SEASONAL TRENDS IN SUPPLY CHAINS

Hans-Peter Barbey
University of Applied Sciences Bielefeld
Wilhelm-Bertelsmann-Str. 10, 33602 Bielefeld, Germany
Email: hans-peter.barbey@fh-bielefeld.de

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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 material flow is rather difficult. In order to recognize these relationships between the parameters, initially very simple models have to be established. For this examination a linear supply chain with 4 stages will be designed. In all stages the stock is closed-loop controlled to a nominal stock. In particular, the seasonal trend on the control is considered. Therefore the only decision which can be done in the entire supply chain is the quantity of an order. It will be shown that the period of the trend has a significant influence to the quality of the controlling. A good quality of control results only for long periods of the seasonal trend.

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. The interaction of all companies creates the bullwhip effect, which 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 this paper. The main influences of the bullwhip effect are as follows (Gudehus 2005):

- Independent orders of the particular companies in a supply chain
- Synchronic orders (i.e. subsidiaries of one company)
- Wrong order policy in an emergency case
- Speculative order policy or sale actions

To avoid 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. This kind of cooperation is rather difficult in reality. The question is if the bullwhip effect can be avoided without any cooperation and providing of information to all members in a supply chain.

A very simple model of a supply chain 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 control strategies should be able to avoid the bullwhip effect.
This model is now being developed to simulate a seasonal ordering behavior. The model is designed in the following manner:
For the examination of the bullwhip effect a model of a supply chain according fig. 1 will be used. The behavior of each stage is the same. The time to place an order is 1 time unit. The time for delivery is 3 time units. The lead time to fill up the stock is for one stage 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. To be able to deliver within the lead time of one stage, each stage needs a stock.
The only decision in this simulation is to decide about the quantity of the order to compensate a difference in the own inventory. All other influences are eliminated. The applied controlling strategies for this decision will be described in chap. 2. This decision has been taken each time unit. It is obvious that these parameters do not

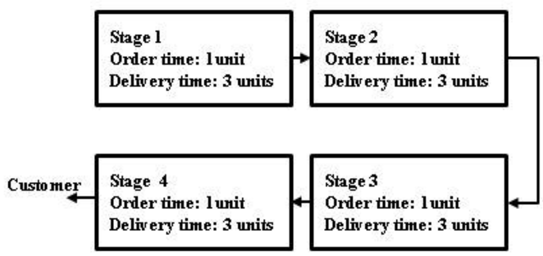

Figure 1: Model of a Supply chain

simulate a real supply chain. Normally the lead time is much shorter than the time for the next order. However,

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this simulation demonstrates with this short order period the bullwhip effect in an impressive manner.

2 DYNAMIC BEHAVIOR OF A SUPPLY CHAIN

Before the dynamic behavior of a supply chain will be examined, a suitable closed-loop controller for a particular stage in the supply chain has to be found. Assuming the unrealistic precondition of a zero lead time the best strategy is: “input is output”. Under this precondition there is no need for a stock at all. Now this strategy is applied to a supply chain as described above (fig. 2).

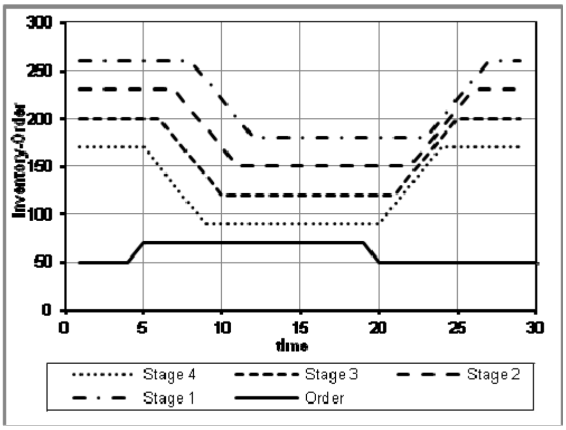

Figure 2: Stock with input=output strategy

If the customer increase his order, here from 50 to 70 items, the stock of stage 4 decrease in a linear manner. The other stages follow after the order time of 1 unit. After the lead time the stock is constant, because now the output of the stock is equivalent to the input. However there is a difference to the nominal stock. Does the customer reduce his order to the original value, the behavior is vice versa.

Assuming the increase or decrease in the order is permanent, the aim of each particular stage is to

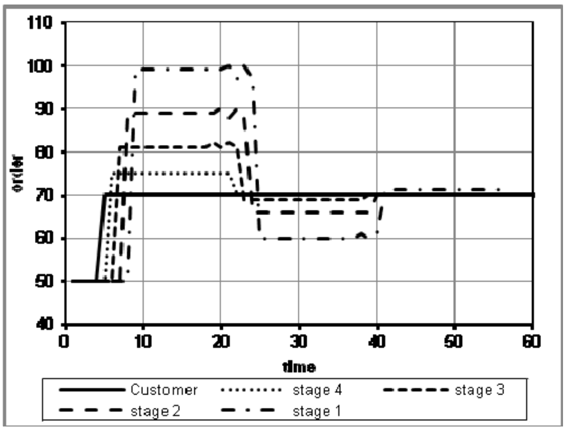

Figure 3: Orders with compensation strategy: constant order within 16 time units

equalize this difference to the nominal stock, which occurred with the strategy “input is output”. Therefore the orders have to be increased for a certain time (fig. 3). In this example the time for compensation is 16 time units. If the compensation time is constant for all stages, the stages upstream have to increase their orders more and more. The reason is that they have to compensate their own stock difference and additional the stock differences in the stages downstream.

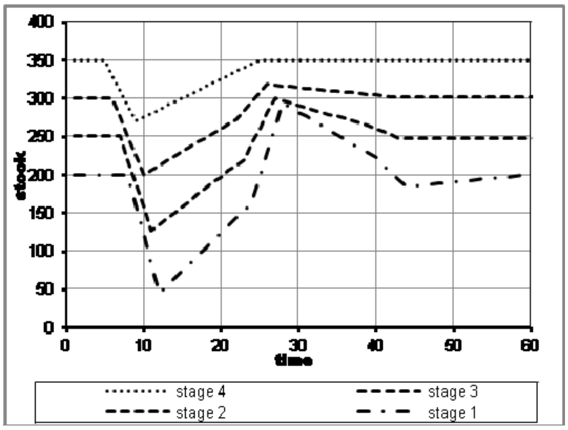

Figure 4: Stock with compensation strategy: constant order within 16 time units

Only the stage at the very end of the supply chain is able to compensate the stock difference within the scheduled time (fig.3 and fig. 4). For all other stages it requires more than double the time. This is quite obvious: The last stage has only to fulfill the customer’s requirement. All other stages have to fulfill the customer’s requirement and have to compensate the stock difference of all stages downstream. Only when the first stage in the supply chain has balanced the stock difference, the order is reduced to the value of the customer. This is the reason why the bullwhip effect also occurs in the stock (fig.4).

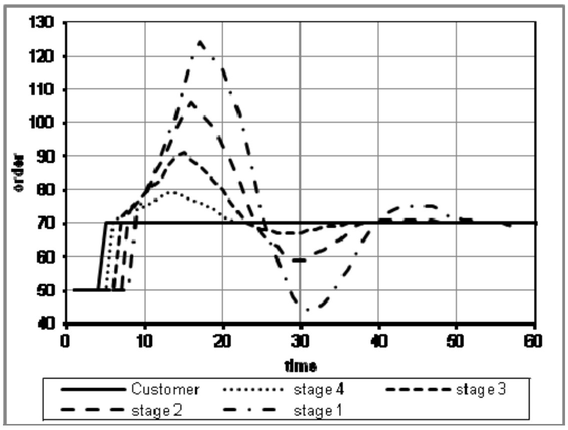

Figure 5: Order strategy of the closed-loop controller: linear increase and linear decrease within 16 time units

The second strategy is relative similar. Instead of a constant order over a certain time there is a linear increase and a linear decrease of the orders (fig. 5). The result is a smoother behavior in the orders and the stock (fig.6).

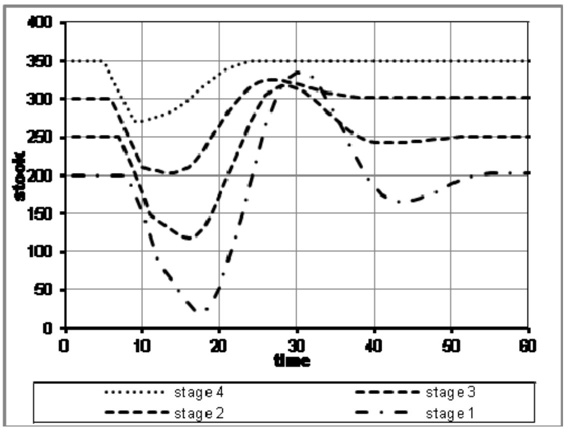

Figure 6: Stock with linear increase and linear decrease order strategy

For both strategies the quantity of these additional orders is calculated by multiplying the lead time and the difference in the customers order. Due to the increasing orders over time for the second strategy there is a higher peak in the orders. This leads to a larger bullwhip effect in the orders and the stock. The time for compensation is more or less the same for both strategies.
For the following examination it seems to be not so important which strategy is applied. For the study, the second strategy is chosen.

3 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 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 +/- 10% of the average. The following simulation examines the fluctuation of the stock for the individual stages in the supply chain (fig.7). The diagram shows the fluctuation of the stock between a maximum and minimum for all stages of the supply chain as a function of the period of the seasonal trend. For a very large period lengths there are only small fluctuations of the stock in all stages of the supply chain. The bullwhip effect is very small. For shorter period lengths the fluctuation in the stocks increases rapidly. The bullwhip effect at the beginning of the supply chain is tremendous.
There is a strong influence of the period length of the seasonal trend to the quality of the closed-loop controlled stocks of each stage. In general terms: The longer the period length of the seasonal trend, the smaller the stock difference in each stage.

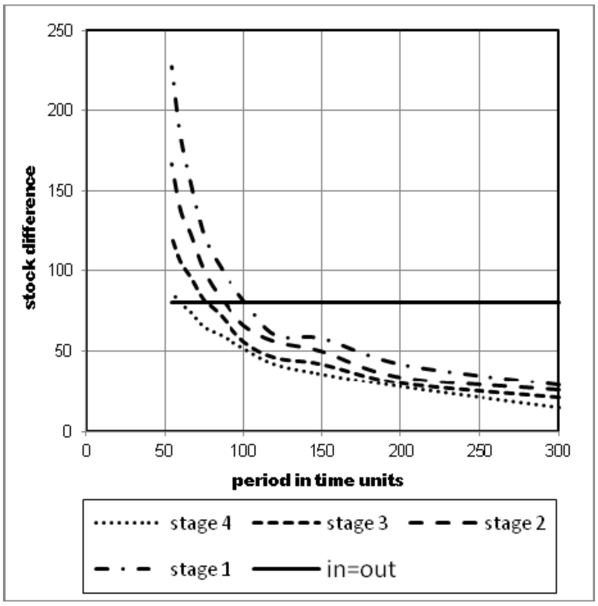

Figure 7: Stock differences for closed-loop controlled supply chain (compensation time 16 time units and in=out strategy

The quality of this closed-loop controlled supply chain is now compared with two other strategies.

1. Input=output (fig.7 and fig.8)
2. Constant order (fig.8)

The controlling strategy input=output is a perfect strategy for systems, where the lead time is zero. In this model with a lead time of 16 time units the strategy gives a permanent deviation in the stock of all stages. Therefore, all curves are identical (fig. 7). The simulation has shown that regardless of the period always occurs a constant deviation of 80 units in the stock. This variation is also independent of the station because all stations always get the same order only with a defined time delay. Fig. 7 demonstrates that this strategy is better than the closed-loop control, if the period is lower than a definite value. This value depends from the stage in the supply chain. For stage 1 the strategy is better for period lengths lower than 100 and for stage 4 for period lengths lower than 70.
The reason for the bad results of the closed- loop control at short period lengths is the lead time. The control could not react fast enough to compensate the variation in the orders. The stages of the supply chain are acting like an oscillator.
The strategy constant order, which is the average of the sine, is not at all a closed-loop control. The variation in the orders has to be compensated with a tremendous high stock in the last stage of the supply chain. Theoretically all other stages upstream do not need any stock, because they get only constant orders from their

customers. All the variation in the stock takes place at the end of the supply chain.
In the next step these results are compared with the input=output strategy and the closed-loop control. This needs a bit different point of view. For this strategy the oscillation in the stock only take place in the stage close to the customer. Theoretically the other stages do not need any stock, because they get a constant order every time. For the comparison all stock differences are added (fig.8). This is now a view to the success of the entire supply chain. For long periods of the seasonal trend the closed-loop control gives the best results for the entire supply chain. If the period falls under a critical value, the strategy “ordering the average” gives better results. The strategy in=out does not give best results in any case.

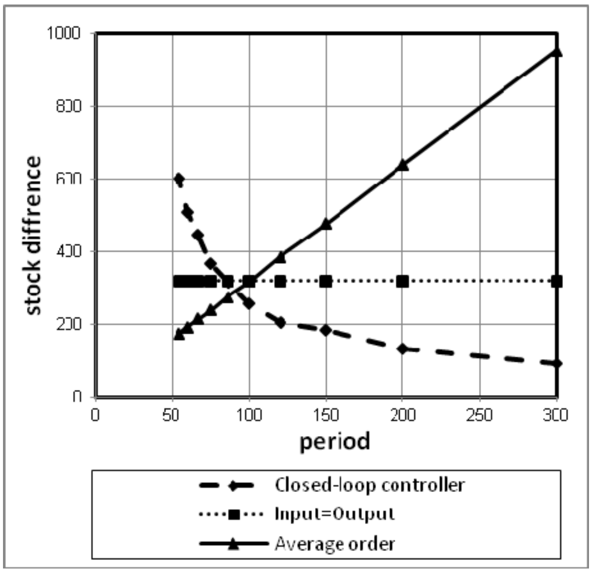

Figure 8: Comparison of the strategies for the entire supply chain

5 SUMMARY AND CONCLUSIONS

This study is a theoretical view of the dynamics in a supply chain. For this examination a quite simple model 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 is to keep the stock at a minimum with a seasonal trend of the customer’s orders. This has been realized by a closed-loop control. The only decision which could be done was the quantity of the orders. Due to lead times caused by orders and delivery, it is difficult or better more or less impossible to get a constant stock by applying a closed-loop control. The seasonal trend has a tremendous influence on the stock: The shorter the period the higher the oscillation in the stock.
For large periods each stage of the supply chain can control its stock independently and get good results. However an increasing bullwhip effect is visible for the stages downstream. Under a critical value of the period the strategies “input=output” and “average order” give better results than the closed-loop controller. Under this critical value the stages of the supply chain are acting like an oscillator. For the “average order strategy” a cooperation of the stages of a supply chain is necessary, because all the variation takes place in the stock close to the customer. It is questionable if such a cooperation can realized in reality. However, this strategy gives the best results for the entire supply chain.
Subsequently, it has to be checked if this theoretical knowledge can be transferred to a real supply chain.

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AUTHOR BIOGRAPHIES

HANS-PETER BARBEY was born in Kiel, Germany, and attended the University of Hannover, where he studied mechanical engineering and graduated in 1981. He earned his doctorate from the same university in

1987. Thereafter, he worked for 10 years for different plastic machinery and plastic processing companies before moving in 1997 to Bielefeld and joining the faculty of the University of Applied Sciences Bielefeld, where he teaches logistic, transportation technology, plant planning, and discrete simulation. His research is focused on the simulation of production processes.

His e-mail address is:
hans-peter.barbey@fh-bielefeld.de
And his Web-page can be found at
http://www.fh-bielefeld.de/fb3/barbey