the in=out strategy for the increase of the customers order from 30 to 50 units in the upper part. The lower part shows the stock order. The customers order is the same for all stages only with a time difference of one time unit, which was defined as the time to place an order (fig. 1). For the stock order the decision is to compensate the stock difference within 16 time units in all stages. The stock order increases from stage to stage. This is obvious because a stage has to compensate its own stock difference and all

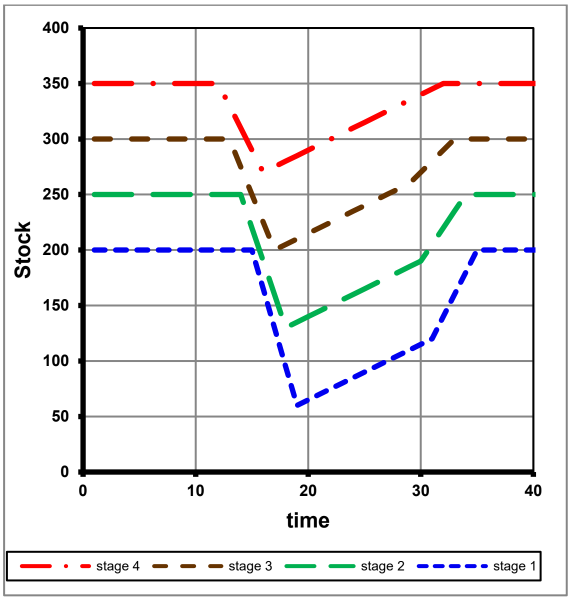

Figure 3: Stock compensation to the nominal stock within 16 time units

differences of the stages downstream. Therefore the bullwhip effect is only created by the stock orders.
Each stage upstream has a higher stock difference (fig. 3). The bullwhip effect occurs in the stock difference too. However, each stage is able to compensate the stock difference in the same time.

3 RANDOM ORDERS

Normally orders are not constant over time. For the next simulation it is assumed, that there is a random part additional a constant order. The orders have a uniform distribution in a range of 200. It is obvious that there is no suitable controlling strategy for a constant stock, if the orders are random. The best strategy is in=out. With this strategy the stock has any values between a maximum and a minimum. In fig. 4 is the difference between the maximum and the minimum marked with a horizontal line. If now a controlling strategy acc. Chap. 2 is applied, a decision of the compensation time has to be done. In fig. 4 the compensation time has been changed from 2 to 122. For short compensation times there is a enormous bullwhip effect in the stock difference. The orders of the customer at the end of the the supply chain are uniform distributed in a range of 200. This order difference is marked in fig. 5 with the horizontal line. All other stages have a much higher order difference for short compensation times. There is an enormous bullwhip effect. For high compensation times the results of the in=out strategy are reached. That means for the order strategy: the longer the compensation time, the lower the bullwhip effect.

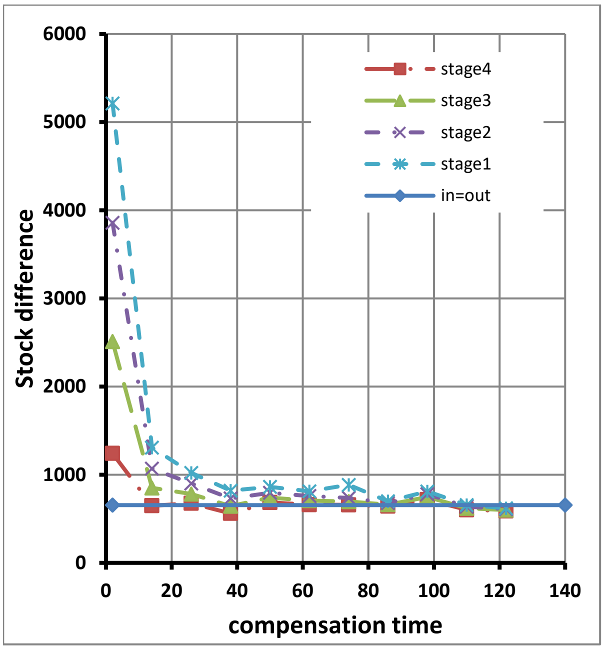

Figure 4: Stock difference for uniform distributed orders in a range of 200

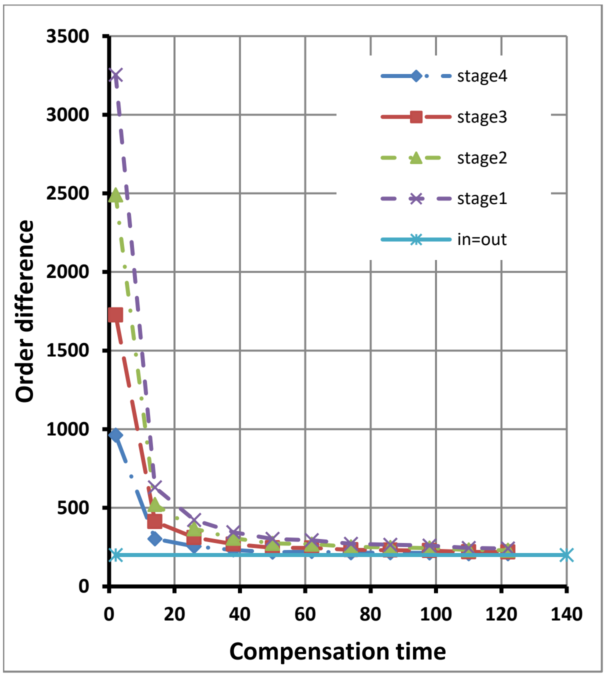

Figure 5: Order difference for uniform distributed orders in a range of 200

4 SEASONAL TREND

A seasonal trend with oscillating orders also leads to major changes in inventories. Therefore the aim must be to minimize the oscillation of the stock by an appropriate closed-loop control. If the oscillation of the stock is minimized, then the average stock is at a minimum too. A seasonal trend is simulated by a sine function very well. In this simulation the amplitude of the sine is +/- 200. Important for a seasonal trend is the period length. For this examination a period length of 300 (fig. 6 and fig. 7) and 100 (fig. 8 and fig. 9) have been applied.

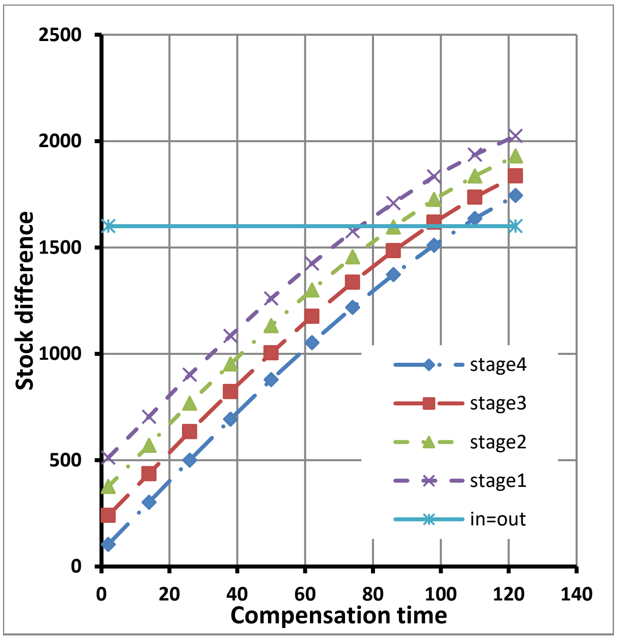

Figure 6: Stock difference at a period length of 300 for a seasonal trend

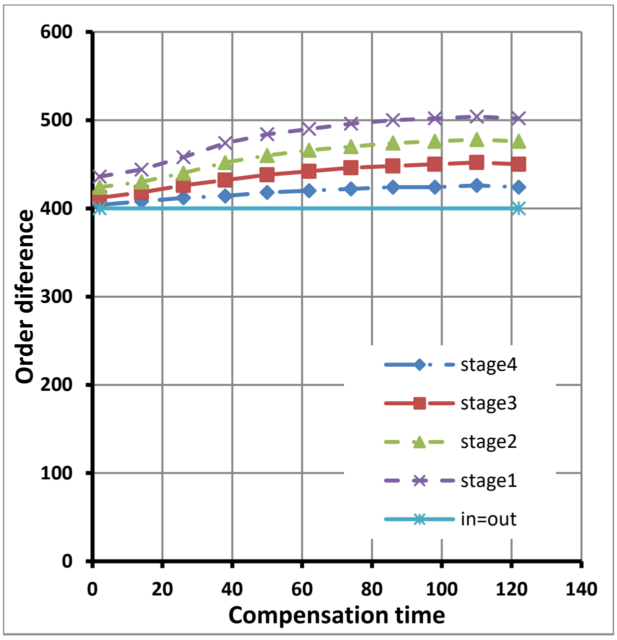

Figure 7: Order difference at a period length of 300 for a seasonal trend

For compensation times less than 70 there are better results for stage 1 than with the in=out strategy. For stage 1 is up to 110 an improvement. Is the period length of the seasonal trend shorter, here 100, the results are quite different (fig. 8 and fig. 9). For stage 1 it does not make any sense to apply another order strategy than in=out, because the stock difference is always higher. For the other stages is for short compensation times an improvement in the stock variation. But there is a enormous bullwhip effect in the the orders.

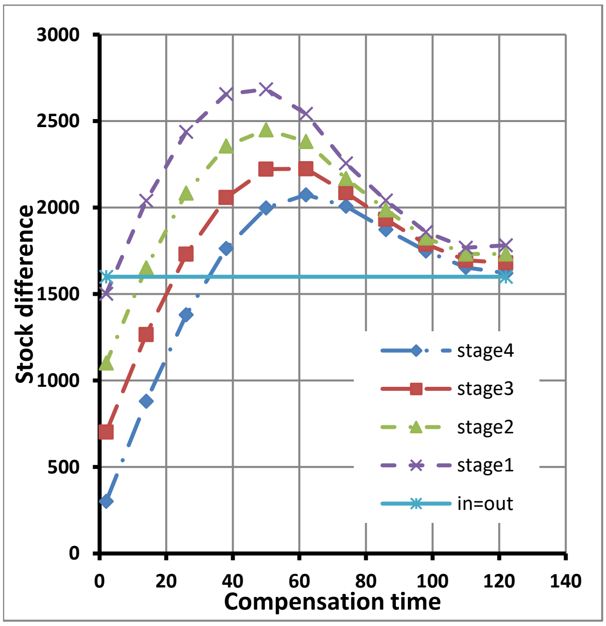

Figure 8: Stock difference at a period length of 100 for the seasonal trend

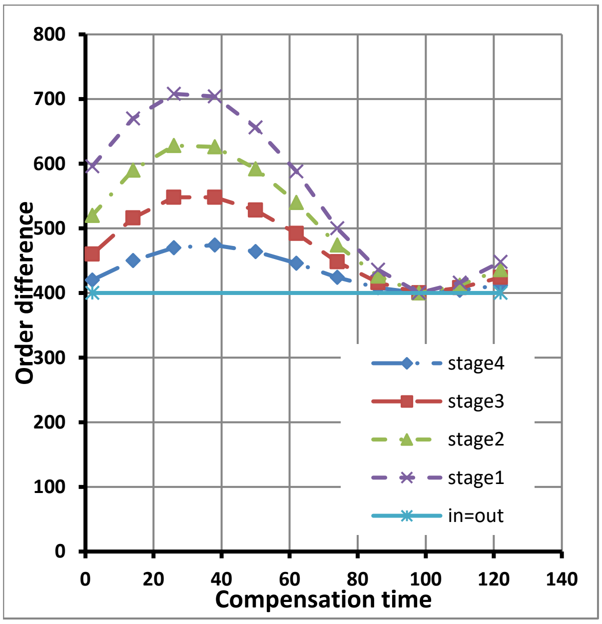

Figure 9: Order difference at a period length of 100 of the seasonal trend

5 ORDERS WITH A SEASONAL TREND AND A RANDOM PART

Random orders need a long compensation time, seasonal orders need short compensation times. The next simulation run should show, if a compensation time can be found to minimize the order difference and the stockdifference. For that the uniform distributed order with a variation of 200 and the seasonal trend with an amplitude of 200 are combined for a period length of 300 (fig. 10 and fig. 11).

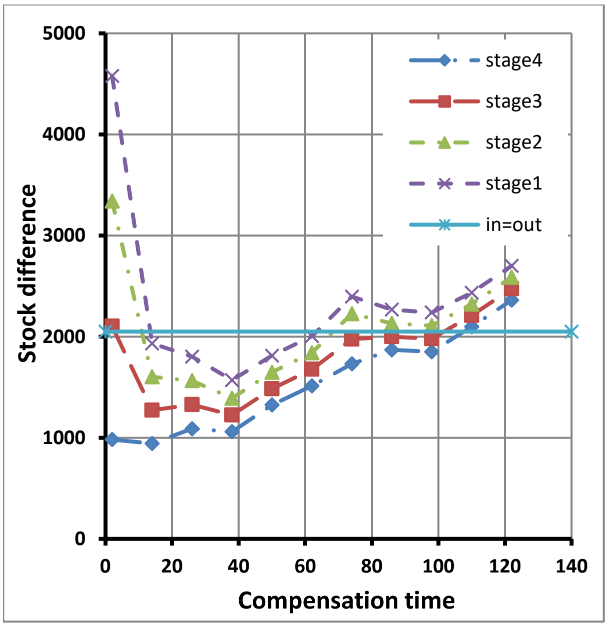

Figure 10: Stock difference at a period length of 300 for the seasonal trend and a uniform distributed random order

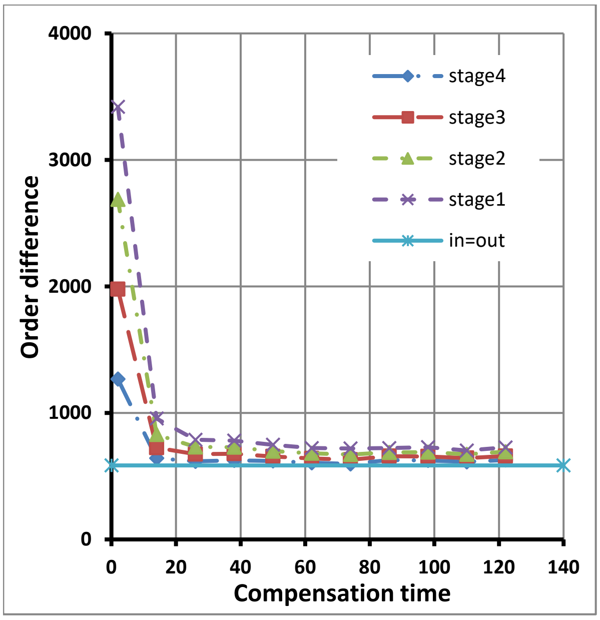

Figure 11: Order difference at a period length of 300 for the seasonal trend and a uniform distributed random order

For short compensation times is the influence of the random part very strong. To minimize the oder differences large compensation times have to be applied. For the order difference a bullwhip effect occurs at the very beginning. With higher compensation times the order difference is in the range of the in=out strategy, but never lower.
For the stock difference exsits a small range whre the results are better than with the in=out strategy. For a compensation time larger than 10 all stages are better than with the in=out strategy. For stage 1 ends this range at 60 and for stage 4 at 100.

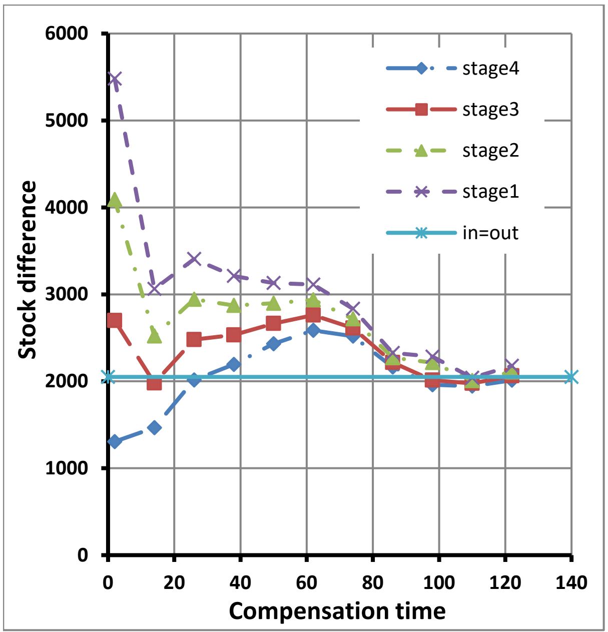

Figure 12:Stock difference at a period length of 100 for the seasonal trend and a uniform distributed random order

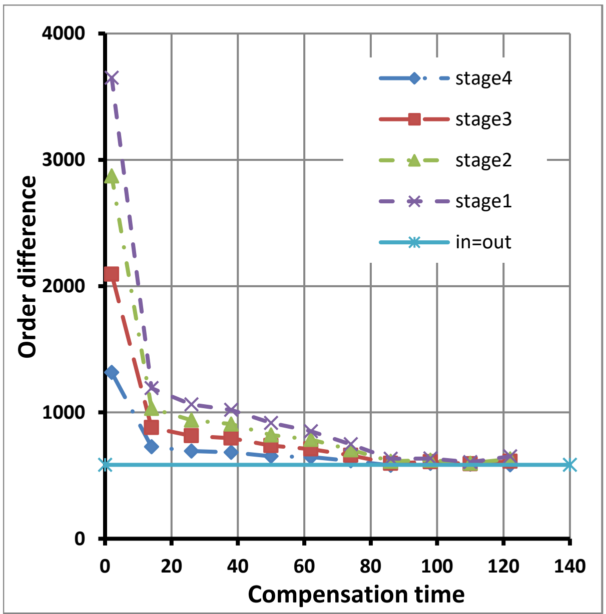

Figure 13: Order difference at a period length of 100 for the seasonal trend and a uniform distributed random order

Quite different are the results of the stock difference for a period length of 100 (fig. 12 and fig. 13). Only up to a compensation time of 20 stage 4 gets better results than with the in=out strategy. All other stages are worse.

6 SUMMARY AND CONCLUSIONS

This study is a theoretical view of the dynamics in a supply chain. For this examination a quite simple model according Forrester has been used. The advantage of a model like that is to see the main influences of the dynamic behavior of the supply chain.
The target of all stages in this examination is to keep the stock at a minimum with a seasonal trend and a uniform distributed random part in the orders. For that the orders have been splitted up in a customers order and a stock order. The customers orders have been handled with the in=out strategy. For the stock order the only decision was compensation time to bring the stock to the nominal stock.
For the random part of the orders long compensation times are neccessary. Then the results for the order difference and the stock difference are similar to the in=out strategy. The seasonal trend requires short compentation times. The stock differences are better with short compensation times than with the in=out strategy. The order differences are always higher than with the in=out strategy.
If seasonal and random orders are applied, only for long periods of the seasonal trend and a small range of the compensation time better results for the stock difference than with the in=out strategy can be found.
At this very simple model only partwise better results than with the in=out strategy can be found. It is doubtful, whether a real system with more parameters can be improved.

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