

## Research Article

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# The Analysis of Orders of Perishable Goods in Relation to the Bullwhip Effect in the Logistic Supply Chain of the Food Industry: a Case Study

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**Abstract:** The bullwhip effect generally refers to the phenomenon where order variability increases as the orders move upstream in the supply chain. It is serious problem for every member of the supply chain. This effect begins at customers and passes through the chain to producers, which are at the end of the logistic chain. Especially food supply chains are affected by this issue. These chains are unique for problems of expiration of goods (particularly perishable goods), variable demand, orders with quantity discounts and effort to maximize the customer satisfaction.

This paper will present the problem of the bullwhip effect in the real supply chain in the food industry. This supply chain consists of approximately 350 stores, four central warehouses and more than 1000 suppliers, but the case study will examine 87 stores, one central warehouse and one supplier in 2015. The aim of this paper is the analysis of the order variability between the various links in this chain and confirmation of the bullwhip effect in this chain. The subject of the analysis will be perishable goods.

**Keywords:** bullwhip effect, perishable goods, logistic chain, order, supply chain, food industry, customer satisfaction

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## 1 Introduction

The bullwhip effect is described as a situation in supply chain when demand uncertainty and variability increases as one moves up a supply chain. This effect can greatly decrease the efficiency and profits within a supply chain. It is very important to reduce or eliminate this phenomenon in supply chains [1, 2].

Other authors define the bullwhip effect as a situation when slow moving consumer demand creates large swings in production for the suppliers at the other end of the supply chain [3]. Evidence of the bullwhip effect was firstly registered by J. W. Forrester in 1958, who discussed its causes and possible remediation in the context of industrial development [4]. After that, several researchers such as Blinder [5], Blanchard [6], Burbidge [7], Caplin [8], Blinder [9] and Kahn [10] also recognize the existence and importance of the bullwhip effect in supply chains [1]. This phenomenon is closely linked with the philosophy of lean production, concretely with “mura”, which is the waste of unevenness [11]. The term bullwhip effect used by Schisgall also Procter & Gamble in the 1990s to refer to the order variance amplification phenomenon observed between Procter & Gamble and its suppliers [12]. Wang and Disney state that this phenomenon is commonly observed in almost every industry [3].

Lee *et al.* identify five main causes of the bullwhip effect, there are: demand forecasting, non-zero lead time, supply shortage, order batching and price fluctuation [13]. Shao *et al.* define five similar main causes of the bullwhip effect, there are: demand forecasting, lead time, order batching, inflated orders and price fluctuation [1]. Wang and Disney described five most important elements in bullwhip modelling, there are: demand, forecasting, time delay, ordering policies and information sharing [3]. Some authors emphasize suitable location of the warehouses and optimal utilization of the fleet [14–16].

The phenomenon of the bullwhip effect is very problematic in the food supply chain, especially in the situation of perishable goods. Perishable goods have durabil-

ity for several hours or days [17]. The existence of bullwhip effect in the logistic chain of food industry can cause losses for every member of this chain, reduction of customer satisfaction, reduction of revenues and put requirements on information systems, collaboration and cooperation between every member [18]. The model of the real food supply chain, where the bullwhip effect was investigated, is illustrated in Figure 1. This model consists of producer ( $P_1$ ), which produces milk products. Authors will investigate only one perishable product – fresh chilled milk which has durability of about seven days from production and five days from delivery to the stores. Producer delivers this product to the warehouse ( $W_1$ ), which distributes it to the stores.

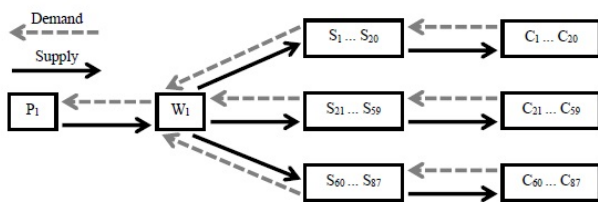


Figure 1: Model of the real food supply chain.

This warehouse supplies 87 stores ( $S_1 - S_{87}$ ), which are divided into three groups by annual turnover – Table 1. These groups are different by a system of orders and supplies, overall demand and quantity of goods for frontloading. Customers are divided into three groups ( $C_1 - C_{87}$ ) as stores.

Stores of the mentioned supply chain are divided into three groups by annual turnover in Czech currency. The first group (stores  $S_1 - S_{20}$ ) have annual turnover exceeding 120 million CZK. These stores are supplied seven times a week by delivery system “A – C”. This system is based on the supplies delivered 36 hours (at the latest) after ordering goods. Ordering goods and delivering supplies is following: Monday (order) – Wednesday (delivery), Tuesday (order) – Thursday (delivery), Wednesday (order) – Friday (delivery), Thursday (order) – Saturday (delivery), Friday (order) – Sunday (delivery), Saturday (order) – Monday (delivery), Sunday (order) – Tuesday (delivery). In case of promotions, discounts or special occasions stores are supplied by goods for frontloading in the three levels. The level is determined by the sales department and the amount of discounts.

The second group (stores  $S_{21} - S_{59}$ ) have annual turnover between 80 and 120 million CZK. These stores are supplied six times a week by the same delivery system as

the first group or by system “A – D”. The last group (stores  $S_{60} - S_{87}$ ) have annual turnover less 80 million CZK. These stores are supplied four or five times a week by delivery system “A – C” or “A – D”.

Goods for frontloading are delivered in the three parts before and during promotion. Stores have a possibility to make order with higher amount of goods than is the supply of frontloading. The first level is used in the case of a discount of up to 10 percent off the original price. The second level is used in the case of a discount between 10 and 25 percent off the original price. And the last level (the biggest supply of frontloading) is used in the case of a discount greater than 25 percent.

Authors will investigate the existence of the bullwhip effect between these members of the chain in Figure 1: Customers and stores, stores and warehouse and warehouse and producer in 2015.

## 2 Methods

The existence of the bullwhip effect will be presented in the logistic supply chain of the food industry on the real case study which is the method of the qualitative research based on the study of one or a small amount of situations for application of the findings for the similar cases [19].

The definition of the bullwhip effect is the amplification of order volatility along the supply chain. This volatility can be measured by Wang and Disney by the coefficient of variation, variance or standard deviation [3]. Other authors use comparison the variance between demand and orders or due to data availability use alternatives such as production quantity, sales and shipments [3, 20–23]. Shao *et al.* recommend measuring the bullwhip effect by the ratio of the variance of order quantity experienced by the supplier to the actual variance of the demand quantity [1]. Authors will use the same approach as Wang and Disney [3] and it is standard deviation.

### 2.1 Standard deviation

Standard deviation ( $\sigma$ ) is usually defined as the square root of the variance ( $D(X)$ ) of a random variable ( $X$ ) – Equation 1:

$$\sigma = \sqrt{D(X)}. \quad (1)$$

Standard deviation ( $\sigma$ ) can be also calculated using the mean value ( $E(X)$ ) or ( $E(X^2)$ ) – Equation 2, 3:

$$\sigma = \sqrt{[E((X - E(X))^2)]}. \quad (2)$$

**Table 1:** Comparison of the stores in the food supply chain.

Stores	$S_1 \dots S_{20}$	$S_{21} \dots S_{59}$	$S_{60} \dots S_{87}$
Annual turnover	>120 million CZK	80-120 million CZK	<80 million CZK
Supply	7 times a week	6 times a week	4 or 5 times a week
Delivery system	A – C	A – C (A – D)	A – C (A – D)
Frontloading (A)	180, 106, 60 cartons	90, 30, 0 cartons	75, 0, 0 cartons
Frontloading (B)	180, 120, 90 cartons	90, 30, 24 cartons	60, 30, 0 cartons
Frontloading (C)	240, 180, 120 cartons	90, 60, 42 cartons	60, 30, 12 cartons

$$\sigma = \sqrt{[1/n \cdot \sum (x_i - (1/n \cdot \sum x_i)^2)]}. \quad (3)$$

## 2.2 Variables

The demand ( $W_D$ ) of the warehouse ( $W_1$ ) is equal to the supply ( $P_S$ ) of the producer ( $P_1$ ). The overall demand of the stores is identified as ( $S_D$ ). It consists of: overall demand of the stores ( $S_1 - S_{20}$ ), which is identified as ( $S_{DA}$ ), overall demand of the stores ( $S_{21} - S_{59}$ ) which is identified as ( $S_{DB}$ ) and overall demand of the stores ( $S_{60} - S_{87}$ ) which is identified as ( $S_{DC}$ ). These relations are in the Equation 4, 5, 6, 7:

$$S_D = S_{DA} + S_{DB} + S_{DC}, \quad (4)$$

$$S_{DA} = \sum S_{Di}; i = \langle 1; 20 \rangle, \quad (5)$$

$$S_{DB} = \sum S_{Di}; i = \langle 21; 59 \rangle, \quad (6)$$

$$S_{DC} = \sum S_{Di}; i = \langle 60; 87 \rangle. \quad (7)$$

The overall demand of the customers is identified as ( $C_D$ ). This demand is based on the information from stores. It consists of: overall demand of the all customers ( $C_1 - C_{20}$ ), which is identified as ( $C_{DA}$ ), overall demand of the all customers ( $C_{21} - C_{59}$ ) which is identified as ( $C_{DB}$ ) and overall demand of the all customers ( $C_{60} - C_{87}$ ) which is identified as ( $C_{DC}$ ). These relations are in the Equation 8, 9, 10, 11:

$$C_D = C_{DA} + C_{DB} + C_{DC}, \quad (8)$$

$$C_{DA} = \sum C_{Di}; i = \langle 1; 20 \rangle, \quad (9)$$

$$C_{DB} = \sum C_{Di}; i = \langle 21; 59 \rangle, \quad (10)$$

$$C_{DC} = \sum C_{Di}; i = \langle 60; 87 \rangle. \quad (11)$$

## 2.3 Calculation

The bullwhip effect was calculated as the standard deviation ( $\sigma$ ). Authors used the comparison of the three standard deviations of the demand of customers ( $\sigma_{CD}$ ), stores ( $\sigma_{SD}$ ) and warehouse ( $\sigma_{WD}$ ). These standard deviations ( $\sigma_{CD}$ ,  $\sigma_{SD}$ ,  $\sigma_{WD}$ ) were calculated by Equation 12, 13, 14:

$$\sigma_{CD} = \sqrt{[1/n \cdot \sum (C_{Di} - (1/n \cdot \sum C_{di})^2)]}, \quad (12)$$

$$\sigma_{SD} = \sqrt{[1/n \cdot \sum (S_{Di} - (1/n \cdot \sum S_{di})^2)]}, \quad (13)$$

$$\sigma_{WD} = \sqrt{[1/n \cdot \sum (W_{Di} - (1/n \cdot \sum W_{di})^2)]}. \quad (14)$$

The existence of the bullwhip effect will be confirmed if the standard deviation will increase from customers to producer. This statement is in the Equation 15:

$$\sigma_{CD} < \sigma_{SD} < \sigma_{WD}. \quad (15)$$

The difference between ( $S_D$ ) and ( $C_D$ ), Equation 16, is loss ( $L$ ) for stores expressed as the number of unsold cartons of the fresh chilled milk which must be discarded.

$$L = S_D - C_D. \quad (16)$$

The Equation 16 is possible transform to the monetary expression in terms of lost revenue ( $R$ ) by multiplying the price of one carton ( $p$ ) (Equation 17).

$$R = L \cdot p. \quad (17)$$

## 3 Results

Authors used methods from the second chapter. The overview of the most important results is in the Table 2, where is presented the annual demand of the fresh chilled milk. Customers ( $C_i$ ) have bought 430 315 cartons ( $C_D$ ) of this product in 2015. One carton consists of six bottles of

the fresh chilled milk. Stores ( $S_i$ ) ordered from the warehouse 443 818 cartons ( $S_D$ ). This amount contains goods for frontloading too. These goods stores have use during promotions, discounts or special occasions. Warehouse ( $W_1$ ) ordered 444 000 cartons ( $W_D$ ) from the producer ( $P_1$ ).

**Table 2:** The overview of the annual demand and its standard deviation.

Number of cartons	Annual demand	Standard deviation ( $\sigma_D$ )
Customers	$C_D = 430\ 315$	$\sigma_{CD} = 4\ 213.96$
Stores	$S_D = 443\ 818$	$\sigma_{SD} = 4\ 596.70$
Warehouse	$W_D = 444\ 000$	$\sigma_{WD} = 5\ 215.02$

The standard deviation of the customers demand ( $\sigma_{CD}$ ) is 4 213.96 cartons. Stores have the value of this indicator about 4 596.70 cartons ( $\sigma_{SD}$ ) and the warehouse have the standard deviation of the demand about 5 215.02 cartons ( $\sigma_{WD}$ ). The Equation 15 is confirmed, because the Equation 18 is valid:

$$4\ 213.96(\sigma_{CD}) < 4\ 596.70(\sigma_{SD}) < 5\ 215.02(\sigma_{WD}). \quad (18)$$

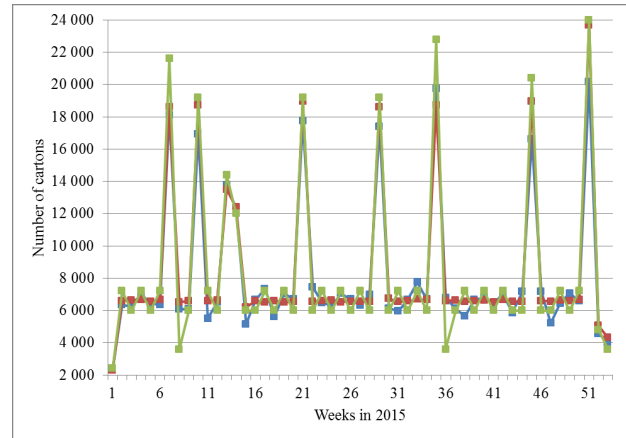
The loss ( $L$ ) for stores expressed as the number of unsold cartons of the fresh chilled milk which must be discarded (Equation 16) in 2015 was 13 503 cartons. Authors assumed the average revenue of one carton of the analysed product is about 100 CZK (Czech crowns). The lost revenue of the 13 503 cartons of the fresh chilled milk in 2015 was in the analysed supply chain according to the Equation 17 is about 1 350 300 CZK.

It should be observed that the lost revenue is not only the loss for this supply chain because customers may perceive these occasions very negatively and they choose other store for the next purchase

## 4 Discussion

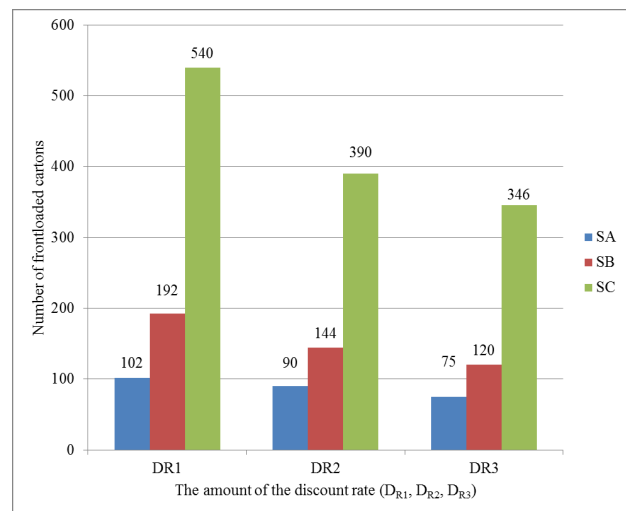
The process of the demand for fresh chilled milk in 2015 by weeks is illustrated in Figure 2. The overall demand of the customers is represented by the blue curve, the overall demand of the stores is represented by the red curve and the demand of the warehouse is represented by the green curve.

The biggest deflections are visible in the 7<sup>th</sup>, 10<sup>th</sup>, 21<sup>th</sup>, 29<sup>th</sup>, 35<sup>th</sup>, 45<sup>th</sup> and 51<sup>th</sup> week. This is caused by promotions, discounts or special occasions as Easter or



**Figure 2:** Annual demand (number of cartons) of customers, stores and warehouse in 2015.

Christmas. Stores are frontloaded for these occasions. The amount of frontloading depends on the type of promotions, discount rate and type of the store according to the annual turnover. Figure 3 presents three types of amounts of frontloading with the type of store ( $S_A, S_B, S_C$ ) and the discount rate ( $D_{R1}, D_{R2}, D_{R3}$ ).



**Figure 3:** Types of frontloading below the type of store and the discount rate ( $D_{R1}, D_{R2}, D_{R3}$ ).

The amount of the discount rate and the number of the frontloaded cartons corresponds to Equation 19 according to the type of the store ( $S_A, S_B, S_C$ )

$$D_{R1} > D_{R2} > D_{R3}. \quad (19)$$

The greatest amount of goods was delivered to the stores from the group ( $S_C$ ) assuming the discount rate ( $D_{R1}$ ). It was 540 cartons of the fresh chilled milk divided

into three deliveries (240, 180 and 120 cartons). Every promotion is planned in advance. It is decisive for every member of the fresh food supply chain.

The bullwhip effect is a distribution problem, when forecast of demand is not correct. Each member of distribution chain is ordering more goods than is real demand and inventory is increasing. This phenomenon is very problematic for every participating member especially in the food supply chain. This case study was focused on the fresh chilled milk in the real food supply chain. Authors confirmed the phenomenon of the bullwhip effect, standard deviation of demand had increasing character and it affected all members of distribution channel. It is crucial information in the supply chain of perishable goods. Expiration of the fresh chilled milk is about seven days from production, but customers require fresh products, especially vegetables. The durability of any kind of vegetables is only 24 hours after delivery to the store.

## 5 Conclusion

Authors studied the existence of the bullwhip effect in a real supply chain of the food industry. Authors compared this phenomenon between four members of the mentioned supply chain, there are: customers, stores and warehouse. The standard deviations of the demand increase from the customers to warehouse and affected all members of distribution channel. Authors confirmed the existence of the bullwhip effect in this chain.

Generally, the issue of the customer service level and availability of the goods is crucial for the customers and stores, but it is very hard to find the equilibrium between possibilities of the stores and customer requirements. This statement is particularly true in the fresh food industries (perishable goods). The maximum effort to satisfy the requirements of the customers can cause losses in the supply chain.

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