BULLWHIP EFFECT EVALUATION WITH INDICATORS IN USE

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Received: June 12, 2022
Received revised: September 4, 2022
Accepted for publishing: September 5, 2022

Abstract

The bullwhip effect is a widely researched phenomenon. Its occurrence has a high impact on supply chain performance. Nonetheless, in practical environment a targeted analysis is less common. This results in a gap between scientific interest and practical application. Due to the high level of adaptation needed it is hard to apply the best practices.

Supply chains use multiple indicators. There are typical measurements that are used by several industries tailored to their own characteristics. These metrics are crucial to support customer service. They measure the quality of the service and the estimation's accuracy. Targeted analysis of the bullwhip effect is not that common due to limited capacity and the elusiveness of the phenomenon.

A deeper investigation of the bullwhip effect can be accomplished if the existing indicator set is used as a basis. Forecast accuracy, bias and service level value are influenced by the bullwhip effect. Using these indicators for - tracking bullwhip effect as well will raise awareness and understanding of the phenomenon. This means process improvement potential using the existing resources.

Key words: bullwhip effect, forecast accuracy, forecast bias, service level

1. INTRODUCTION

The bullwhip effect phenomenon is broadly researched in the scientific literature. The interest is not only significant from an academic perspective but also from a practical point (Wang & Disney, 2016). In the past 40 years several analyses researched the bullwhip effect but there is still no ready to use solution to avoid it. Its importance in business is mainly connected to the cost related impact that is generated as a consequence. The financial impact is not the only outcome, the effective operation

is also damaged. That results in further costs and requires additional attention (Disney & Lambert, 2008).

The business network and environment are complex and complicated. Focus needs to be divided between several relevant and important area (Simchi-Levi et al. 2008). The bullwhip effect is only one of the factors. The phenomenon is intangible, and it is hard to precisely define it in practice. As a result very limited capacity can be dedicated to only monitor the occurrence. Nonetheless the impacts are still harmful. Case studies present in the literature are mainly mathematical methods that needs resource investment. In addition, adaptability is also low due to the differences on sector and supply chain level. Literature also introduces the bullwhip ratio, but this is also a special metrics with the aim of the quantification of bullwhip effect. However, the adaptability of this metrics is good still application needs high investment on human and financial resources.

As the tracking of the bullwhip effect is essential (Fu et al., 2015) it is important to integrate the measurements in the set of indicators in use. It enables better understanding and detectability of the bullwhip effect. There are several metrics that are in use to keep under control the daily operation and to support the mid- and long-term improvement (Behzadi et al., 2020). Forecast accuracy, forecast bias and service level are basic measurements that are widely used in multiple industries and levels of the supply chain. The mention measurements are highly depending on demand parameter which is key factor also regarding the bullwhip effect. It worth to check if calculation of these measures can show the presence or impact of the phenomenon. Using existing tools from a different perspective would support to improve the performance of the supply chain without high level of investment. It could also deepen the understanding of the phenomenon.

The aim is investigating the potentials of the currently used indicators in analysis of the bullwhip effect phenomenon. This paper is checking the possibilities of extending the current operational usage of metrics with a new perspective.

2. METHODOLOGY

This paper consists of two parts. First the literature review is presented. It both introduce bullwhip effect phenomenon and selected indicators frequently used in practice. Bullwhip effect introduction focuses on the reasons and impacts of the phenomenon (Chapter 3.). The introduction of the indicators contains forecast accuracy, forecast bias and service level (Chapter 4.). These measures are the ones used in the extended supply chains which are typically affected by the bullwhip effect. The second part of the paper is the authors' analysis (Chapter 5.). It investigates how the presence of the bullwhip effect influence the introduced metrics. The analysis is separated to three levels based on the timing and purpose of the investigation: indicative, mitigative and analytic measures. The paper is looking for answer on below research questions:

- Does the occurrence of the bullwhip effect have impact on forecast accuracy, forecast bias or service level?

- Are these indicators applicable for bullwhip effect analytic purposes?
- How can we apply the mentioned metrics regarding the bullwhip effect analysis?

3. BULLWHIP EFFECT

Due to the malfunctions faced in the supply chain when the bullwhip effect occurs the analysis of the phenomenon is important. The research of the phenomenon has several approaches and directions. The main understanding of the phenomenon is still the same. The research of the phenomenon has a long history. It was known as the forrester effect based on the first researcher of the topic (J.W. Forrester, MIT Sloan School of Management). The term itself was defined in a 1997 study by Lee, Padmanabhan and Wang. From a practical perspective the first recognition is attributed to Procter and Gamble. The scope of their analysis was the causeless fluctuation of diaper demand and orders. Customer's needs did not explain the level of variability. The phenomenon was also present in other sectors and companies. The authors phrased the upcoming definition: "the phenomenon where orders to the supplier tend to have larger variance than sales to the buyer (i.e., demand distortion), and the distortion propagates upstream in an amplified form (i.e., variance amplification)." (Lee et al., 1997, p546) Another definition approaches from a different perspective. It is defined based on the difference between customer demand and the produced quantities. "The effect by which slow moving consumer demand creates large swings in production for the suppliers at the other end of the supply chain." (Wang & Disney, 2016, p691) Financially the bullwhip effect becomes crucial once the fluctuation of production leads to higher costs than the inventory holding (Wang & Disney, 2016). The occurrence of the phenomenon is also influenced by the market environment. Competition also needs to be considered as a factor. In addition, the structure of the supply chain is also impactful from the bullwhip effect perspective (Xuluo, 2021).

3.1. Reasons for the bullwhip effect

Traditionally the focus of the research is the operational consequences and causes of it. The solutions are also covering this perspective regarding influencing the lead time and increasing transparency (Lee et al., 1997; Yang et al., 2021). Lee et al. (1997) described the main operational reason groups behind the bullwhip effect: demand signal processing, rationing game, order batching and price variation (Lee et al., 1997). These reason groups have been complemented by the lead time parameter (Geary et al., 2006). This is due to the change in the lifestyle of the customers and the supply chain operations. Longer, international chains lead to an increase in lead time. The lead time element is still among the operational causes. Studies with a focus on operational reasons of the bullwhip effect assume the behaviour of the humans rational (Yang et al., 2021). Even if the described categories may seem outdated based on the time they were defined they are still valid. Digital technology has had a

significant impact on supply chain operation. The change is mainly visible in information, financial and material flow (Wiedenmann & Größler, 2019). In theory the tools available should support avoiding the bullwhip effect, but practical experience does not confirm this. These categories are still valid in practice.

As human factors have not been considered in these studies, it meant a potential improvement of the bullwhip effect research. As another aspect, irrational decisions and a stressful environment was also included as a behavioural reason for the bullwhip effect (Sterman, 2006). The number of studies considering the human factors have increased. The focus topics are information sharing, training and communication, trust in collaboration, human influence in forecasting and reactions on the bullwhip effect (Yang et al., 2021).

The aforementioned reason groups can be further broken down into sub-elements (Geary et al., 2006; Potter & Disney, 2006; Bhattacharya & Bandyopadhyay, 2011; Yang et al., 2021).

- Demand signal processing: inaccurate forecast; misunderstanding of the market information; the applied forecasting strategy; handling of stock-out; and lack of learning
- Rationing game: number of echelons; lack of transparency, control, and synchronization; fear of shortage; local approaches versus global
- Order batching: applied lot size; ordering timelines; lack of harmonization of replenishment strategies; limited capacity
- Price variation: planned and unplanned promotions; fluctuation of material price and finished goods price; change of other costs
- Lead time: impact forecasting strategy; delay in information flow
- Human factor: information sharing, trust, human influence on forecasting

3.2. Impacts of the bullwhip effect and reduction opportunities

The bullwhip effect can result in opposite outcomes - both overstock and stock-out can be the outcome. These results have a detrimental effect on the supply chain performance and have direct or indirect financial impacts. For example - cost impact can be realized due to lost sales opportunities or via increased warehousing costs. This impact can increase through the chain due to the multiplication effect. This leads to serious consequences at the chain level and mainly impacting the manufacturing level. In addition the cost information is also affected, becoming distorted due to the bullwhip effect. The impact is not only realized at a stock level but also highly influence the capacity utilisation. The production schedules are also impacted by losing the stability (Disney & Lambrecht, 2008; Wang & Disney, 2016).

There is research showing that collaboration has a supportive impact and it can strengthen the system measurements so the solution can be close to optimal (Tliche et al. 2019). Today's supply chains are considered complex networks rather than streamlined chains. The different chain and echelon level approaches can indicate different goals and expectations. Beside the global goals of delivering value or service to the customer they also try to maximize profits on a local level (Disney & Lambrecht 2008). Due to global and local differences and complex operations, cooperation became much harder. An ideal chain could be characterised by information

transparency, coordinated processes and common strategy. If these circumstances were realised, the bullwhip effect would be less likely to happen. However, the above characteristics are not likely to happen in real-life circumstances in the foreseeable future. The competitiveness of the industries of the real world results in incomplete information flow. As a consequence the customer demand information comes through the chain in a distorted manner (Zarandi & Moghadam, 2016).

For better forecasting processes and accuracy information sharing is needed. This would not be the final solution, just a first step. Highest peaks can be avoided in the long term. Beside the information flow lead time should also be considered. Analysation of the bottlenecks from this perspective can highlight critical processes. This can support having better control, more manageable processes, and lower uncertainty. Once the first steps through information sharing and analysation of the bottlenecks are made further synchronisation approaches can also be initiated. These can cover both batch sizes and processes (Towill et al., 2007) Based on case studies smoothing of the replenishment rule can result in a balanced solution between the bullwhip effect and the customer service level (Ponte et al., 2022). Although, transparency and information sharing seem to be supportive in decreasing the impact of the bullwhip effect, it has been demonstrated in various research that it does not always work (Haines et al., 2017). Even if the phenomenon does occur, an increased level of transparency and information is still important. It is easier to realize the bullwhip effect this way and it also supports the resolution of the problem.

4. INDICATORS USED IN PRACTICE

The harmonization of indicators can support the defined goals in the supply chain. This supports the harmonization of processes. These measurements can be personalized at each level according to the circumstances, but the calculations and basis need to be the same to be comparable. There are several performance measurement tools, frameworks and systems applied in the different industries. The metrics integrated in them are customised for the user company or the chain. Still there are some metrics that are typically used in practice. These measurements are integrated in the key performance indicator system in several industries and applicable at all levels of the supply chain. These metrics are the followings: forecast accuracy, forecast bias, and service level.

The common factor in the measurement below is that all of them can be measured in all levels of the supply chain. The scope of the measure can always cover two viewpoints. First is the comparison with the connected parties; second, the comparison to the final customer. The other common point is the scope of the measurement. Both of the three measurements consider forecasting as the basis with the calculation built on the demand value. For the calculation the following abbreviations can be used:

S actual sales quantity
Dc customer demand
D-1 demand of the previous echelon
F forecasted quantity
Fx fixed forecasted quantity (x month ago)

4.1. Forecast Accuracy (FCA)

The forecast accuracy aims to analyse the deviation between the actual- and the forecasted demand. This comparison gives information on the quality of the forecasting. The targeted value of the metric can differ based on the industry or segment. It can be influenced by frequently changing products and market requirement (e.g. fashion) or economical changes (e.g. COVID19). The calculation can be initiated in multiple different ways. It can be an absolute value of the difference, but it can also be calculated as a percentage (Moller et al.,2021).

Various calculation are in use to evaluate the forecast quality. The difference is mainly in the penalization of the errors. However, the negative and positive deviations of the same magnitude are assumed to result in the same loss, penalized symmetrically. The most widely used methods are the mean forecast error, mean absolute percentage error and the root mean squared error (Moller et al., 2021).

In several cases due to the length of the supply chain comparison of the current forecast and the sold quantity does not give sufficient information. Lead time can be two months or even longer (for example, sales in Europe with production in China). In this case the earlier forecast can be considered as the signal for the production. From a supply chain and production perspective the length of the chain also needs to be considered in the calculation. It is more informative with regards to the performance of the chain and/or echelon. In the case of these extensive chains forecast accuracy calculation can be based on a two months fixed forecasting period. The equation of the forecast accuracy based on Moller et al (2021) and practical applications is present below (Equation 1.): The customer demand is compared with a fixed forecast (fixed period depending on the supply chain characteristics):

$$FCA = \frac{D_c}{F_x} \tag{1}$$

As the calculation of the forecast accuracy is based on the forecasted quantities and the demand the value changes once the bullwhip effect is present. Both over and under forecasted periods will lead to oscillation of the metric. This phenomenon is first visible in the demand fluctuation. In cases of significant peak or drop of order the measure will move out of the targeted interval. If everything is sold according to plan bullwhip effect should not occur. Once the value of the FCA is out of the tolerated interval it means a significant drop or peak that is a signal of the bullwhip effect. The mentioned tolerated interval shows differences on industry level. Taking example of food industry, it is typically over 80%, in machinery industry it is 60%.

4.2. Forecast Bias (FB)

Besides the forecast accuracy it is also important to see how large the discrepancy is from the plan. Bias shows the trends if the forecasting is above or below the actual sales. It shows if the given product is over or under forecasted (Wan & Sanders, 2017).

Forecast bias and forecast error need to be separated. Forecast error is "the deviation of the customer forecast from the final order". Forecast bias means "structural or strategical deviation". In the case of positive bias, the customer, due to systematic or strategical reason, inflates their demand forecast; this is the result of the rationing gaming (Seitz et al., 2020). Therefore, analyzation of the bullwhip effect results can be highly supported with the bias results.

This metric is worth tracking on a monthly basis, it can show the sales trends of the selected product. It can also highlight monthly peaks and support reaction. Using forecast bias the product portfolio can be divided taking into consideration the tendencies of the market. A revision of the planning can be executed to improve quality. The higher product variety leads to an increase in complexity. Due to this the quality of the forecast cannot be kept on the highest level. To support the estimation process forecast bias that shows the tendencies can be used (Wan, Sanders, 2017).

Bias can be connected to operational performance and bullwhip effect elimination due to the results of the tracking. Tracking of tendencies can increase the quality of the forecast and it can also support the identification of the gaming behaviour (Seitz et al., 2020).

The calculation of forecast bias is a comparison of the actual volumes and the plans. The result can be both positive and negative. If the bias is positive the product is over forecast. In case of negative bias, it is under forecast. Equation 2. presents the calculation based on Seitz et al (2020) and practical applications.

$$FB = \frac{D_c - F}{F} \tag{2}$$

Due to the length of the supply chain, from a process improvement perspective usage of the latest forecast is not enough in several cases. Lead time needs to be taken into consideration in the case of long supply chains and supply networks. This can be supported by the fixed period for forecast. It can be, for example, two months: that can cover delivery time and reaction, also at the supplier and manufacturing level. In this case the fixed forecast needs to be used in the equation.

$$FB = \frac{D_c - F_x}{F_x} \tag{3}$$

Bias calculation is also based on demand and forecast. It has a targeted interval that shows acceptable level of change. Bias shows in the case of deviation also its' direction. This gives further information regarding the bullwhip effect. Once we know the direction, it is also known in the chain in which direction the first actions need to be done to eliminate harmful impacts.

4.3. Service level (SL)

The importance of service level is justified by the fierce competition of the market. Multiple replacement products are competing for the market share. Service level shows the availability that is crucial to reach the customers. Service level also

influences the demand, as products with higher service levels typically have a higher demand (Bhuniya et al., 2021). Through this forecast is impacted.

Service level shows the percentage of the fulfilled orders compared to the requested quantity. It can be introduced at all levels of the supply chain. Differentiation in calculation can also be introduced based on product classification or any predetermined criteria (Sereshti et al., 2021).

At the customer end of the chain, it also gives information on customer satisfaction (Customer service level (CSL)). At the same time it still shares information between the other members of the chain. It can point out where the problem occurred that resulted in poor performance. It can also potentially highlight gaps in the forecasting procedure. As this metric compares the requested and the supplied quantity only actual data can be used. Equation 4 and 5 shows the calculation method based on Buhniya et al (2021) and practical applications.

$$CSL = 1 - \frac{D_c - S}{D_c} \tag{4}$$

$$SL = 1 - \frac{D_{-1} - S}{D_{-1}} \tag{5}$$

The service level in practical use is attached with a target. The targeted service level can differ on an industry level. It is typically the highest in the food industry due to the short shelf life of the products. Once the value is out of the target the potential reasons behind need to be analysed. As the calculation shows peak demands that can lead to the bullwhip effect an immediate filtering option can be achieved if the occurrence is reacted to.

4.4. Combination of the indicators

In practice the aforementioned metrics are commonly used together. This combined usage can highlight additional information. If only forecast accuracy is used no information is obtained if the product is over or under-forecast. This information is added by the forecast bias.

The service level is primarily important due to the customer focus approach. It is worth checking the CSL (customer service level) and SL between other members. Checking the SL and FCA together can also give us information. Sufficient service level should be paired with proper forecast accuracy and positive or close to zero bias. There can be some exceptional cases (like sales of dead stock) but normally the values of the aforementioned metrics analysed together should answer product accessibility related questions.

Both aforementioned measurements aim to reach a better forecast. It is crucial to have proper inventory control. A lack of accurate planning results in lower effectiveness and quality (Moller et al, 2021). Supporting better demand planning can impact the bullwhip effect. As demand management is one of the core reasons behind the phenomenon, improvement of the field is very important. As all the aforementioned measurements are calculated based on the forecast, demand, and real sales value they can show the bullwhip effect. Using them in a targeted way to indicate

the phenomenon can increase the flexibility and decrease the level of negative impacts.

The FCA, FCB and SL are not only connected to each other but also reflect other areas such as inventory. Over or under forecasted products cannot be considered as optimal regarding the kept stock which can also be impacted by the presence of the bullwhip effect. The question is: Can any of the mention indicators be used to predict bullwhip effect? Can any of the indicators show the presence of the bullwhip effect?

5. INDICATORS TO MANAGE BULLWHIP EFFECT

The indicators used in the supply chain can be analysed during the investigation of the bullwhip effect. Those can initiate preliminary, on the spot and subsequent analysis. From this perspective metrics can be categorized into three different groups:

- Indicative

These metrics potentially show the occurrence of the bullwhip effect in advance or in the early phases. The aim is to take immediate action to reduce the probability of the occurrence with as many members of the supply chain as possible. It is also important to avoid impacting the customer.

- Mitigative

These metrics can be used to eliminate or at least decrease the impact of the bullwhip effect. They reflect the occurred phenomenon. Using these metrics the degree of oscillation can be reduced. Mitigative purpose can also help maintain a high level of the customer satisfaction.

- Analytic

These measurements support a deeper understanding of the phenomenon's background. They are mostly used for further investigation once the problematic period is over. They can be also the basis of process improvement actions.

5.1. Indicative measurements

Forecast bias and forecast accuracy can possible be used for indication of the bullwhip effect. In the calculation of these metrics current demand is compared to the historical forecast. The expectations and the realization are compared. The exact timing of the frozen period is adaptable based on the supply chain and industry's characteristics (number of echelons, geographical distances, etc.). As a result the indication can be realized in time. When the bullwhip effect is present forecast numbers do not cover the real demand. These two measurements indicate the deviation from the forecast. If the bullwhip effect is present forecast accuracy decreases and the absolute value of bias will be higher.

The change of bias and accuracy can be caused by other factors as well. These can be, for example, IT issues, so the forecasting system does not show realistic numbers or handling of returned goods. These cases can result in bias or accuracy change but the root cause can be identified, and the issue quickly solved.

These metrics are widely used due to their adaptability and scope. Based on the length of the chain, lead time, number of echelons etc. these are customized.

Meanwhile the indicators essentially remain the same. The planned and actual quantities are compared. This shows if customer demand has any unachievable fluctuation considering the flexibility of the chain.

When using forecast accuracy and forecast bias small deviations are noticeable. It allows a chance to check whether it is caused by something known or something unpredictable. It is also possible to take steps in advance if the bullwhip effect is predicted based on the investigation. These steps can reduce potential losses. It can shorten the range of the bullwhip effect and the number of effected echelons.

Using the aforementioned metrics, the bullwhip effect can be recognized before all members of the chain are impacted. It gives space for communication or compensation towards the customer. At the same time, it also enables modification of the forecast toward production to provide a much clearer and more transparent picture in all parts of the supply chain.

In addition to the indicative purpose forecast accuracy and bias can be used for analytic purpose with regard to the bullwhip effect as well. It can give information on the quality of the forecasting methodology used. This also has a significant impact on the bullwhip effect.

5.2. Mitigative measurements

Indicators used with mitigative purpose aims to eliminate the impact of the existing bullwhip effect. The widely used measure that can be applied for this purpose is service level. The metric reflects the existing situation. The low service level value can indicate the bullwhip effect if the stock level is not sufficient to cover the incoming orders. The measure cannot be applied as an indication due to the scope, but it can be used to reduce the negative impact. Service level is applicable when the demand is higher than the available quantity.

The realization of the presence of the bullwhip effect is important to reduce impact. It enables proactive approach instead of reactive. As a result, potential financial losses can be prevented and the degree of oscillation of the bullwhip effect can be decreased. Action can drive a positive result both at an echelon level and on chain level.

At an echelon level, for example, substitute products, a delay in promotional activity or compensative discounts can be offered to cover the sales gap generated. These activities will not terminate the bullwhip effect, but the sales results will be impacted less severely.

It can also support the chain level action. As the out of ordinary order can be handled in place, further parts of the chain do not need to be impacted. Exceptional information on the market situation can change manufacturing plans or orders sent to the supplier. Both are small steps, but at the end significant financial impact can be prevented. It can also support the non-financial areas.

The aforementioned example shows a case with information flow from the customer to the production. It can also work inversely. For example, production can communicate through the information chain regarding a missing part. This enables the distribution and retail level to develop solutions to decrease the impact.

The service level is highly monitored in most of the supply chains due to the importance of the customer focus approach. It is easy to extend the current way of using it with some additional check points. As the metric is present the task is to incorporate its usage into mitigation of the bullwhip effect. This metric is calculated by all echelons of the supply chain.

The service level is mainly useful for outstanding orders. If the order can be served from the available stock this metric does not show any difference. Nonetheless, this can still be problematic. For sales significantly under expectation forecast bias or accuracy can be used. It can also be highlighted using inventory management metrics.

5.3. Analytic measurements

Analytic metrics help to determine the impact of the occurred bullwhip effect. For analytic purposes it worth checking the aforementioned three KPIs first. It can show trends and tendencies. If reoccurring fluctuation of accuracy or bias is typical, we may face seasonality that is not considered in the plans. It also needs to be considered if SL, FCA or bias value is low in the long term for a given product or product group. This also show inappropriate forecast. To introduce corrective measurements the highlighted metrics can support select products, product groups or time periods.

Besides the performance indicators showing the presence of the bullwhip effect, there are ones which show the consequences. We can use them once it has been determined which product or area is impacted. These measurements cannot be used for indication or immediate action. The focus is rather at the echelon level than chain level. Metrics show cost and non-cost related impacts and do not focus on the cooperation of the supply chain members.

The fluctuation of these values can be caused by several other reasons besides the bullwhip effect. The measurements that can be used to justify that the bullwhip effect has happened are potentially used to precondition process improvement activities.

In this category example indicators are listed that can be impacted by the bullwhip effect. These are also important because the costs in the supply chain are increased by them as well. The supply chain and industry specific factors can be considered during the selection of the measurements. The critical areas are highlighted this way. Below some potentially impacted indicators are listed as examples.

- level of inventory and inventory turnover
- capacity utilization
- development of the safety stock
- lead time and delivery time of goods
- warehousing and transportation costs

The listed metrics are supply chain related impacts. Nonetheless, besides the immediate reflection on calculation the effect is more complex. It has financial consequences both immediately and in the long term due to the need for time and cost to return to the standard status.

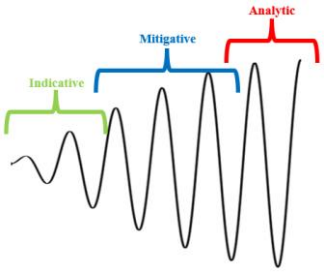
5.4. Time aspect

Time is a crucial aspect in respect of the bullwhip effect. As time passes the impact of the phenomenon becomes higher due to the increasing degree of oscillation. Based on the time passed the bullwhip effect can be split into three phases: early phase, intense phase, recovery phase.

In the early phase the first signals of the occurrence are present. The intense phase is already noticeable at multiple levels of the supply chain. The recovery period is once the phenomenon has already decayed; the consequences are appearing. By this time the impact has reached all levels of the supply chain.

The figure below shows in a timely manner the application of the aforementioned indicators and grouping. Moving from left to right indicates the time passed and the progress within the chain. In the early phases the signal is only present at the customer-retailer level of the supply chain. Forecast accuracy and bias can be used with indicative purpose. At the intense phase the phenomenon has already reached more actors of the chain and it is present in the service level metrics. Here the service level can be used together with the accuracy and bias to indicate the impacted products. The analytic purposes are in scope at the latest stage. By this point most of the chain members have already been impacted, recovery has started.

Figure 1. Time aspect of indicators analysing bullwhip effect



Source: Authors' edition

Integrating the targeted analysis of the bullwhip effect can increase the supply chain performance. As the indicators used are already applied no extra resource or process change is needed to be added. Only the perspective and approach change are needed. The measurements are already known and used; the task is to show the different method of use.

Identification of the presence of the bullwhip effect can show the relevant reasons of the phenomenon that are impacting a given chain. This support targets process improvement actions and in the long-term mitigation of occurrence. The most affected products can also be determined.

5.5. Application of the indicators

Table 1 shows the indicators that can be used for the different purposes. Regarding indicating the bullwhip effect forecast accuracy and bias are the

measurements. For this purpose, daily calculation is the most efficient which enables proactive approaches. In practice the calculation can show the value of these indicators on item level. Indication of the bullwhip effect can happen through filtering out the products with FCA or FB out of threshold. Once the problematic items are selected it can be simply checked if the difference is due to known reason (e.g., quality issue) or further investigation is needed. Recognizing the probability of bullwhip effect occurrence can prevent unnecessary productions and extra stock. On the other hand, it also can support to serve potential extra needs of the customers.

Table 1. Used indicators and application directions

	Indicative	Mitigative	Analytic
Forecast accuracy	X		X
Forecast bias	X		X
Service level		X	X
Application	Daily measure Threshold value	Daily measure Not sufficient availability	Big Data Patterns

Source: Authors' edition

For the mitigative purpose usage of service level is suggested. The value of this metric is also calculated on item level and daily basis. Here the application is also through analysation of the items with not sufficient availability. It enables reacting on the lost sales opportunities and preventing further supply chain echelons from unrealistic demand information.

Using these measures on analytic purpose is building on the technological development (such as Big Data) that enables long-term data availability. This approach has multiple application possibilities such as analysation of price increase, promotion, new product launches, seasonal products (in or out of season) etc. During the analysation, patterns are being researched. Cases from the historical data with similar discrepancies of measures. Processes can be improved through building in the learning of this analysation.

6. CONCLUSION

The bullwhip effect is a phenomenon of both scientific and business significance. Its occurrence leads to a decrease in performance and direct and indirect costs. The current competitive environment puts pressure on supply chain operations. To gain an advantage on the market, the supply chain needs to be competitive as well. At the same time the capacity to improve processes is also limited. Human and cost level limitations narrow down the possibilities.

Currently scientific and practical approaches are separated. There are several case studies and best practices to support handling the bullwhip effect. However, these are specialize in the studied environment and characteristics. Adaptability of these best practices is very limited.

Forecast accuracy, forecast bias and service level are indicators that are used in multiple industries at all levels of the supply chain. The aim of the usage is to improve the quality of the estimations to reach a higher level of customer service. These measurements compare the estimations with the real demand value.

The bullwhip effect influences the value of these metrics; as in all calculations demand plays an important role. The measurements show deviation from the targeted value. Forecast accuracy and bias currently mainly support exceptional cases, such as allocation planning when there is a shortage or a need to sell overstock. In daily use it is less in focus; they are rather used to evaluate the performance of the employees or systems. Service level is more commonly applied also in the daily operation, due to the customer focus approach. This measure is mainly used for local, echelon level purposes. The main purpose its usage is the monitoring of unexpected bottlenecks.

Targeted usage of these measurements can support conscious operation at a chain level. It can help in the early recognition and more successful handling of the phenomenon. As the metrics exist and are known in the chain additional resource requirement is not high.

This approach does not aim to solve all the negative impacts of the bullwhip effect in one step. The goal of this study is to present a solution to make the first step. This solution use existing resources and processes. It adds a new perspective to a tool in use. The requirement is a slight change in the way of reading and understanding the measurements and a higher awareness of the phenomenon. In the mid-term it can have a process improvement effect also, as it leads to better visibility on the bullwhip reasons of the examined chain or echelon.

In the continuously changing environment this subsequent analysis enables the process to be investigated from a different perspective. Additional information can possibly be explored. A combination of preliminary, on the spot and subsequent analysis allows the process to be evaluated taking all the perspectives into consideration. The analysis can be specified based on the characteristics of the given chain member and considering the main attributes of the chain. Easy adaptation is due to the measure's flexibility.

The conclusion reached by indicator and mitigative measurements should also be integrated into the subsequent analysis. It is supplemented by the potential listed metrics to view all the aspects. The investigation of the full picture allows process improvement actions to be initiated that target the reduction of the impacts caused by the bullwhip effect.

This research is focused on practices where the mentioned indicators are used. In multiple industries the application of these measures is typical. However, interpretation or calculation level can differ which limits the adaptability. The mentioned measures may not indicate all the instances when the bullwhip effect occurs.

As extension of the research, further frequently used indicators can be analysed. The impact of bullwhip effect is typically on stock fluctuation, inventory related measures (such as inventory turnover rate or days to sell inventory) can be used in analysis phase. Beside the extension of the scope of metrics also practical analysis is needed. The result should be tested in multiple industries.

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