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Developing a Model for Using New Technologies of Big Data and Business Intelligence to Reduce the Bullwhip Effect in Supply Chain

Sadegh Danandeh[1], Davood Talebi[*2] , Mohammad Mehdi Movahedi[3]

[1]Department of Industrial Management, SR.C., Islamic Azad University, Tehran, Iran

[*2] Department of Industrial Management, Shahid Beheshti University, Tehran, Iran

[3] Department of Industrial Management, SR.C., Islamic Azad University, Tehran, Iran

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Abstract

Purpose: Supply chain has a very complex nature and is getting more complex due to increasing globalization, market growth, and constantly-changing customer preferences. This increasing complexity can lead to a lack of visibility of assets, inefficient inventory administration, or logistical mismanagement. These complexities lead to the well-known phenomenon of the "bullwhip effect" (BE) in supply chain.

Design/methodology/Approach: This research is of applied type in terms of purpose and descriptive-survey in terms of methodology. First, the information resulted from library studies, field surveys, and comparative comparisons was collected and the components and variables of this field were extracted after interviewing 19 experts and specialists in the petrochemical industry who were selected using the purposive sampling method. Then, the resulting indicators were screened in three rounds after developing a questionnaire and using the fuzzy Delphi method, which ultimately resulted in 38 indicators, presented in the form of 11 components and 3 aspects. The statistical population of the research in quantitative part includes managers and stakeholders of the petrochemical industry, 60 of whom were selected as the sample group using the simple random sampling method and the Cochran sample size determination formula. Subsequently, the questionnaire resulting from the final Delphi part was distributed among this sample. The judgment of 6 specialist experts from petrochemical companies who had PhDs with scientific and managerial backgrounds and at least 5 years of work experience in the industry under the research was used to confirm the validity of the questionnaires. The questionnaire reliability was also tested through Cronbach's alpha and composite reliability.

Findings: Finally, the data analysis was carried out by structural equation modeling and PLS4 Software. The results of the study indicated that the business intelligence, big data, and each of their factors have a significant effect on the bullwhip effect reduction.

Keywords: Supply Chain, Bullwhip Effect, Big Data, Business Intelligence, Fuzzy Delphi, Structural Equations

[*]Corresponding Author: d-talebi@sbu.ac.ir

Introduction

A growing number of companies are relying on various and constantly-evolving methods to extract valuable information through big data and business intelligence to make better decisions. The terms “big data” and “business intelligence” refer to the large volume (number) of information or data at a certain time period and within a specific scope. However, these new technologies have a short shelf-life and their effective value is quickly decreasing, which makes it difficult for academic research to keep up with their rapid pace. In addition, big data and business intelligence have no limitations on their type, form, or scale, and their scope is too broad to be limited to a specific area of study.

Big data and business intelligence are a hot topic in IT, jobs, and companies today, but defining what it really means is not always so clear and easy. If we ask the people around us to describe the "big data" and "business intelligence", we will most likely receive different answers, some may think of their own sets of images, documents, music, etc., small and medium-sized companies that are registered as systems to store large amounts of prices and invoices, or databases typically referred to as big data, or they may think of business intelligence as having acumen in business.

However, big data and business intelligence are actually more than what we have just read. Big data is not only about the huge amounts of data or how they are consumed, but also about the structure of these data aiming at providing added value with the organization and the business intelligence is “a set of methods, processes, architectures, and technologies that transform the raw data into meaningful and useful information to benefit from tactical and operational insights and more effective decision-making” (Forrester, 1958).

Big data and business intelligence, which are increasingly present in our lives, are changing our daily lives. Whether in our personal space or in our business environment, we are creating a continuous stream of GPS (Global Positioning System) data, phone records, text messages, and other information that are prepared to be analyzed, whether we like it or not. Social media platforms such as Twitter and Facebook, but also professional networking platforms such as LinkedIn are processing millions of records per second. On the other hand, the bullwhip effect refers to a sort of distortion occurring in the flow of upstream order information transfer, which is a larger fluctuation in terms of upstream order quantity caused by fluctuations in downstream demand, which is a common phenomenon in the supply chain. The existence of the bullwhip effect makes it difficult for companies to access market demands, which leads to overstocking and reducing the practical efficiency of the entire supply chain. The best way to solve the bullwhip effect is to reduce the nodes in the supply chain as much as possible; but this is affected by the abundance of data and the inability to process them in a timely and accurate manner. Consequently, the need for technologies, which guarantee the information accuracy to a large extent, becomes necessary. The supply chains are facing a large volume of data given the expansion of geographical boundaries and the increase in the amount of data and the increasing progress of artificial intelligence. On the other hand, the need to analyze them is

an undeniable necessity. Therefore, this increase in input data and the increase in the pace of their publication make the need for newer technologies inevitable. Among these new technologies, we can mention big data and business intelligence technologies, which can be used to manage this volume of data and to be used effectively in the supply chain, and ultimately, to reduce the whiplash effect and detect an immediate reaction that reduces the practical costs of companies directly. Factors that lead to the bullwhip effect include demand forecast modification, fluctuations in prices, order quantity decisions, shortage game, inventory imbalances, lead (procurement) times, etc. (Lee and Padmanabhan, 1997), whose analysis is considered as big data. The organizations have changed their view of the customer in recent years. Trying to understand customer needs, the level of customer demand, not only knowing what they have actually purchased, but also which products they investigated, how long they spent on a particular web page, how customers were influenced by promotional emails, and how they navigated the website is important.

Many researchers claim that information sharing can reduce the bullwhip effect in various industries (Tang, L, Yang, T, Tu, Y. et al, 2020). However, the impact of big data and business intelligence on reducing the bullwhip effect has not yet been analyzed. Since there can be various reasons for the bullwhip effect, the first goal of this research is to understand what actually causes the bullwhip effect in the supply chain. Then, it is investigated how to precisely apply the big data and business intelligence in the supply chain.

In this research, first, it will be briefly clarified what the bullwhip effect is and what its causes and countermeasures are. Then, there will be more focus on what big data and business intelligence are and how they can be used. Afterwards, more emphasis will be on the supply chain. The important factors that influence the adoption of BD and BI in SC in the context of a developing country were finalized through a literature review in the first step. The literature related to “big data”, “business intelligence”, “bullwhip effect” and “supply chain management” were studied.

literature Review

The Bullwhip Effect:

The bullwhip effect is a well-known concept in the business world and is observed in many industries. There is no specific definition of the bullwhip effect, however, there are many researchers who explain this phenomenon in their business. Therefore, this section of the paper first makes an attempt to explain what the bullwhip effect, big data, and business intelligence are, then, the causes of the bullwhip effect and what can be done to deal with it, and the research background are discussed.

Definition of the Bullwhip Effect

One of the first researchers who wrote extensively about the bullwhip effect was Lee et al (Lee et al.,1997a, 1997b). According to (Lee et al.1997a, 1997b), the bullwhip effect refers to “a phenomenon in which orders to the supplier are significantly different from sales to the purchaser (i.e., demand distortion), and the distortion is diffused in the amplified flow upstream (i.e., variance amplification).” The bullwhip effect can lead to “distorted information from one end of the supply chain to the

other" (Lee et al. 1997a). This in turn can lead to massive inefficiencies such as missed production schedules and lost revenue.

(Fransoo and Wouters, 2000) describe the bullwhip effect as "the result of information distortion in a supply chain, where upstream firms do not have information about actual consumer demand." Here, upstream refers to the part of the supply chain where suppliers and producers operate.

(Towill, Disney, 2008) describe the bullwhip effect as demand fluctuations at each level of the supply chain and amplification of these fluctuations in a way that they go beyond the customer. According to (Wang and Disney, 2016), the bullwhip effect is "the phenomenon where the order variability increases as the orders in the supply chain upstream increase." The bullwhip effect is often presented as arising from ineffective communication between the customer and the various members of the supply chain, but the bullwhip effect has only one cause: demand. However, these explanations are still a bit ambiguous. Therefore, an example of a case where the bullwhip effect is evident is now given.

Forrester first noted this phenomenon without using the bullwhip effect and only by an industry dynamics perspective about 45 years ago. The effect was later observed and recognized by Procter & Gamble (P&G) in connection with one of their products. Although the actual sales in stores were relatively stable and predictable in this problem, wholesalers and distributors' orders for P&G (the producer) fluctuated wildly, causing inventory problems for the produced product for P&G. Research showed that the distributors' orders fluctuated irregularly due to poor forecasting of the demand and a lack of coordination and trust among supply chain partners, as each individual entity in the supply chain made orders and inventory decisions from its own interests' view towards the supply chain upstream, which causes an increase in the amount of forecasting towards the supply chain upstream and led to excess inventory throughout the supply chain. Here, you can see a typical example of the bullwhip effect, where a small change in demand leads to a large change in order variety in the supply chain upstream (Lee et al., 1997a, 1997b; Wang & Disney, 2016).

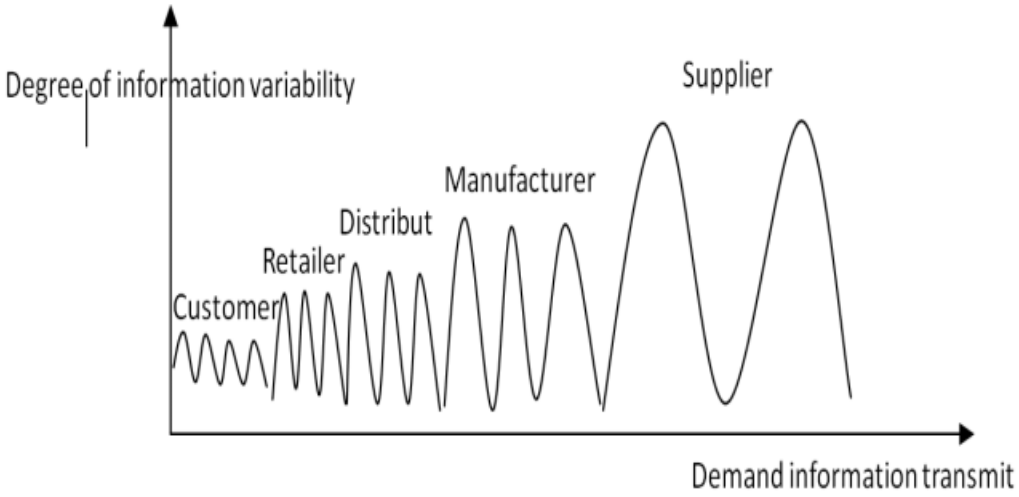

Figure 1: Information and Materials Flow in a Supply Chain (Dai, Li & Peng, 2017)

Figure 1 provides a visual representation of the bullwhip effect. It is clear from the figure that the degree of information variability increases as the demand information moves through the supply chain from the customer and ultimately to the supplier.

Big Data

Big data is a rapidly-growing technology and is widely used in many industries. As mentioned earlier, information sharing in the supply chain is important. Big data is considered to play a vital role in creating information sharing processes in the supply chain by enabling it. Siddique et al. (2020) describe the visibility as: "the ability of anyone, including customers, to access inventory, orders, raw materials, and delivery points at any time". Companies can minimize the future risks and maximize the supply chain profitability from end to end with regard to the big data. One of these risks includes the bullwhip effect. This part is deeper in big data technology due to this impact on the trend of visibility, supply chain, and information sharing.

(Brown et al, 2011) stated that "Big data refers to datasets whose size don't exceed the ability of conventional database software tools to capture, store, manage, and analyze". Similarly, (Jacobs, A. 2009) explains that big data is about "data whose size makes us look beyond the tried and true methods that are prevalent at the time". Both definitions include the idea of big data being something that cannot be processed using conventional equipment or methods nowadays. This phrase also implies that "data that we consider big today may not be considered big tomorrow due to advancements in processing, storage, and other system capabilities" (Mishra, Gunasekaran, Papadopoulos, et al, 2018).

According to (Cukier and Mayer-Schönberger, 2013), big data can be defined as "the ability of society to use information in new ways to produce useful insights or goods and services of significant value." These insights may be

an opportunity for managerial level enhancement with regard to jobs. As (Brynjolfsson and McAfee, 2012) stated data-driven decisions are better decisions. Using big data enables managers to make decisions based on evidences rather than intuition. (Brown et al, 2011). This statement implies that the more personal information one has, the better decisions one will make. Therefore, a company should start collecting as much data as possible. "Size is important, but there are other important attributes of big data, namely data variety and data pace" (Russom, 2011). In addition to large volume, data also needs to be processed as quickly as possible in real time and from as many resources as possible to best support the decision-making process (Brown et al, 2011). The big data can be considered as an enabler for decision-making and a tool for improving business processes in the context of SCM (Cecere 2013). Inspired by (Chen, Chiang and Storey, 2012), the following practical definition of big data is derived: The big data approach, in general, is a brief of rapid gathering and analysis of large amounts of data from various sources in order to improve business decision-making and overall performance and to reduce the bullwhip effect. Trying to show how big data can help reduce inefficiencies and bullwhip effect in the supply chain, this definition is appropriate for the purpose of this paper.

Business Intelligence

Business Intelligence (BI) is defined as "a set of methods, processes, architectures, and technologies that transform raw data into meaningful and useful information so that the organizations can benefit from tactical and operational insights and more effective decision-making" (Muriithi GM, Kotzé JE, 2013). The explosion of computing power and information acquisition techniques has led to the creation of big data in organizations. Big data analytics has received more attention than ever before, and organizations are investing heavily to acquire the necessary infrastructure and skilled workforce to use the large volumes of operational and external data to gain competitive advantage. This has led to a high demand for professionals with skills in data management, statistics, and business analytics. The BI technologies such as data warehousing, online analytical processing, data mining, and data semantics have matured and become mainstream in creating valuable controls and providing decision-making support.

For decades, corporate executives have made strategic business decisions based on information gathered from multiple reports that IT compiles, often conflicting sets of data.

Business intelligence systems promise to transform data by gathering data from all internal systems plus external sources to present a single version of the truth. This truth can then be presented to decision makers in the form of answers to highly-strategic questions. Gartner, an information technology research firm, coined the term "business intelligence" during the 1990s. Business intelligence generally refers to the process of transforming raw data from a company's various operations into usable information (Quinn, K, 2003). Companies are increasingly choosing to use business intelligence software to achieve the full potential of their data since data are used pretty limitedly in their raw form. The BI software includes specialized computer software that allows a company to easily collect, manipulate, and display data as

actionable information or information that can be used in informed decision-making.

The BI enables companies to improve the way they do business and forecast their supply chains by providing insight into critical information. Companies are empowered to reduce the amount of bullwhip effects in their supply chains and return to maximum revenue and profit by being able to forecast and deliver products and services at the lowest possible cost with the highest possible efficiency and productivity.

Some companies are finding it useful to share BI capabilities with business partners as well as employees. To do this, they are building web-based "BI networks" to provide information with suppliers, consultants, and others.

BI capabilities are expanding to nearly every part of the organization as companies try to provide business users with the critical data they need to do their jobs. Users need the following from their business intelligence systems:

- The ability to execute ad hoc queries
- Access to multiple databases
- Scalability, price, and reliability
- Ease of integration with back-office systems
- Real-time demand and volume
- Flexibility in increased interactions of businesses
- Fast and unconstrained processing of market data

Thus, business intelligence abilities and its applications can help solve supply chain inefficiencies and problems, including the bullwhip effect.

(Hsu et al, 2021) used big data improvement and agility enhancement to reduce the bullwhip effect. They used quality function deployment to analyze the interdependence between big data and supply chain agility, as well as between supply chain agility and the bullwhip effect. An integrated multi-criteria decision-making framework is proposed in this study and the largest relay producer in China is selected to identify the key factors of big data to improve the supply chain agility and reduce the bullwhip effect.

(Zeng, J. Y., Hsu, C. H., & Chen, X, 2022) studied the use of key agility metrics to quickly respond to the bullwhip effect problem in the supply chain to achieve the sustainability goal. Using the fuzzy Delphi method, they synthesized the impact of key factors and key principles of agile force, and then studied the impact of key factors on bullwhip effect and the relationships between them using fuzzy interpretive structure modeling analysis. And the results achieved indicate that agility can effectively improve the adverse impact of bullwhip effect and improve sustainability.

(Nyamukoroso, M , 2022) used a research to reduce the bullwhip effect by increasing supply chain agility through improving big data. An integrated multi-criteria decision-making framework was proposed and the largest relay producer in China was selected to identify the key factors of big data to increase the supply chain agility and reduce the bullwhip effect, thus providing an effective method for electronic equipment producing companies. Create a supply chain that can respond quickly to changes and uncertainties.

(Jafari ET AL, 2023) in a paper investigated how business intelligence, integration, and agility affect the supply chain performance. This study was conducted using a sequential mixed exploratory method in two stages: metasynthesis as a qualitative method and survey as a quantitative method.

Structural equation modeling was used to test the hypotheses, and the results of the research show that BI, integration, and agility play an important role in achieving better supply chain performance. The BI has the greatest impact on supply chain performance among them.

(Özlen et al, 2013) conducted a research to investigate the level of implementation of supply chain management, customer relationship management in small and medium-sized enterprises using a survey questionnaire developed by clients of small and medium-sized enterprises. The results generally showed appropriate levels of implementation of thematic items. The results indicate the effective communication level of customer relationship management to continuous challenges emerged and the supply chain complexities and, consequently, the bullwhip effect, to adapt and implement new strategies and solutions for the supply chain.

(Lele, V. P., Kumari, S., & White, G. 2023) studied the use of big data and supply chain management to increase efficiency in fast-paced environments. This paper provides useful information and recommended approaches with companies looking to use big data in their customer relationship management (CRM) and supply chain management (SCM). The study also emphasizes the importance of timely gathering, analysis, and interpretation of data in supply chain operations to improve responsiveness and reduce time to do job, optimize operations, reduce costs, increase productivity, and reduce the bullwhip effect in fast-paced environments.

(Michna, Z., Disney, S. M., & Nielsen, P. 2020) show how reducing lead times using new technologies reduces the bullwhip effect, which represents the variance of replenishment orders and increases as you move up the supply chain.

(Michna, Z., Nielsen, P., & Nielsen, I. E. 2018) found the advantages and disadvantages of stochastic delivery time approaches to the bullwhip effect problem in a paper using models to quantify the bullwhip effect in supply chains. In addition, they found interesting insights into the behavior of the bullwhip effect and stochastic lead times using computer simulations and big data. Their findings confirm that under certain conditions, delivery time itself is a fundamental cause of the bullwhip effect and that the insight of new technologies is influential in controlling and reducing the detrimental effects of inefficiencies and supply chain complexities.

(Agrawal, S. S. RN, and Shanker, K., 2009) studied a two-tier supply chain (warehouse-retailer) using modern technologies and analyzed the impact of information sharing and lead time on the bullwhip effect and inventory. Their research results show that some of the bullwhip effect remains even after sharing information between levels and within levels. Moreover, by reducing the lead time is more beneficial than sharing information in terms of reducing the bullwhip effect phenomenon.

(Moharana et al, 2012) concluded in a study that there should be easy access to integration and transparency between suppliers for effective supply chain management. These elements are equally important for order fluctuations, inventory holding, replenishment time, transportation costs, etc. and ultimately lead to reduction of bullwhip effect and

increased visibility in the supply chain. High quality information can prevent manual errors with regard to essential aspects.

Researchers (Wadhwa et al, 2010) investigate the effect of information transparency and collaboration among front nodes of the supply chain in a research. Simulation is used as the research method. Simulation results show that new technologies provide transparency and these initiatives improve the time performance of the supply chain. It is also observed that greater benefits can be achieved via collaboration and information transparency when the supply chain bullwhip effect is reduced.

(Ran et al, 2020) in a study focuses on improving the application level of new technologies including big data in the supply chain through coordination and collaboration to increase performance. The bullwhip effect and random demand coexist in supply chain operations management, leading to lower performance. Many companies hope to use them in recent years to weaken the bullwhip effect and improve profits.

(Tesfay, Y. Y. (2015) analyzes the bullwhip effect's potential cause using empirical simulation data. The result indicates that the bullwhip effect can be reduced by intra- and inter-organizational coordination of trading partners in the supply chain. The analysis shows that coordination is needed in order to make the supply chain more efficient and effective.

(Hofmann et al, 2017) in a study investigates the big data potential to improve various supply chain processes. The aim of this paper is to explain which big data features (leverages) has the greatest potential to reduce the bullwhip effect. Using an existing system dynamics model, they show that the propensity for high order volumes and big data (BD) does not depend on supply or demand but depends on the extent of the bullwhip effect in the supply chain. The results of this research will help justify the use of big data in supply chain management.

(Sarkar et al, 2023) used an improved retailing methodology for a dual-channel supply chain with a retailer and a producer, affected by the bullwhip effect and asymmetric data sharing. In this scenario, measuring the bullwhip effect is essential in retailing strategy. Their study focuses on dual-channel retailing, where the demand for a product in both channels differs with the selling price. The retailing system faces a loss due to the asymmetric information, which leads to the bullwhip effect. Therefore, information sharing is beneficial for dual-channel retailing.

(Tang,L, Yang,T, Tu,Y. et al,2020) in a study indicate that the supply chain system experiences variance amplification in order fulfillment and inventory level, which leads to severe system inefficiency. Information distortion is known as a fundamental reason for the variance amplification phenomenon. Their goal is to investigate the impact of demand information sharing in reducing the bullwhip effect and improving the robustness of supply chain systems. This research provides insights to improve supply chain performance through information sharing.

Few studies have investigated the impact of BD and BI capabilities on various aspects of the supply chain, especially the bullwhip effect in

developing countries according to a careful investigation into the relevant literature. According to the research, it is necessary to investigate the BI and BD and the bullwhip effect of the supply chain, especially in developing countries, and the existing research play an important role in the supply chain (Shokouhyar et al., 2019). These are the issues that have been ignored in the literature. According to previous research on BD and BI, there is no study on the development of regional BD and BI. The papers, which deal with the BD and BI of the supply chain, emphasize that BD and BI are powerful tools to solve many problems in organizations and the supply chain. On the other hand, the bullwhip effect of the supply chain is a problem that can cause more problems if ignored. On the other hand, there is a high possibility that the BD and BI can also be influential in reducing the bullwhip effect of the supply chain (Stodder, 2015).

From the literature review and synthesis, eleven factors related to petrochemical supply chains were identified including flexibility of supply chain (FSC), trust in supply chain (TSC), information quality in supply chain (IQSC), agility capability in supply chain (ACSC), customer relationship management (CRM), lead time in supply chain (LTSC), integrity and transparency in supply chain (ITSC), coordination and collaboration in supply chain (CCSC), order volume in supply chain (OVSC), information sharing capability (ISC), visibility (VC), were identified from the literature and validated after an expert opinion. Factor analysis was conducted on the collected data to determine the regression weights and construct importance. The identified constructs of BD and BI adoption to reduce the bullwhip effect in supply chain were analyzed using structural equation modeling (SEM) approach. SEM assesses the observed and unobservable constructs of BD and BI through empirical analysis. And finally, the analysis will be conducted to determine the extent to which BD and BI affect the bullwhip effect in supply chain. In brief, the focus of this research is to find out which factors cause the bullwhip effect to emerge in the supply chain, how BD and BI are used in it, and to what extent they affect the bullwhip effect. To do this, this paper attempts to develop a model to use new technologies of big data and business intelligence in reducing the bullwhip effect in the supply chain.

Methodology

This section of the research is of an applied type in terms of purpose and a descriptive-survey in terms of methodology. First, information from library studies (documentation), field surveys, and comparative comparisons was collected and the components and variables of this field were extracted after interviewing 19 experts and specialists in the petrochemical industry, who were selected using the purposive sampling method. Then, the resulting indicators were screened in three rounds after developing a questionnaire using the fuzzy Delphi method, which ultimately resulted in 38 indicators presented in the form of 11 components and 3 aspects (Figure 2). The statistical population of the research in the quantitative section includes managers and stakeholders in the petrochemical industry, 60 of whom were selected as the sample group using the simple random sampling method and the Cochran sample size determination

formula. Subsequently, the questionnaire resulting from the final Delphi part was distributed among the sample. The judgment of 6 professional experts from petrochemical companies, who had PhDs with scientific and managerial backgrounds and at least 5 years of work experience in the company under the research, was used in order to confirm the validity of the questionnaires. The reliability of the questionnaire was also tested through Cronbach's alpha and composite reliability. Finally, the data analysis was carried out with the help of structural equation modeling and Smart PLS.4 software.

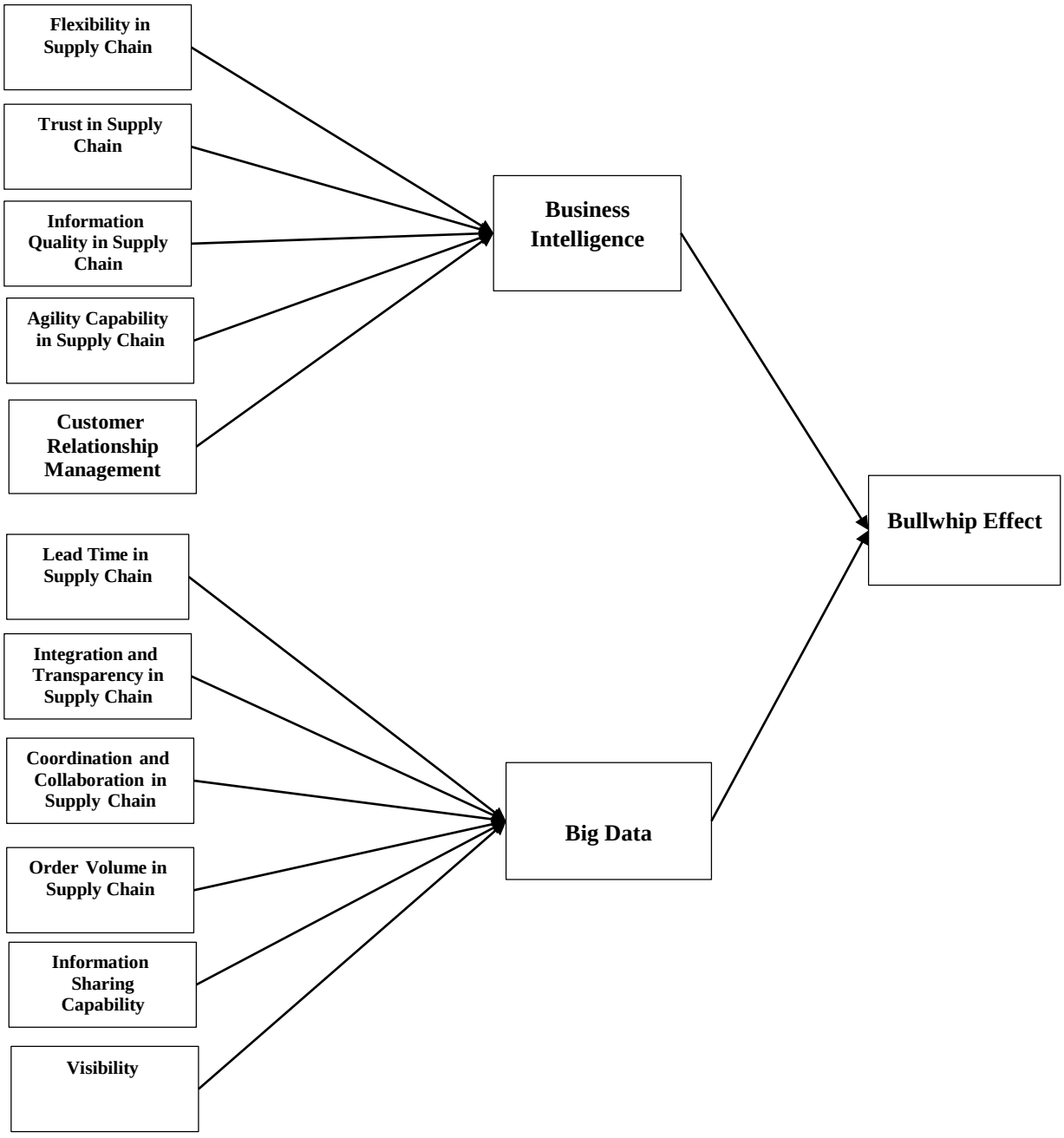

Figure 2: Conceptual model of the research

Result and Conclution

An attempt is made in descriptive methods to describe the research data by presenting a table and using descriptive statistics tools such as central and dispersion indices in order to help clarify the subject. The following table contains descriptive statistics for all variables used in the research. The most important central and dispersion indices of the research variables are presented in the first section. The mean and median are used among the central indices and the standard deviation of the variable is used among the dispersion indices. In addition, the maximum and minimum are also presented for each variable, and the difference between these two values yields one of the simplest dispersion indices, namely the coefficient of variation. The figures in this table were calculated using SPSS Software.

Table 1: Descriptive statistics of research variables

Variable	Number of samples	Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis
Flexibility in SC	60	5.00	20.00	13.7833	3.68732	-.405	-.539
Trust in Supply Chain	60	3.00	10.00	6.9833	1.94406	-.205	-.793
Information Quality in SC	60	3.00	10.00	7.1333	1.80833	-.277	-.493
Agility in Supply Chain	60	3.00	10.00	7.0667	1.86735	-.262	-.661
Customer Relationship Management	60	4.00	15.00	10.4833	2.76474	-.235	-.741
Lead Time in Supply Chain	60	6.00	25.00	17.6500	4.59117	-.454	-.373
Integrity and Transparency in SC	60	9.00	20.00	16.6000	2.93546	-.747	-.282
Coordination and Collaboration in SC	60	5.00	15.00	11.1333	2.93123	-.545	-.839
Order Volume in SC	60	5.00	15.00	10.4167	2.91862	-.077	-.865
Information Sharing Capability	60	5.00	15.00	10.5333	2.58068	-.183	-.565
Visibility	60	6.00	20.00	14.0500	3.69344	-.264	-.865
Bullwhip Effect	60	3.00	15.00	10.4833	2.82538	-.430	-.126
Business Intelligence	60	18.00	65.00	45.4500	11.14987	-.336	-.583
Big Data	60	41.00	110.00	80.3833	17.97842	-.393	-.693

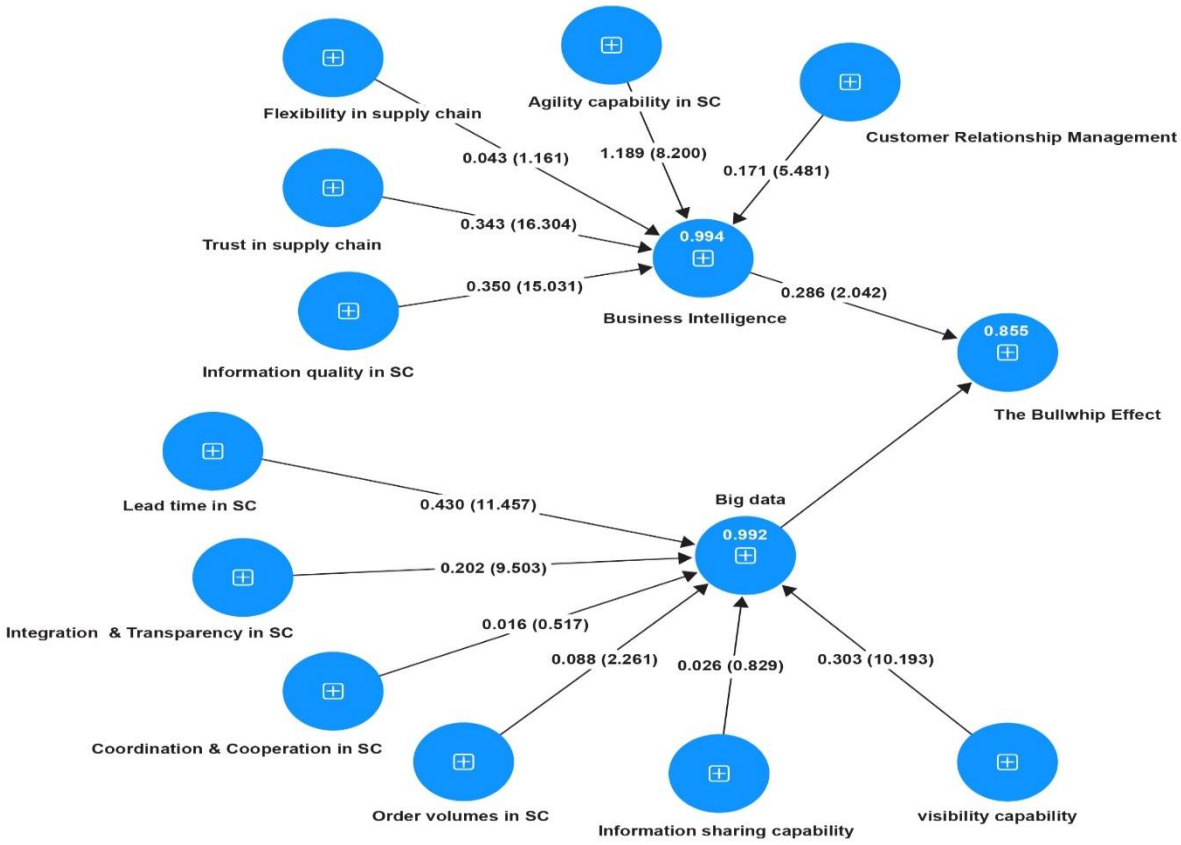

Figure 3: Initial measurement model in the state of estimating standard coefficients of factor loading and significance of path coefficients (research findings)

Testing the validity and reliability of the measurement model:
Testing the Homogeneity:

According to the researchers, a reflective measurement model will be a homogeneous model if the absolute value of the factor loading of each of the observable variables corresponding to the latent variable of that model is at least 0.7 and is significant at the desired significance level. According to Table 1, all factor loadings have values greater than or close to 0.7, so it can be concluded that the measurement model is homogeneous.

Measurement Model Reliability Test:

The composite reliability index (CR) is actually the ratio of the sum of the factor loadings of the latent variables to the sum of the factor loadings plus the error variance; its values range from 0 to 1 and is an alternative to Cronbach's alpha. Another index called composite reliability is used in PLS path models given that Cronbach's alpha provides a stricter estimate of the internal consistency reliability of the latent variables. The value of this index should

not be less than 0.7. the Cronbach's alpha (CA) index is a classic index for reliability analysis and provides an estimation of the reliability based on the internal correlation of the indicators. To establish reliability, the Cronbach's alpha coefficient for all constructs or variables should not be less than 0.7. For this purpose, first 15 questionnaires were distributed among the sample members and then the Cronbach's alpha coefficient of 10 returned questionnaires was calculated; Therefore, the correlation of the constituent components of each of these structures with the entire structure was investigated, and finally, the acceptable reliability was achieved for the questionnaire after removing the weakly-correlated components. In this research, first, research conducted on the subject was extracted, and an attempt was made to set comprehensive and complete indices to measure the structures by investigating the presented models and related variables. Additionally, the AVE index was used to measure the convergent validity of all research variables (Table 2). As can be seen in Table 3, the values of the AVE statistic indicate the acceptable model fit. The AVE index is used in order to evaluate the convergent validity in the Smart PLS software. The value of this coefficient also varies from 0 to 1, with values above 0.5 being accepted.

Table 2: Reliability and validity results of structural model variables

Latent Variables	Convergent Validity		Reliability	
	Composite Reliability (CR)	Cronbach's Alpha Coefficient (CA)	AVE Index	CR>AVE
Flexibility in Supply Chain	0.736	0.838	0.669	Confirmed
Trust in Supply Chain	0.874	0.802	0.609	Confirmed
Information Quality in Supply Chain	0.709	0.886	0.695	Confirmed
Agility in Supply Chain	0.856	0.894	0.645	Confirmed
Customer Relationship Management	0.876	0.778	0.639	Confirmed
Lead Time in Supply Chain	0.849	0.734	0.652	Confirmed
Integrity and Transparency in Supply Chain	0.799	0.789	0.667	Confirmed
Coordination and Collaboration in Supply Chain	0.829	0.794	0.667	Confirmed
Order Volume in Supply Chain	0.736	0.838	0.669	Confirmed
Information Sharing Capability	0.761	0.817	0.694	Confirmed
Visibility	0.795	0.785	0.650	Confirmed

It is clear from the results of the table above that the model variables have appropriate reliability since the Cronbach's alpha values and the composite reliability of these variables are greater than 0.7, and also given that the convergent validity values are greater than 0.5, consequently, the research variables have an appropriate validity.

Measurement Model Quality Test

The GOF criterion is used to investigate the quality of the structural model. Values of 0.1, 0.25, 0.36 are described as strong, medium, and weak, respectively. In fact, this variable is between zero and one, and values close to 1 indicate an appropriate model quality. The results show a value of 0.805 for GOF, which indicates a very acceptable fit of the model.

$$GOF = \sqrt{\overline{R^2} * \overline{Communality}}$$

GOF goodness of fit index formula:
Communality (common values) = This value is obtained from the mean square of the factor loadings of each variable.
Communality √ = It is obtained from the mean of the common values of each endogenous variable of the model.
R^2 = The average of the R Square values of the endogenous variables of the model.
The GOF goodness of fit index is obtained as a number between zero and one (Wetzels et al, 2009). Three values have been considered to evaluate the GOF index:
Weak: if it is between 0.1 and 0.25.
Moderate if it is between 0.25 and 0.36.
Strong: if it is greater than 0.36.
The closer the GOF index value is to one, the more appropriate the model is.

According to the results of this research, the average R Square values of the endogenous variables of the model is 0.675 and the average square of the factor loadings of all variables is 0.745. Therefore, the GOF index value is calculated as follows.

$$GOF = \sqrt{0.675 * 0.745} = 0.709$$

The results show a value of 0.709 for GOF, which indicates a very acceptable fit of the model.

An Investigation into the Research Model Fit

The values of R^2 and F^2 have been used to investigate the structural model fit. If their values are greater than 0.33 and 0.35, respectively, then the structural model has a good fit.
R^2 is a measure used to connect the measurement and structural parts of structural equation modeling and indicates the impact that an exogenous variable has on an endogenous variable. Three values of 0.19, 0.33, and 0.67 are used as the criterion values for weak, medium, and strong R^2 values (Hulland J.1999) and (Henseler, J.2009).

The F^2 criterion determines the intensity of the relationship between the model structures. The impact size criterion uses the R^2 index to analyze the relationship between the structures. The values of 0.02, 0.15, and 0.35 indicate the small, medium, and large impact size of one structure on another structure, respectively (Hosany, S. & Martin, D, 2012).

Table 3: Structural equation model fit indices

Variable	R^2	R^2 Criterion	F^2	F^2 Criterion
Flexibility in Supply Chain	0.69	Strong	2.203	Strong
Trust in Supply Chain	0.68	Strong	1.952	Strong
Information Quality in Supply Chain	0.73	Strong	1.425	Strong
Agility in Supply Chain	0.70	Strong	0.389	Strong
Customer Relationship Management	0.69	Strong	1.452	Strong
Lead Time in Supply Chain	0.63	Strong	3.129	Strong
Integrity and Transparency in Supply Chain	0.74	Strong	2.977	Strong
Coordination and Collaboration in Supply Chain	0.55	Strong	2.772	Strong
Order Volume in Supply Chain	0.60	Strong	2.143	Strong
Information Sharing Capability	0.70	Strong	1.484	Strong
Visibility	0.72	Strong	3.392	Strong

It is clear from the results of the table above that the R^2 values for all dependent variables of the structural model are greater than 0.33 and the F^2 values for all dependent variables of the structural model are greater than 0.35, so the model has a good fit.

An Investigation into the Model Significance

Figure 3 indicates the results of the standard coefficient and the significance number t using structural equation modeling. Significant coefficients Z investigates the significance state of the relationship or lack of relationship between independent and dependent variables. Thus, if the relationship between two variables is higher than the absolute value of 1.96, that is, there is a significant relationship between them with a 95% confidence level and if the number is higher than 2.58, then there is a 99% confidence level between the two variables. According to Table 4, all relationships are significant with a 99% confidence level since the significance values are higher than 2.58.

Table 4: Sig nificance of factor loadings

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Trust in Supply Chain → Bullwhip Effect	0.098	0.097	0.048	2.046	0.041
Trust in Supply Chain → Business Intelligence	0.343	0.342	0.021	16.304	0.000
Flexibility in Supply Chain → Bullwhip Effect	0.012	0.014	0.013	8.964	0.٠35
Flexibility in Supply Chain → Business Intelligence	0.043	0.048	0.037	3.161	0.046
Order Volume in Supply Chain → Bullwhip Effect	0.057	0.055	0.026	2.210	0.027
Order Volume in Supply Chain → Big Data	0.088	0.087	0.039	2.261	0.024
Big Data → Bullwhip Effect	0.649	0.649	0.138	4.691	0.000
Lead Time in Supply Chain → Bullwhip Effect	0.279	0.280	0.065	4.266	0.000
Lead Time in Supply Chain → Big Data	0.430	0.431	0.037	11.457	0.000
Information Sharing Capability → Bullwhip Effect	0.017	0.019	0.023	4.751	0.003
Information Sharing Capability → Big Data	0.026	0.028	0.032	3.829	0.007
Visibility → Bullwhip Effect	0.197	0.195	0.044	4.457	0.000
Visibility → Big Data	0.303	0.301	0.030	10.193	0.000
Agility in Supply Chain → Bullwhip Effect	0.054	0.053	0.027	2.002	0.045
Agility in Supply Chain → Business Intelligence	0.189	0.188	0.023	8.200	0.000
Customer Relationship Management → Bullwhip Effect	0.049	0.048	0.025	3.934	0.033
Customer Relationship Management → Business Intelligence	0.171	0.170	0.031	5.481	0.000
Coordination and Collaboration in Supply Chain Bullwhip Effect	0.010	0.010	0.020	4.502	0.016
Coordination and Collaboration in Supply Chain → Big Data	0.016	0.015	0.030	5.517	0005
Business Intelligence → Bullwhip Effect	0.286	0.285	0.140	2.042	0.041
Information Quality in Supply Chain → Bullwhip Effect	0.100	0.099	0.050	2.018	0.044
Information Quality in Supply Chain → Business Intelligence	0.350	0.348	0.023	15.031	0.000
Integrity and Transparency in Supply Chain → Bullwhip Effect	0.131	0.131	0.031	4.270	0.000
Integrity and Transparency in Supply Chain → Big Data	0.202	0.203	0.021	9.503	0.000

Conclusion and Discussion

First, it was briefly defined in this research what the bullwhip effect is and what its causes and countermeasures are. Then, more focus was given on what the big data and business intelligence are, how it can be used. Afterwards, more emphasis was given on the supply chain. In the first step, the important factors that influence the adoption of BD and BI in SC in the context of a developing country were finalized through a literature review. The literature related to "big data", "business intelligence", "bullwhip effect", and "supply chain management" was studied. In the following, eleven factors, namely, flexibility in supply chain (FSC), trust in supply chain (TSC), information quality in supply chain (IQSC), agility in supply chain (ACSC), customer relationship management (CRM), lead time in supply chain (LTSC), integrity and transparency in supply chain (ITSC), coordination and collaboration in supply chain (CCSC), order volume in supply chain (OVSC), information sharing capability (ISC), visibility (VC), were identified from the literature and then validated by expert opinion. Factor analysis was conducted on the collected data to determine the regression weight and the construct significance. The identified constructs of BD and BI adoption were analyzed using the structural equation modeling (SEM) approach to reduce the bullwhip effect in the supply chain. SEM evaluates the observed and unobservable constructs of BD and BI through the empirical analysis. Finally, the analysis was conducted and the results revealed that both Big Data (BD) and Business Intelligence (BI) had a significant impact on reducing the bullwhip effect in the supply chain. And all the factors of the Big Data and Business Intelligence also had a significant impact on reducing the bullwhip effect in the supply chain of the studied company.

Key Research Recommendations

1) One of the components that leads to the reduction of the bullwhip effect in the supply chain is flexibility in the supply chain. Supply chain flexibility is important in that when a major operational arm fails or faces a problem, there is a contingency plan to meet the customer demand. This need for greater flexibility was created after the COVID-19 pandemic and the economic recession after creating a wave of delays in the supply chains. Therefore, it is suggested that this important factor can be improved by strengthening managerial support, human resources, training, and organizational culture. Because having a flexible supply chain strategy prepares you for disruptions that may occur in the supply chain. The production levels can be easily adapted to demand by a flexible supply chain strategy, in other words, the demand, which is one of the main factors causing the bullwhip effect in the supply chain, can be controlled and improved, the capacity to transport goods can be improved, and the company's profit can increase.

2) Trust in supply chain is one of the components that leads to reduction of the bullwhip effect in the supply chain. Some problems may arise during the supply chains since they may be long and complex and include a large number of trading partners. If these problems are delayed in resolution, they lead to customer dissatisfaction and loss of sales, and they incur high costs for the organization to resolve. As the complexity increases and the supply chains expands the management of these chains has faced many uncertainties (due to uncertainty in the chain loops) in recent years and has been forced to take risks. Ultimately, it is not possible to achieve successful and reliable supply chain management without increasing confidence and trust between members. Establishing supply chain security does not necessarily have to be an expensive or time-consuming operation. This security is rooted in good practice and technique and a correct safety culture that must be taken seriously by all members of the chain. Each participant in the

supply chain should consider itself a member of the chain, not an individual and independent entity. A safety culture and the existence of a safe supply chain are the desires of all businessmen. They want to ensure that their shipments are transported correctly and safely, and only then a pleasant business will be established. Therefore, it is recommended to build trust in the supply chain by expanding the market and selecting an important strategy.

3) Supply chain is one of the processes that is achieved through information sharing and is related to customer reactions. The personal and confidential information that is usually used during the supply cycle operations, maintaining their quality from change is a very important issue. The quality of information in the supply chain can lead to the reduction of the bullwhip effect and it is suggested to improve the quality information system and quality strategy in this regard so that this important factor can be used to reduce the bullwhip effect in the supply chain.

4) Agile supply chain refers to responsiveness, competence, flexibility, and acceleration in managing the supply chain during its daily activities. The organization's supply chain must have the necessary agility in order to respond quickly and timely to changes in market needs and requirements. Looking at organizations, we realize that past approaches and solutions have lost their ability and capability to deal with organizational challenges and the contemporary external environment, including the bullwhip effect and its control. Hence, the need for new approaches, including organizational agility is felt. In the meantime, the importance of agile supply chain is more evident because such a chain can respond quickly and effectively to market changes. Agile supply chains can not only can respond to regular changes, but can also respond appropriately to dramatic changes in market requirements that are felt for the first time, and ultimately reduce the bullwhip effect.

5) Supply chain management is one of the fundamental pillars in any supply chain and plays a vital role in the survival and continuity of the successful supply chain activity in the global competitive market. Many variables play a role in the successful performance of SCM, but the element that plays the most important role in today's business is the identification of customer needs and demands through the Customer Relationship Management (CRM) system. Therefore, it is suggested that they become diligent by greater commitment of the organization to customers, helping to increase the customer retention and to optimizing marketing, understanding customers and their needs, as well as their feedback, in order to achieve a high level of accurate forecasting of demand and market price fluctuations and reduce the bullwhip effect in the supply chain.

6) Big data and business intelligence technologies can be used to reduce delivery time and subsequently, to reduce the bullwhip effect in the supply chain. These technologies allow all supply chain stakeholders to view the supply chain status in real time using their tools and capabilities, including sensors, network data, digital collaboration, shared dashboards and to predict the future demand using predictive algorithms, which helps reduce uncertainty and improve planning, and to identify trends and take corrective actions for continuous improvement by analyzing trends using historical analysis and cause the reduction of errors and increase in reliability factor between supply chain partners. Finally, these technologies lead to improvement of existing conditions using their tools, namely, collecting and analyzing supply chain data, collecting real-time data, predictive analysis, reducing order cycle time, improving logistics, and monitoring and continuous improvement. By using these technologies, delivery times in the supply chain can be reduced and the bullwhip effect can be minimized. This not only improves the supply chain efficiency, but also increases th e customer satisfaction.

7) Integration and transparency in the supply chain is one of the key aspects in improving the efficiency and performance of organizations in today's world. Interaction and coordination between different parts of an organization and its external partners is of particular importance given the complexity and breadth of the supply chain. The integration of these systems allows for the optimal flow of information and data, reduces costs, improves the forecasts' accuracy, and increases the speed of response to market changes. This transparency allows each member of the supply chain to act based on real information rather than guesswork, which reduces the demand fluctuations. Additionally, this integration helps organizations to centrally manage their business processes and, consequently, make better decisions. Technology plays a vital role in integrating the supply chain and helps organizations manage their processes more harmoniously and efficiently. Through modern technologies such as big data and business intelligence, organizations can manage their supply chain and customer relationships and exchange information in real time, optimize the flow of materials and goods, and reduce the delivery times. These technologies, along with other technologies such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain, also help improve the demand forecasting, real-time tracking of shipments, and automated inventory management. These tools provide greater transparency in the supply chain, reduce errors, and improve decision-making. Consequently, technology allows organizations to respond faster and more effectively to market changes and customer needs, and make the supply chain more integrated and flexible. Therefore, it is suggested that special attention be paid to innovation, accessibility, processing speed, and shared value creation by using big data and business intelligence, which can reduce the bullwhip effect by improving the integrity and transparency of the supply chain.

8) Coordination and collaboration in the supply chain are of great importance to redu ce the bullwhip effect. The coordination and collaboration mechanism aims to improve the supply chain efficiency by adjusting the plans and goals of independent supply chain inventories. Organizations can forecast the demand more accurately, improve the transparency and coordination in the supply chain, respond quickly to changes, strengthen the collaboration between supply chain partners, optimize the inventory, and reduce costs using the big data and business intelligence. By gathering and analyzing a huge amount of information from various sources (such as sales data, customer behavior, market conditions, social media, etc.), big data and business intelligence help organizations predict future demand more accurately. This more accurate forecast reduces unnecessary fluctuations in orders and inventory. Big data and business intelligence help organizations optimize their inventory levels by using forecasting algorithms to determine the reorder point and optimal order quantity by analyzing historical data and demand forecasting. This causes a reduction in costs of holding inventory and prevents shortages or surpluses of goods.

Coordination and collaboration in the supply chain is improved and the bullwhip effect is significantly reduced by implementing these solutions. This leads to increased efficiency, reduced costs, and greater customer satisfaction. These measures directly contribute to reducing the bullwhip effect and improving the overall supply chain performance. Ultimately, organizations can increase their efficiency and improve their competitiveness in the market using these technologies.

9) Optimal order quantity management helps improve the supply chain efficiency and reduce costs. Order quantity in the supply chain and the factors affecting the order quantity depend on the customer demand, inventory holding costs, ordering costs, production and supply capacity, and discount policies. Forecasting customer demand and

needs determines the order quantity. On the other hand, the higher the order quantity, the higher the inventory holding costs. Reducing the number of orders by increasing the quantity of each order can reduce the costs associated with the order, and some suppliers offer discounts for large orders, which can increase the order quantity. The benefits of optimizing the order quantity lead to reduced inventory holding costs, reduced ordering costs, improved cash flow, increased customer satisfaction by reducing the product shortages, which are among the main causes of the bullwhip effect. Therefore, this concept is one of the key factors in supply chain management and reducing the bullwhip effect and has a direct impact on costs, inventory levels, customer satisfaction, and operational efficiency.

10) Sharing information in the supply chain using big data and business intelligence is one of the effective methods to reduce the bullwhip effect. Sharing information creates greater trust and cooperation between supply chain partners. This improved relationship leads to a reduction in tensions and fluctuations caused by lack of trust. Sharing information in the supply chain reduces the bullwhip effect effectively by creating transparency, reducing information delays, improving demand forecasting, and increasing coordination between departments. This not only helps improve the supply chain efficiency, reduces supply chain costs, but also increases efficiency and customer satisfaction. Sharing information ensures that an accurate and timely information related to demand is transferred, inventory and orders are transmitted accurately and timely from the end of the supply chain (such as retail) to its highest level (such as raw material suppliers), and unnecessary fluctuations can be prevented. This information can include sales data, demand forecasts, and inventory status. Demand fluctuations are minimized by reducing lead times and reducing order quantity (batching).

Smaller orders mean that inventory is replaced more quickly and that more up-to-date information about demand and production is available to all members of the chain. Establishing agreements among companies in the supply chain to coordinate demand forecasts and production planning can help reduce the bullwhip effect. Additionally, sharing financial and strategic goals makes all members seek to reduce costs and improve efficiency. The demand fluctuations are reduced and the bullwhip effect is minimized when all members of the supply chain use similar forecasts for demand and production. Demand information is transmitted between departments with a delay in traditional supply chains. This delay causes each department to make decisions based on old data. Information delays are reduced and more optimal decisions are made by sharing information in real time. One reason for the bullwhip effect is the accumulation of excess inventory in response to fluctuations in demand. Companies can manage their inventory optimally and avoid unnecessary stockpiling by sharing information.

Sharing information enables better coordination between suppliers, producers, distributors, and retailers. This coordination prevents incorrect decisions, such as over- or under-ordering. The technologies such as big data and business intelligence can automatically gather, analyze, and interpret data. These technologies help improve the accuracy of forecasts and reduce human errors. The big data and business intelligence allow companies to respond quickly to changes in demand or market conditions. This rapid responsiveness causes a reduction in supply chain delays and the bullwhip effect.

11) Visibility and bullwhip reduction are two important concepts in supply chain management. Visibility in supply chain is the ability to view and access information about inventory, demand, production, transportation, and other relevant data across the supply chain. These capabilities help companies and

organizations make better decisions, coordinate better, and prevent the problems such as the bullwhip effect. One of the main reasons of the bullwhip effect is the delay in transferring information from one step to another. By using big data and business intelligence and improving the visibility in supply chain, information is transferred quickly without delay, which helps all parties in the chain react faster and respond to real demand.

Big data and business intelligence provide access to up-to-date and accurate information with all actors (suppliers, producers, distributors, and retailers) creating visibility across the supply chain. This visibility causes a reduction in uncertainty and improves coordination between different parts of the supply chain and reduces the bullwhip effect. This leads to improved efficiency, reduced costs, and increased competitiveness in the market.

Practical Suggestions of the Research

In line with the results of the model, the following suggestions are presented:

• Using these transformative technologies in the petrochemical industry helps in coordination and collaboration in the supply chain.

• The use of these technologies, advances in data analysis, and supercomputing will significantly improve the progress and these analyses can help in early detection of supply chain problems, including the bullwhip effect, and improve its performance.

• Implementing customer relationship management and information sharing capability have a significant impact on the relationship between information quality and visibility in the supply chain. With such a confirmation, data sharing is an effective factor in improving supply chain performance and reducing the bullwhip effect.

• Using these technologies allows inspectors to evaluate the real-time performance, product delivery time, and product conditions.

• Failures' prediction, improved production planning, performance optimization, bullwhip effect and cost reduction in petrochemical processes are performed using these technologies.

• Waste management and increasing resource consumption efficiency in petrochemical industries are being carried out in order to protect the environment developing these new technologies in the field of pollution reduction.

In total, research and development in the petrochemical industry causes the creation of international interaction and scientific and technological cooperation between countries, which leads to the exchange of knowledge and experiences among countries, especially for Iran, which is under severe sanctions. The interaction between universities and research centers allows more research to be conducted in the petrochemical industry and facilitates the development of new technologies and improved performance in these industries.

Key Research Suggestions

- ✓ Evaluation and and selection of the most influential suppliers, selection of suppliers with a superior performance and track record that have the necessary conditions and capabilities to provide flexibility.
- ✓ Long-term sales contracts with fixed delivery quantities can always smooth a supplier’s BE by reducing demand uncertainty.
- ✓ Determination and distribution of common standards for product and service performance levels in the petrochemic al industry supply chain

along with performance evaluation and measurement criteria contribute to the supply chain.

- ✓ These technologies can help improve the accuracy and efficiency of detecting failures and leaks in the petrochemical industry by developing, innovating, and investing in new technologies.
- ✓ Research and development in the petrochemical industry can help reduce the harmful impacts on the environment. This includes technologies for reducing carbon dioxide, waste management, and the optimal use of natural resources.

Conflict of Interests

This research does not have a conflict of interests.

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