

CONTEMPORARY SCIENTIFIC LANDSCAPE OF THE BULLWHIP EFFECT RESEARCH

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Abstract

There are several researchers working with the questions of supply chain management and the bullwhip effect. The goal of this paper is presenting the different organizations investigating this topic. These institutions relate to each other on several angles. Research and publications are also made in cooperation between them. These relations can influence the concept used in the different research groups. This study aims to define the most significant schools of bullwhip effect and scientific network behind. The main authors of the topic can be determined as well. It is also important to see how the main researchers are influencing the cooperation landscape. This article is investigating these connections considering both the most significant researchers of the topic and the research groups. Basis of this study is dimensions database and the VOSviewer program is used to visualize the scientific landscape. Using this method, the connection and cooperation can be visualized. This research is a literature review from the perspective of network generated by the publications analysing bullwhip effect and supply chain management. There is potential to further extend the scope of the study by involving connected areas such as performance measurement. The investigation can point out whether bullwhip effect researchers are extending the scope with the performance measurement systems or the other way around. This will also answer the question how the key performance indicators in use measure bullwhip effect based on literature. It will also reflect on the direction of research between theory and practice.

Key words: literature mapping, bullwhip effect, scientific landscape, performance measurement

1. INTRODUCTION

There are thousands of studies investigating different fields of the supply chain. The areas considered in the research are diverse, different fields are in focus from

multiple perspective. Bullwhip effect is one of the fields appearing in a lot of research. It can be stated based on checking the articles of the main authors that even if the understanding of the basics of principle is common there are huge differences in the further investigation, direction. Bullwhip effect interpretation can determine the main research schools that are presenting studies on the topic. These research groups can define a scientific landscape of the bullwhip effect.

The topic of bullwhip effect is not only important from the scientific perspective, but it has industrial importance also due to the high practical impact. The different members of the supply chain need to be able to handle the consequences of the bullwhip effect. To improve operational performance, they need to be able to recognize the phenomenon and manage it in the most effective way. Different methods, metrics and measures need to be initiated. Research on the topic help to find the most appropriate tool to be used. Through case studies, results and examples presented by the research groups bullwhip effect can be translated to the practical implementation. It supports highly to find a solution.

In this research the database of dimensions.ai has been used as the source of the information. The investigation is focusing on the past four years (2016-2019). The information is visualized with the VOSviewer software which is a tool to show network based on the bibliometric database. Using the program both the connection of authors and institutional network can be presented. Beside the time frame other criteria is also limiting the database. Only the authors and institutions that are having more than five articles are considered in the research. This minimum quantity is filtering out the not relevant parties.

Using the mentioned source and software the aim is the visualization of the network of the bullwhip effect researchers and the institutions they are working at. Based on the result of the literature mapping the goal of the article is also definition of the bullwhip effect research schools, their cooperation and focus of research.

Performance measurement is highly connected to the bullwhip effect. In this article the connection of the researchers of the two area is investigated. It is also interesting to check if the authors are extending their research from the bullwhip effect analysis to the performance measurement or the other way around. Defining the direction in this question is also aim of this research.

This article first presents the network of authors and institutions investigating the bullwhip effect. Then the joint research of bullwhip effect and performance measurement are checked. Here the subject is also author and institution level landscape. Based on the result of the literature mapping three bullwhip schools are defined by the authors. These schools are following different approaches to investigate bullwhip effect.

2. LITERATURE MAPPING

2.1. Bullwhip effect

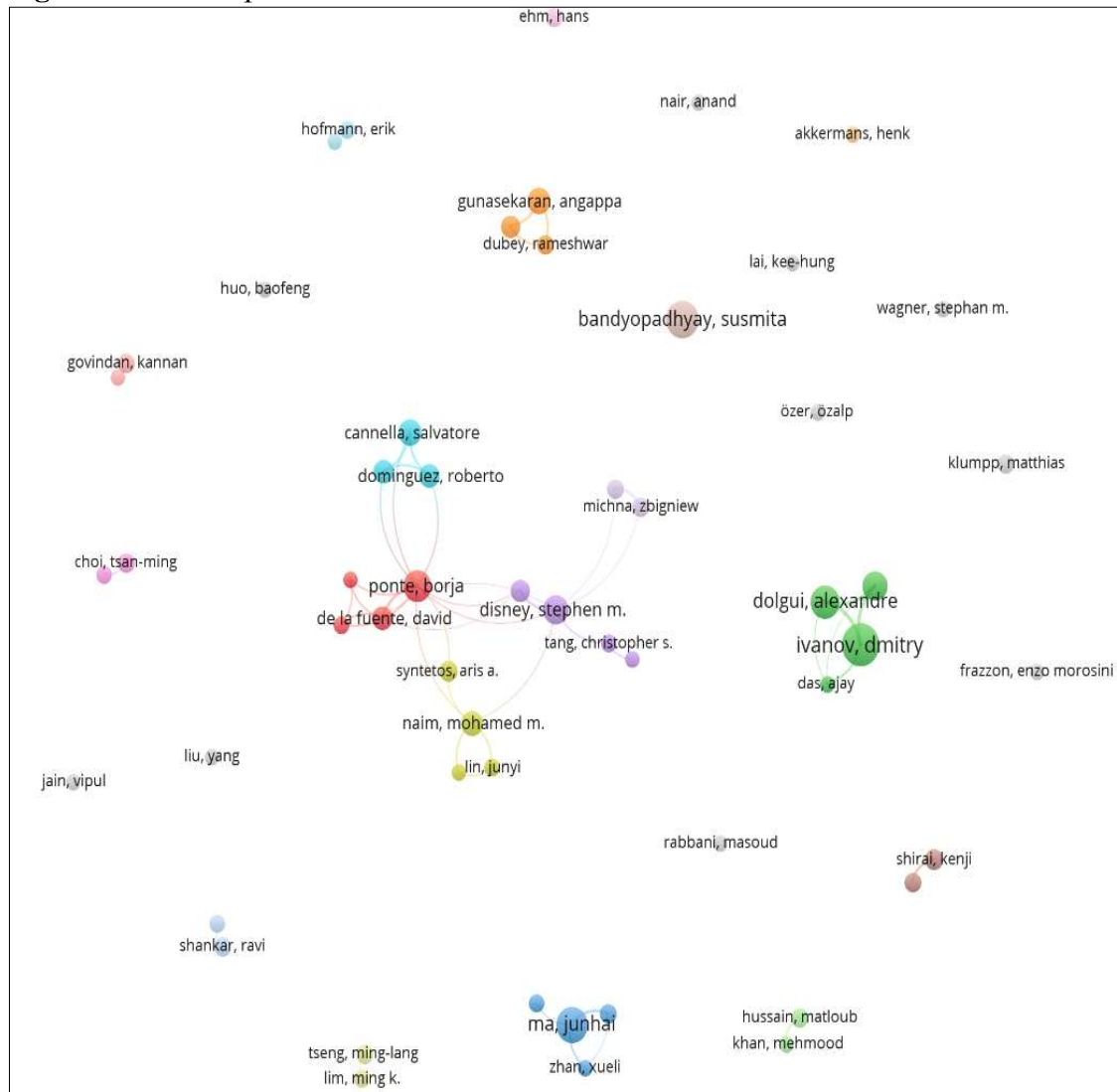
Bullwhip effect (BWE) has strong academic and business interest due to the potential malfunctions that can be generated in the supply chain if it occurs. The main

understanding of the phenomenon is common but still among different research groups interpretation differ highly. The bullwhip effect term was defined in a 1997 study by Lee, Padmanabhan and Wang. It was recognized by Procter and Gamble through the analysis of the diaper orders. Customer demand fluctuation was not explaining the level of variability. The phenomenon was also present at other sectors and companies. As the main causes the authors define price, demand signal processing, batching of orders and rationing game. The authors describe bullwhip effect as below: “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)” The subsequent research discovered further causes and details on the topic, but the core understanding of the phenomenon is as above.

Based on dimensions.ai database bullwhip effect is considered in 10653 research since 1970. The main researchers are Stephen M Disney, Denis R Towill and Dmitry A Ivanov based on the number of studies published. Disney has studies on this field since 1997, many of them in cooperation with Towill under the umbrella of the Cardiff Business School. Towill is also remarkable person in the bullwhip effect research. He has been working closely with Disney until he passed away in 2015. He played important role in the establishment of the research group in the Cardiff University. If the investigation is focusing on the most recent period (past 4 years) Dmitry A. Ivanov is leading the list, more than half of his articles on the topic is from this time. Stephen M Disney is still on the top 10 but only 15% of the related articles are from the most recent period.

Figure 1 shows the landscape of cooperation regarding the bullwhip effect researchers considering 2016-2019 period. To limit the mapping only for the most relevant actors of the area only the authors with at least five articles are considered in the investigation, which means the 10% of the authors (57 authors matches the criteria). The bigger the mark the higher number of articles are written by the given author. It is visible that Dmitry Ivanov and Stephen M Disney is considered as centre of research groups. Beside them also Ma Junhai and Ponte Borja can be mentioned as significant character. The map is presenting that direct or indirect connections are formed between several authors. Even so there are still some relevant researchers with no significant collaboration with the other authors in the bullwhip effect subject.

Figure 1. Bullwhip effect authors and connections 2016-2019



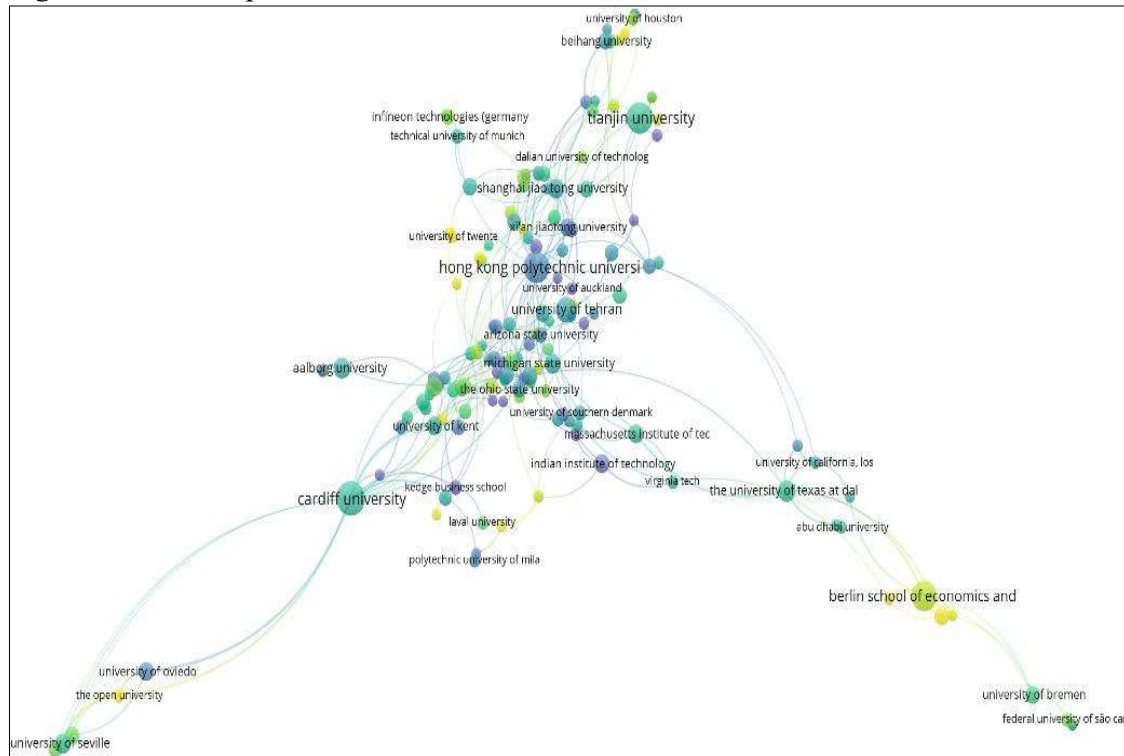
Source: Dimensions.ai database, visualized with VOSviewer software

Figure 1 also presents the cooperation of authors and research groups. Dmitry Ivanov has strong connection with some researchers such as Alexandre Dolgui, but his network is isolated. It is not extended further with other bullwhip effect researchers. In contrast other author communities are more connected with each other. For example, the group lead by Stephen M. Disney is connected both with the one led by Borja Ponte and the one led by Mohamed Naim.

It is also interesting to see these connections on organization level. Figure 2 presents the institutional landscape. The minimum number of documents by an organization is still considered as five, 10% of the organizations meet these criteria (148 organizations). Based on the mapping Hong Kong Polytechnic University is highly connected to other institutions, it has central position in the network. Cardiff University, Berlin School of Economics and Tianjin University are also significant players with several links. These institutions with the most significant connection

chains are not related to each other, only through additional elements. This scientific network is not limited on geographical level, cooperation is found all around the world. It is visible that the network and cooperation on institution level is much more complex and the collaboration is tighter than on author level. As authors can have relation with multiple institutions through the years, connections are more likely to be generated. Furthermore, a given author can publish under the umbrella of multiple organizations.

Figure 2. Bullwhip effect institutions and connections 2016-2019



Source: Dimensions.ai database, visualized with VOSviewer software

As number of institutions presented are high it worth to highlight the most relevant ones and connect them with the main authors. Cardiff University is represented in author level by Stephen M Disney (in the 2016–2019 period, also by Denis R. Towill in the earlier years). Berlin School of Economics is the institutional background behind Dmitry A. Ivanov, Tianjin University represented by Ma Junhai on the author level summary. Regarding Hong Kong Polytechnic University it is difficult to pick a researcher, several smaller research groups are representing it led by Choi Tsan Ming or Wong Wing-Yee.

2.2. Bullwhip effect and Performance measurement

As stated by Kaplan and Norton: “No measure, no improvement. (Kaplan, Norton, 1992)” Performance measurement is appearing in several research. The area has strong industrial connection and interest behind. It can have huge impact on the operation of any supply chain. The topic occurred in more than 40 thousand research

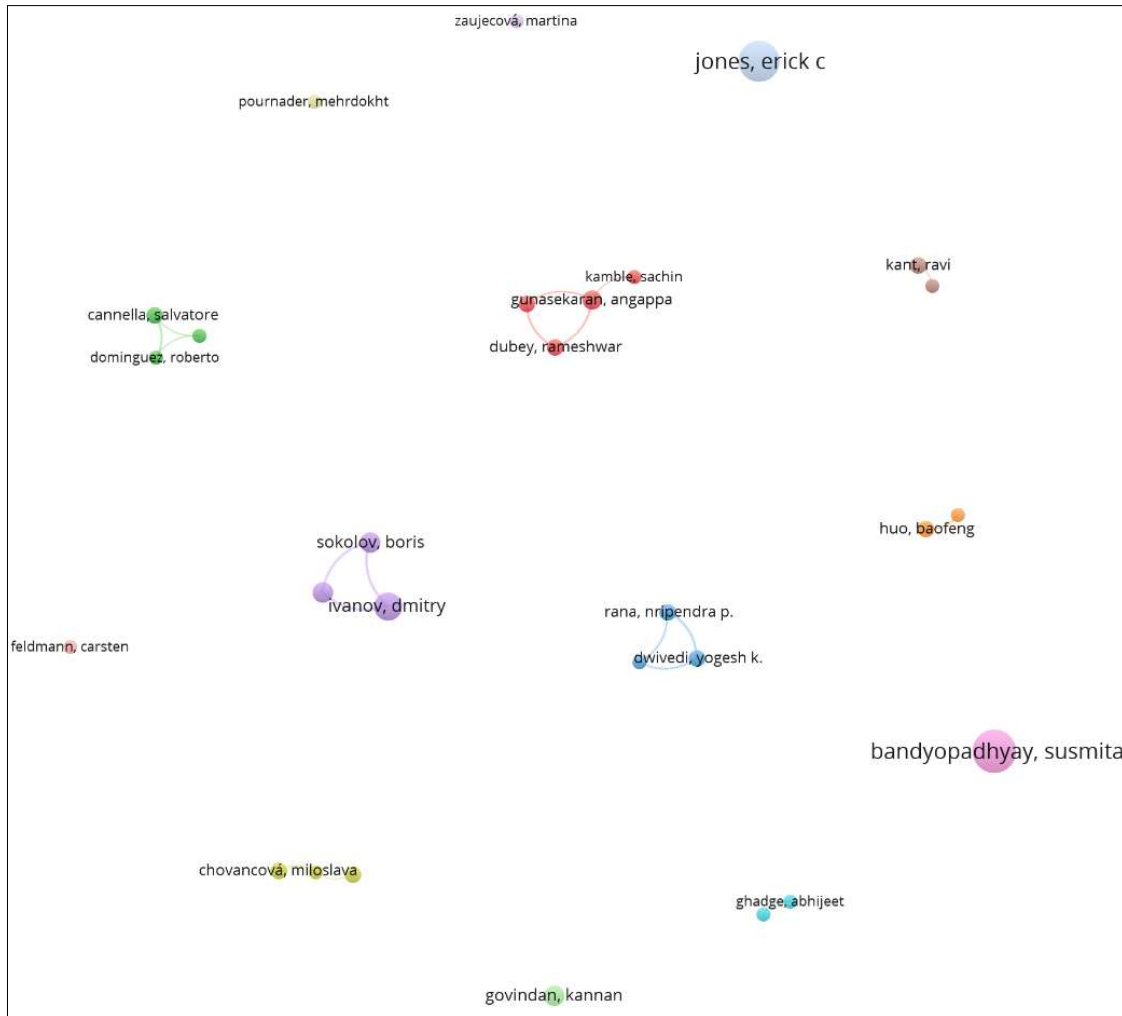
based on dimensions.ai database, the first article is from 1899. If the most recent years are considered (2016-2019) almost 13 thousand relevant publications are available in the database. The areas of research are mainly connected to management, information technology and systems or engineering.

Performance measurement framework is established to measure and enhance the efficiency of the supply chain. It is an enabling tool for managers to manage supply chain in an efficient way, support with information in regards the needed enhancement to achieve excellence. It is fundamental to reach and sustain competitive advantage. (Balfaqih et al., 2016) There can be different reasons to develop and establish performance measurement system (PMS). PMS can support in identification of success, understanding if customer needs are met, perceiving business processes, making decision, enabling, and tracking progresses. It can also take part in bottleneck, problem, or waste identification or in finding the improvement potentials. (Gunasekaran & Kobu, 2007) There are several ways to approach performance measurement. Such as models like SCOR or BSc model, process based technics that are building on the process based analysis of the supply chain, perspective based models building on generic measures but also consider interrelationship between them and hierarchical approach that consider that metrics on the different level of hierarchy on the SC. (Jagan et al., 2018)

Bullwhip effect and performance measurement has several common interests. The result of the bullwhip effect is malfunction in the operation, therefore supply chain performance is affected. This malfunction means that goods and/or information are not getting through the chain perfectly. Result can impact both on time and quantity, that ends in cost related consequences. (Wiedenmann & Größler, 2019) Due to the mentioned results it is important to investigate impact of BWE on the performance and the possibilities how it can be integrated to the PMS, metrics, and models.

If bullwhip effect and performance measurement is checked together the number of publications is much less as this is a more specific part of the performance research area. First research was written in the 1980s and all together there are 2267 publications including both two fields. Considering the same period (2016-2019) 737 publications can be found in the dimensions.ai database related also to management, IT, or engineering field. If the threshold value of minimum five article per author is still considered this case only seven authors are meeting the requirement. If this quantity is decreased to three 28 authors are present in the examination. As it is a more specific area threshold value has been decreased to three, this is considered in below results. As visible on Figure 3 these 28 authors mean eight research groups and rest of them are individual researchers with no co-author connection. Compared to the bullwhip effect network (Figure 1.) below chart shows much less connection and co-authorship. We can only see individual researchers and small research groups of two or three author, but these groups are not having further connections.

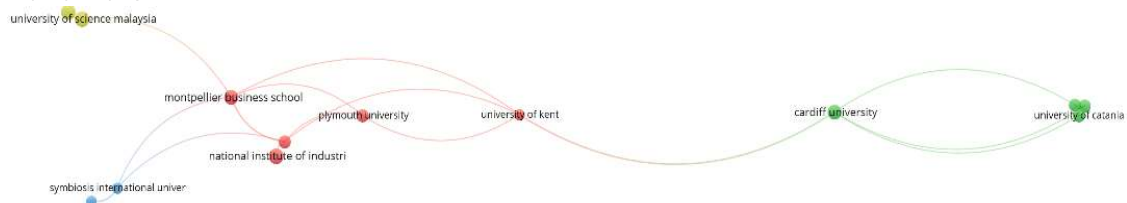
Figure 3. Bullwhip effect and performance measurement authors and connections 2016-2019



Source: Dimensions.ai database, visualized with VOSviewer software

The connections are valid on institution level as well. Network is visualized on Figure 4. In the program also three articles were set as minimum per institutions due to the smaller number of relevant articles. Figure 4 shows which organizations are working together on research of bullwhip effect and performance measurement. As visible considering the institutions there is no single item that is separated. All the institutions with at least three relevant articles relate to at least one other organization.

Figure 4. Bullwhip effect and performance measurement institutions and connections 2016-2019



Source: Dimensions.ai database, visualized with VOSviewer software

Some similarities can be pointed out not only regarding the authors but also regarding the organizations. Cardiff University is visible both on Figure 2 and 4. Bullwhip effect is analysed not just on its own but also with performance measurement perspectives involved. We can also see that Montpellier Business School and National Institute of Industry has the biggest network. These institutions relate to five different organization, co-authorship is very strong related to this associations.

2.3. Bullwhip schools

Based on the most relevant authors and institutions it is possible to define the schools or approaches regarding bullwhip effect. Different groups are handling the phenomenon from diverse perspective. In the sub-chapters the key elements related to the different groups are summarized and presented with some examples related to it.

The three schools defined are the followings:

- Bullwhip focus concept: The researchers of this school are focusing on the phenomenon itself. Research goes deeply into forecasting, information sharing, replenishment and ordering policies mainly.
- Supply chain performance concept: The aim is improving global supply chain performance. BWE is considered as a part of the bigger picture. The focus is performance improvement based on the result of other bullwhip effect research and integration of the potential methods.
- Customer focus concept: This aspect uses a different viewpoint. Customer is the centre of the research. More focused on price, promotion, and customer satisfaction. This approach is more practical, market driven.

The approaches mentioned before relating to the scientific landscape as well that is visible on Figure 1. Bullwhip focus concept is in the centre of the figure with Stephen M. Disney as a main author. The supply chain performance concept is represented by the research group led by Dmitry Ivanov, BWE and performance measurement common landscape (Figure 3) presents further authors as well. The customer focus concept is more fragmented. For example, Junhai Ma is part of this group with pricing related research.

2.3.1. Bullwhip focus concept:

Cardiff Business School is one of the key institutions for BWE research since the 1990s. The main researchers are Stephen M. Disney and Denis R. Towill. The understanding of the phenomena is described as “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)”

The focus of the research is the replenishment rules, forecasting, ordering policy, trends, and information sharing. Demand signal processing was already mentioned as one of the reasons behind the bullwhip effect in chapter 2.1. It is understood as adjustment of the demand forecast and through this adjusting the inventory

replenishment parameters. The result can be over-reaction, which can lead to variance amplification. Usage of different forecasting methods can induce the BWE. (Dejonckheere et al., 2003) The setup of the supply chain can also highly determine the replenishment methods used. Vendor managed inventory (VMI) chains and traditional chains differ on this question. VMI concept supports the reduction of the bullwhip effect by elimination of a decision layer and a potential information delay. (Disney & Towill, 2003)

Demand fluctuation and non-zero lead time is among the main reasons also. However, these factors have been examined earlier separately also, phenomenon caused is known as demand amplification or the Forrester effect. Bullwhip focus concept investigation is partly focusing on this area. There are several case studies made on the topic. Disney, Towill 2003 study presents analytical examination and solution for bullwhip effect in case of a specific ordering policy. (Disney & Towill, 2003) It is also analysed how the reduction of the bullwhip effect meets the inventory performance requirements. As a result, a trade-off has been revealed. Reduction of the phenomena ends in increase in the performance requirements. (Warburton & Disney, 2007)

The information sharing in the supply chain is in focus as well. Currently information sharing due to technological development does not have technical barriers through the supply chain. Dejonckheere et al. investigate how traditional supply chain with no information sharing differs from the supply chain where the customer demand is known in all level. As a result of the mention research it came out that information sharing can decrease the amplitude of the bullwhip effect in the chain. (Dejonckheere et al., 2004)

The other side of the examination of the bullwhip effect is the reduction of it. Mentioned research group consider ten potential principles to reduce the bullwhip effect. These are partly built on the causes stated by Lee et al. and on other examples summarized as below (Geary et al., 2006)

- Control system principle: target and control to be harmonized
- Time compression principle: time requirement of task to be minimized, remove waste from the system
- Information transparency principle: transparency for all relevant member with no delay, holistic control
- Echelon elimination principle: number of echelons to be defined based on supply chain goals on the minimum level
- Synchronization principle: events are synchronized
- Multiplier principle: orders can be multiplied mainly between manufacturers and suppliers.
- Demand forecast principle: as forecasting is one of the reasons behind BWE this are should be improved by the already mentioned points such as information transparency. Different trend detections and safety factors should be eliminated, harmonized.
- Order batching principle: harmonization of the batching is needed in the chain

- Price fluctuation principle: price changes to be driven and planned
- Gaming principle: double guessing should be eliminated

Supply Chain performance is considered as connected area by this research group also. BWEs impact on performance can be measured based on Likert scale. Scores has been defined based on value streams: process, supply, demand, and control uncertainty. This covers the full supply chain, both abilities to meet production target, problems occurring due to poor performance suppliers, unpredictable demand changes and malfunctions in the information flow. (Geary et al., 2006)

2.3.2. Supply chain performance concept

As it was described in chapter 2.2 performance measurement and bullwhip effect research has lot in common. This aspect has been led in the past few years by Dmitry Ivanov based on the number of articles published. Beside the research group lead by Ivanov there are several other who analyse the topic. The most relevant authors based on number of articles are visible on figure 3. The focus among these researchers is not the bullwhip effect itself, it is investigated as a connected field that has impact on the performance of the supply chain. The main point is ensuring the planned economic performance. To reach this, potential barriers and bottlenecks are analysed. BWE is examined as one of those. The main point of checking it is the influence on information sharing, forecasting, inventory policies and ordering methods. Via these fields the supply chain echelons are highly connected with each other. Both global and local performance has significant dependency on BWEs operational occurrence.

Supply chain performance is highly affected by numerous different factors. These can be for example number of echelons and cooperation of them, coordination of the global concept, having the common understanding on the performance goals in the chain. In addition to the mentioned elements demand uncertainty (amplification of variation of demand) and differences in forecasting is also an important factor. (Ducq & Berrah, 2009)

For Dmitry Ivanov, the core of the research is control theory, ripple effect, disruption in the supply chain. Bullwhip effect is an important area influencing the mentioned topics. The direction is the analysis of the dynamics and performance in the supply chain. Ripple effect is one of the fields extensively studied by Ivanov, “describes a downstream propagation of the downscaling in demand fulfilment in the SC as a result of a severe disruption (or a series of disruptions) (Dolgui et al., 2019)”. It has been examined if ripple effect can drive the bullwhip effect. It has been proven that missing control during disruption causes bullwhip effect. Supply chain behaviour changes during this period, panic reaction can be observed. Coordination can allow elimination of bullwhip effect. Based on the research ripple effect and bullwhip effect is on negative interrelation which leads to backlog accumulation. That results in destabilization of inventory. (Dolgui et al., 2019) The main difference between BWE and ripple effect is summarized from several perspective. Main points are in the recovery timing and in the affected performance. Bullwhip effect is more focused on short term actions and effect on performance is also connected to this. It occurs regarding current performance and it means operational risks. (Ivanov et al., 2019)

Information sharing can be considered as key element regarding the bullwhip effect and the supply chain performance also. It is considered as potential to decrease risk in case of disruption. It has been proven by analysis that it improves supply chain resilience and robustness. (Hosseini et al., 2019) Information distortion has negative effect such as heavy fluctuation of orders on manufacturer side. It leads to unreliable picture on inventory level on multiple part of the supply chain. Increased number of echelons increase the uncertainty as well. Transparency is a solution to ensure timely and valid customer demand information. This decision is long term oriented and needed to consider rather global than local perspective. (Otto & Kotzab, 2003)

Information sharing is highly connected with forecasting, transparency can help in improvement of the quality of the forecast in the supply chain. Collaborative environment can lead to collective forecasting that can decrease uncertainty, improve forecast, and reduce probability of bullwhip effect. (Ramanathan, 2014)

Information transparency in the supply chain is an important question from the performance perspective. This is also crucial regarding the bullwhip effect. Supply chain performance can be improved via collaboration and information sharing. At the same time this can be also a tool to solve bullwhip effect or at least reduce it. Information management has impact on forecasting, ordering policies and inventory as well. Supply chain performance can highly depend on it.

It can be also recognized that the direction of research is performance measurement, BWE appear as a smaller part, component of research. Staying with the example of Dmitry Ivanov bullwhip effect is not the centre of the research. Ivanov is focusing on supply chain disruption, ripple effect and control theory. Bullwhip effect is appearing in the research as influencing factor. The research made is more likely to be carried out first on performance measurement and then on bullwhip effect.

2.3.3. Customer focus concept

Beside the two concepts mentioned before we can find a third approach. The starting point in this perspective is the customer. Ordering and inventory policies are not relevant directly for the customer. Also, the global performance of the supply chain is out of scope for this perspective. The more relevant information regarding bullwhip effect is the price and promotions. In the literature not only the supply chain related impacts of the BWE are investigated but also the more customer and sales focused outcomes. Bullwhip effect can result in lost sales and service level problems. (Trapero & Pedregal, 2016)

There are several research and approach regarding promotions and prices as it is one of the major causes of bullwhip effect. Market demand and supply is commonly considered as cause of price dynamics. Different results are also presented regarding pricing. Tai et al. conclude that last period price and demand has larger impact on bullwhip effect than the current period. This shows that pricing strategy (steady or dynamic) should be defined based on last period result. (Tai et al., 2019) Competitor behaviour is also analysed regarding the price. Bigger bullwhip effect is expected if competitors influence the prices more. Due to this fierce competition leads to bigger bullwhip effect. (Ma & Bao, 2017)

Promotional activities play important role in retail stores, it has been proven by an A.C. Nilsen survey. Based on this constant price does not seem satisfactory to maximize profit. This goes contrary with BWE theoretical research regarding stabilization of prices. From marketing perspective, it has been studied that promotion can be beneficial even for supply chain system if it is properly designed. With greater frequency of the deals, peaks expected to be smaller. Su and Geunes study shows the coexistence of the bullwhip effect and increased system profit. Several factors need to be considered here: discount needs to be set judiciously; proper number of customers need to be interested to buy the discounted product; decreased price should not lead to significant level of forward buying. Profit generated with promotion partly ends up at the retailer level, extra costs mostly realized at supplier level. This needs to be counted as well to see if it worth to implement activity. It needs to be defined if cost of bullwhip effect is higher than the potential extra profit generated. (Su & Geunes, 2012)

Beside promotions customer satisfaction is also important. Service level is considered as quantitative measure for the supply chain. (Bandyopadhyay & Bhattacharya, 2014) It has been also studied how changes of service level requirement influence the level of bullwhip effect. Based on Khosroshahi et al. by increasing the required percentage of service level impact on bullwhip effect will also increase. The higher service level is required the more impact on bullwhip is expected. As the service level requirements in the practice are getting higher and higher this aspect and the cost related to it is also worth to be checked. The reason behind this correlation is that higher service level requires greater order size fluctuation. (Khosroshahi et al., 2016)

3. CONCLUSION

There is widespread interest in regards bullwhip effect. There are several researchers investigated the topic in the past more than 20 years. This article is presenting the last four years research network. On author level both research groups and individuals can be found. Typically, the main authors of the research groups have co-author connections also out of group with other researchers, organizations. The network of the institutions is even more complex. The threshold of five article per institution can be met easier, more data is present. We can see that common work; co-authorship generates dense and complex network on organization level.

Performance measurement is a highly connected area. Bullwhip effect has high impact on the supply chain performance, it worth to check the two area also connected to each other. We can find the institutions that are actively taking part in research in this engraving area. Checking the authors publishing it is mainly seen that the researchers of the broader performance measurement topic conducts sub-research on the more specific bullwhip effect topic. They mainly focus on the impact of bullwhip effect on the supply chain global performance or on performance measurement systems.

Checking the scientific landscape generated by the network of authors and institutions bullwhip effect schools or research perspectives can be defined. The first

group is deeply investigating the phenomenon. They deep dive on reasons, consequences, and possibilities of elimination. Second group is emphasizing this phenomenon as a part of the bigger picture, from global strategical perspective. BWE is generating malfunction and negatively affect the performance of the supply chain. This group check how this affect the other performance related questions. The third group is focusing on the customer. Pricing, promotion, and service level is mostly relevant for this perspective. As price is one of the main reasons behind the bullwhip effect it is also crucial to put focus on that as well.

As this research is limited only to the last four years period to further investigation extension of the examined time frame is suggested. It worth to check the last ten years and compare the results with the narrowed time frame. It is also possible to narrow down the research by choosing a specific performance measurement tool. As the goal is to support the practical application of the scientific researches Balanced Scorecard (BSc) could be an examined measurement system. BSc is widely used in practice that makes it proper performance measurement tool for this check.

4. REFERENCES

- Bandyopadhyay, S. & Bhattacharya, R. (2014). Solving a tri-objective supply chain problem with modified NSGA-II algorithm, *Journal of Manufacturing Systems*, 33, 41-50
- Balfaqih, H., Nopiah, Z. M., Saibani, N. & Al-Nory, M. T. (2016). Review of supply chain performance measurement systems: 1998–2015, *Computers in industry*, 82, 135-150
- Dejonckheere, J., Disney, S. M., S. M., Lambrecht, M. R. & Towill, D. R. (2003). Measuring and avoiding the bullwhip effect: A control theoretic approach, *European Journal of Operational Research*, 147, 567-590
- Dejonckheere, J., Disney, S. M., Lambrecht, M. R. & Towill, D.R. (2004). The impact of information enrichment on the Bullwhip effect in supply chains: A control engineering perspective, *European Journal of Operational Research*, 153, 727-750
- Disney, S. M. & Towill, D. R. (2003). On the bullwhip and inventory variance produced by an ordering policy, *Omega*, 31, 157-167
- Disney, S. M. & Towill, D. R. (2003). The effect of vendor managed inventory (VMI) dynamics on the Bullwhip Effect in supply chains, *International Journal of Production Economics*, 85, 199-215
- Dolgui, A., Ivanov, D. & Rozhkov, M. (2019). Does the ripple effect influence the bullwhip effect? An integrated analysis of structural and operational dynamics in the supply chain. *International Journal of Production Research*, 58, 1285-1301
- Ducq, Y. & Berrah, L. (2009). Supply Chain Performance Measurement: management models, performance indicators and interoperability, *IFAC Proceeding Volumes*, 42, 2053-2058

- Geary, S., Disney, S. M. & Towill, D.R. (2006). On bullwhip in supply chains – historical review, present practice and expected future impact, *International Journal of Production Economics*, 101 (1), 2-18
- Gunasekaran, A. & Kobu, B. (2007)., Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995–2004) for research and applications, *International Journal of Production Research*, 45 (12), pp. 2819-2840
- Hosseini, S., Ivanov, D. & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis, *Transportation Research Part E*, 125, 285-307
- Ivanov, D., Dolgui, A. & Sokolov B. (2015). Supply Chain Design with Disruption Considerations: Review of Research Streams on the Ripple Effect in the Supply Chain, *IFAC-PapersOnLine*, 48-3, 1700-1707
- Jagan Mohan Reddy. K, Neelakanteswara Rao. A & Krishnanand. L (2018). A review on supply chain performance measurement systems, *Procedia Manufacturing* 30 (2019), 40-47
- Kaplan, R. & Norton, D. (1992). The Balanced Scorecard Measures That Drive Performance, *Harvard Business Review*, January–February
- Khosroshahi, H., Hussein, S.M. & Marjani, M. R. (2016). The bullwhip effect in a 3-stage supply chain considering multiple retailers using a moving average method for demand forecasting, *Applied Mathematical Modelling*, 40, 8934-8951
- Lee, H. L., Padmanabhan, V. & Whang, S. (1997). Information distortion in a supply chain: the bullwhip effect, *Management Science*, 43, 546-558
- Ma, J. & Bao, B. (2017). Research on bullwhip effect in energy-efficient air conditioning supply chain, *Journal of Cleaner Production*, 143, 854-865
- Otto, A. & Kotzab, H. (2003). Does supply chain management really pay? Six perspectives to measure the performance of managing a supply chain, *European Journal of Operational Research*, 144, 306–320
- Ramanathan, U. (2014). Performance of supply chain collaboration – A simulation study, *Expert Systems with Applications*, 41, 210-220
- Su, Y. & Geunes, J. (2012). Price promotions, operations cost, and profit in a two-stage supply chain, *Omega*, vol. 40, issue 6., 891-905
- Tai, P. D., Duc, T. T. H. & Buddhakulsomsiri, J. (2019). Measure of bullwhip effect in supply chain with price-sensitive and correlated demand, *Computers & Industrial Engineering*, 127, 408-419
- Trapero, J. R. & Pedregal, D. J. (2016). A novel time-varying bullwhip effect metric: An application to promotional sales, *International Journal of Production Economics*, 182, 465-471

Wang, X. & Disney, S. M. (2016). The bullwhip effect: Progress, trends and directions, *European Journal of Operational Research*, 250, 691-701

Warburton, R. D. H. & Disney, S. M. (2007). Order and inventory variance amplification: The equivalence of discrete and continuous time analyses, *International Journal of Production Economics*, 110, 128-137

Wiedenmann, M. & Größler, A. (2019). The impact of digital technologies on operational causes of the bullwhip effect – a literature review, *Procedia CIRP* 81, 552-557