Mitigating the Bullwhip Effect Through Sustainable Supply Chain Practices: A Systematic Literature Review

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Abstract

The study's primary purpose was to review studies on the bullwhip effect and mitigate its negative impacts through sustainable supply chain practices. To accomplish the study, a comprehensive review of the literature was conducted along with the application of screening criteria. Data extraction was carried out using preferred reporting items for systematic reviews by the inclusion and exclusion criteria for the articles. The analysis of 40 publications already published in Google Scholar, Wiley, Springer, Taylor & Francis, Emerald Insight, and Science Direct, yielded useful information. The bullwhip effect threatens hierarchical structural supply networks among the most obvious signs of supply chain inefficiencies. The bullwhip effect is mostly caused by interruptions in the flow of information and resources, lead-time delays, a lack of coordination, and fear of stocking in the face of local risk factors. To address the bullwhip effect, one should adopt a comprehensive strategy that considers all the variables contributing to its occurrence and follows the consequences. To develop appropriate remedies, it is crucial to consider this phenomenon's dynamics, causes, and effects. Most researchers argue that sustainable supply chain practices are useful for dealing with various supply chain management problems. A literature study on reducing the bullwhip effect through sustainable supply chain practices benefits academics, researchers, practitioners, politicians, and business groups by providing comprehensive knowledge and decision-making support.

Keywords: *Bullwhip Effect, Mitigating, Sustainable, Supply Chain Practices, Systematic Review of Literature.*

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1. Introduction

As we proceed up the supply chain, order variability tends to rise (Chen et al., 2000a). This phenomenon is known as the "bullwhip effect." The bullwhip effect (BWE), sometimes referred to as whiplash or the Forrester effect, is defined as "the process of amplification of order in the upward direction of a supply chain" (Jaipuria and Mahapatra, 2014). The bullwhip effect is a phenomenon wherein the chain network's first-stage supplier experiences greater unpredictability in inventory levels and delivery than the final consumer (Wang & Disney, 2016). The bullwhip effect can be described as a situation in which variances in demand get worse as you move up the supply chain. The bullwhip effect is a phenomenon in which differences in demand are extraordinarily amplified as one advances away from the final consumer. The name was popularized byLee and Padmanabhan (1997), However, Jay Forrester was the first to investigate it and believes that the actors in the logistics chain's illogical behavior is where it begins.

BWE happens because salespeople react to changes in sales by changing demand, which leads to further changes in suppliers' plans (Chatfield, 2012). Various researchers (Wang & Disney et al., 2016) have provided an analysis of the factors that contribute to the bullwhip effect's negative impact on important supply chain efficiency indicators as well as suggestions on ways to mitigate or eliminate it. The Forrester effect, order batching, promotion, and rationing are all controlled processes that can lead to system instability. The Burbidge effect, promotion, and rationing are all essential for achieving economic growth and preventing supply chain shortages (Makui et al., 2009).Simulating the impact of price variation on a supply network revealed that price variation is the main cause of inefficiency and energy loss in a supply chain (Ma and Bao, 2017).Demand forecasting is the accuracy of the demand forecast, which also affects the BWE's intensity. High demand forecasting accuracy could lower the

likelihood of overproduction or backorder, which would lower the variability of demand for suppliers (Lee and Whang, 2016).

Many experts contend that a lack of information sharing and supply chain visibility is what causes the bullwhip effect (Jeong & Hong, 2017). Research in this area indicates that the bullwhip effect, which is the focus of in-depth study, is thought to play a significant influence on supply chain management (SCM) (Mackelprang, and Malhotra, 2015). As the product goes through various supply chain levels, the Bullwhip Effect results in inconsistent orders that do not match ultimate demand, distorting product demand and information (Lee, and Padmanabhan, 1997). Popularized by Lee et al. (2014) the bullwhip effect has detrimental effects on all actors in the chain since it results in a significant loss of profits excessive inventory, decreased sales, subpar customer service, inadequate quality, and numerous disruptions to flow and organization. The supply chain's overall effectiveness is significantly influenced by the bullwhip effect (Tai, et al. 2019). One of the most important factors in an organization's success and the long-term attainment of its objectives, particularly its profitability, is the supply chain's correct functioning (Kin Keung et al.,2021). The SC's expenses, waste generation, and product availability are all negatively impacted by the BWE because each step must maintain high-precaution safety supplies (Papier & Thonemann, 2018). Moreover, additional costs derive from scaling production capacities (machines, workforce, and workload), poor supplier relationships, or general system nervousness (Wang & Disney, 2016). Because of the bullwhip effect, it is harder for businesses to meet consumer demands, which leads to inventory overstocking and decreased operational performance throughout the whole supply chain (Dai& Peng, 2017). Bullwhip leads to poor supplier-customer interactions, high expenses in warehousing, and unfavorable production scheduling, affecting machinery start-stopping, upstream inventories, and overall service levels (Cannella et al., 2013; Disney et al., 2007; Wang & Disney, 2016).All of the aforementioned factors cause the supply chain-connected businesses to experience lower

economic results, and over time, they lose their competitive edge and visibility (Jakšič, and Rusjan, 2007).

Overcoming the bullwhip effect is one of supply chain management's biggest challenges (Mackelprang, and Malhotra, 2015; Reyes, and Singh, 2002). More production capacity than needed has been added to handle the rush of orders (Ghasemi, 2010). As a result, the high inventory level not only raises the supply chain's overall costs but also prevents its participants from timely meeting client demand (Agrawal, and Shanker, 2009; Bayraktar et al., 2008; Jaipuria, and Mahapatra, 2014). For these reasons, it becomes crucial for the supply chain management team members to have access to accurate and trustworthy information as well as to reduce the bullwhip impact (Dai, et al., 2016; Krol, and KeZelewski, 2005; Lee, & Whang, 2004). Moreover, sustainability within the supply chain has become one of the areas receiving considerable interest(Klumpp, 2018). Collaboration between the supply chain participants is likely the most obvious solution to the issue. Collaboration in the supply chain is defined by Ciancimino (2010) as "converting incomplete solutions at individual links into comprehensive solutions through sharing customer and operational information." Numerous writers have demonstrated how cooperation could lessen the amplification of commands moving upstream (Chen et al., 2000b). Order batching and price change are crucial for businesses to manage costs and increase customer satisfaction. Electronic Data Interchange (EDI) can reduce paperwork and increase order frequency. Stabilizing prices through everyday low-price policies (EDLP) can save customers time and money by preventing fluctuating prices and reducing the expenses associated with price changes. A supply chain encompasses all steps necessary to fulfill a customer's request, including transportation agencies, warehouses, merchants, customers, manufacturers, and suppliers (Najafi et al., 2007).

The bullwhip effect theory was the conceptual framework for this study. Forrester (1961)originated the bullwhip effect theory while

analyzing inventory replenishments in a multi-echelon supply chain network. In Normal Accident Theory, Nunan and Domenico (2017) argued that the complexity of supply chain management leaves the organizational system vulnerable to normal accidents that are both unanticipated and inevitable. Perrow (1999) formulated the concept of normal accident theory on the premise that accidentsare unavoidable, especially within a complex integrated system. In Resource Dependence Theory, Pfeffer and Salancik (1978) introduced the resource-dependent theory (RDT) based on the premise that leaders use organizational resources to drive performance. Supply chain leaders use organizational resources to create value, sustain short-term business imperatives, influence long-term growth opportunities, and enable sustained competitive advantage.Wolf and Floyd (2014) stated that the leader's ability to align the organization's strategies with appropriate resources facilitates long-term business sustainability.

Contingency theory says some supply chain leaders face both internal and external environmental pressures within their operational locations. The environmental factors stem from internal process inefficiency, external rivalry pressure, multicultural differences, and social, economic, and environmental responsibilities (Agigiet al. 2016).

There is a gap such as a lack of comprehensive studies addressing the bullwhip effect by systematically exploring its intersection with sustainable supply chain practices. Also, the majority of literature focuses on specific industries while neglecting others. There is a gap in understanding how sustainable supply chain practices mitigate the bullwhip effect across diverse sectors.

The objective of the review of the article is to analyze the bullwhip effect and mitigate its negative impacts through sustainable supply chain practices.

2. Methodology and Review Process

2.1. Methodology

This article reviews the theoretical and empirical literature on the bullwhip effect and its impact on sustainable supply chain practices. It uses a structured review approach for in-depth understanding and suggests directions for further study, emphasizing common research methodologies.

2.2 Review Process

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is a widely used framework for conducting and reporting systematic reviews and meta-analyses. The article selection procedure is a vital part of a systematic review, and the PRISMA framework guides how to do this openly and reliably. The article selection procedure used by PRISMA consists of the following steps:

Identification of relevant studies: The first step is to use a thorough search approach to find all potentially relevant studies. Finding all studies that match the inclusion requirements, requires examining electronic databases, reference lists, and other sources.

Screening of titles and abstracts: The titles and abstracts of all discovered papers are screened in the second phase to determine whether they qualify for inclusion in the review. This entails assessing the relevance of each study using pre-established inclusion and exclusion criteria.

Full-text screening: The third step is to collect and read every study's full text that satisfies the inclusion requirements mentioned in the first two phases. This entails a more thorough evaluation of the study to ascertain whether it satisfies all inclusion criteria and whether there are any grounds for excluding it.

Data extraction: The fourth stage entails using a pre-designed data extraction form to extract data from the listed research. Information on the study's design, participants, interventions, results, and other pertinent data may be included in the data that was extracted.

Quality assessment: The quality of the included studies is assessed using a pre-established quality evaluation instrument as the fifth step. This entails examining the likelihood of bias in every study and the overall quality of the evidence.

Data synthesis: The data taken from the included research must then be combined as the last stage. In order to produce an overall estimate of the effect size estimation, it is necessary to summarize the data of each study and combine those using statistical techniques.

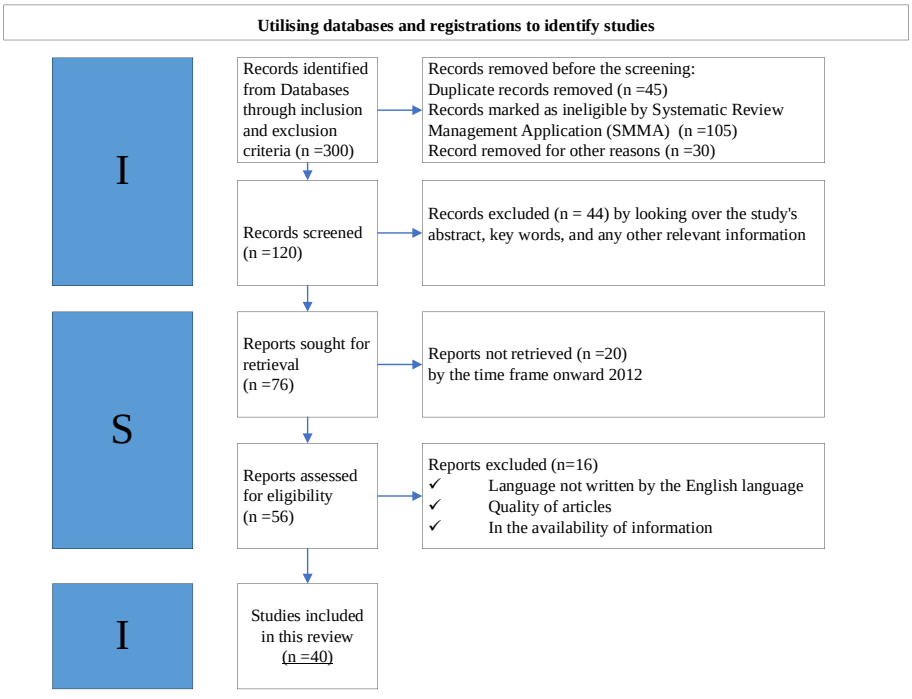

Figure 1: Preferred reporting items for systematic reviews and meta-analyses.

Source: (Moher et al., 2009)

This review procedure outlines criteria for selecting relevant papers for a systematic evaluation of the bullwhip effect and sustainable supply chain practices. English-language articles published between 2012 and 2023 were selected, covering approximately 12 years. Non-English-language, pre-2012, irrelevant, duplicate, or irrelevant studies were excluded. The reviewer successfully achieved the scientific review goals using these criteria.

2.3 Selection of Databases

The review utilized various online resources, including databases like Google Scholar, Wiley, Springer, Taylor & Francis, Emerald Insight, and Science Direct, to gather current and relevant information on the Bullwhip effect and sustainable supply chain practices.

2.4 Data Analysis

This study utilized an organized review process, combining scientific and structured reviews to summarize recent data in a modern, calculable manner.

The approach used in the reviewed articles

The study revealed that 50% of the articles utilized qualitative research, emphasizing a focus on understanding subjective experiences and perspectives. While both quantitative and mixed research strategies were employed by 25% of the articles each, the preference for qualitative methods emphasizes the significance of gaining an in-depth understanding.

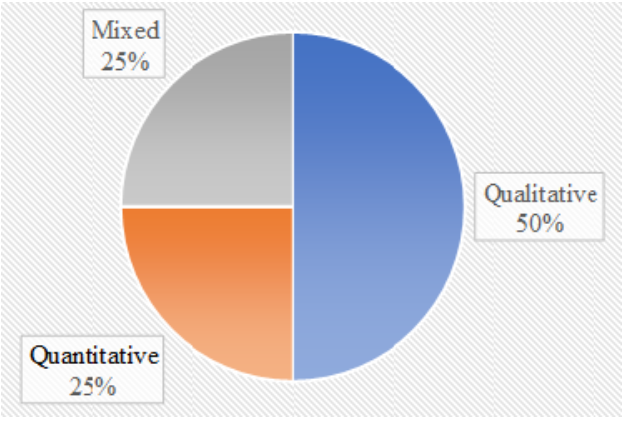

Figure 2**:** Research approach used
Source:Own development from reviewed articles,2024

Data Analysis Techniques

The analysis uses case studies, supply chain management software, review analysis, forrester system dynamics model, simulation, qualitative analysis, linear regression, and forecasting approaches to assess their prevalence.

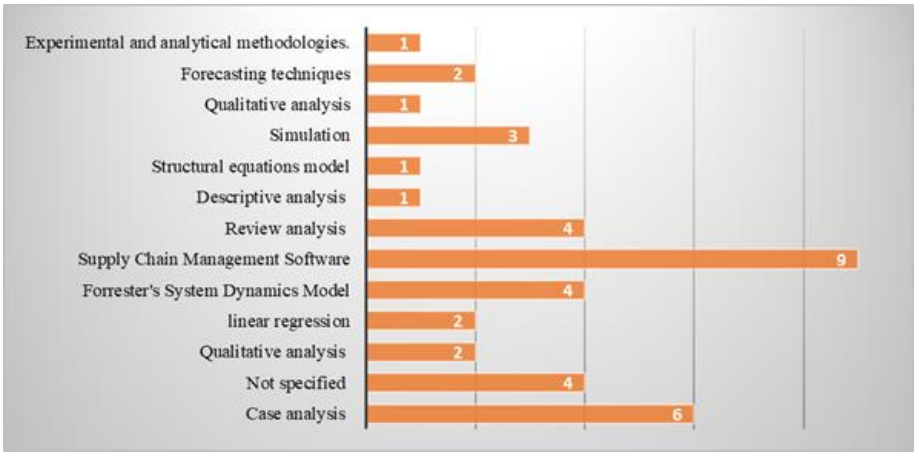

Figure 3: Data analysis techniques
Source: Own development from reviewed articles,2024

Articles published within the specified year of review

The data shows annual publications from 2012-2023,The number of publications per year included in the review increased steadily from one in 2012 to six in 2022.The output of publications experienced two notable improvements, one in 2017–2018, when it increased from 4 to 5, and another in 2020–2022, when it reached its highest of 6 publications.Periods of more moderate publication levels, such as two to three articles annually from 2013 to 2016, occurred in between these increases. With just one publication included in the review, 2019 had the fewest publications overall. After reaching thehighest of six publications in 2022, the number of publications featured decreased somewhat to four in 2023. This information implies that during the 12years, the research or publication topic under evaluation has attracted more attention and produced more work. The increases in 2020–2022 and 2017–2018 might be a reflection of increased resources, interest, or output during those years.

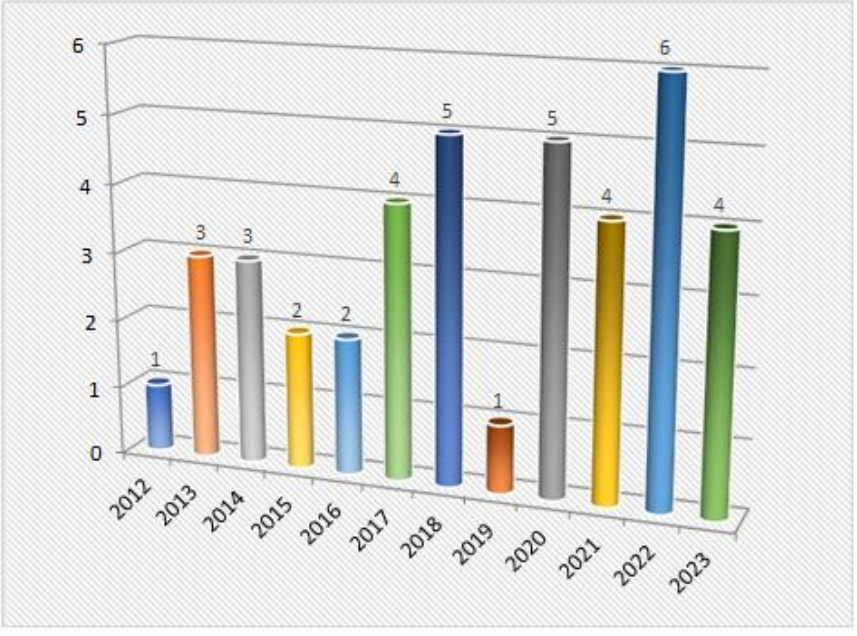

Figure 4: Articles published within the specified year of review
Source: Own development from reviewed articles,2024

3. Results and Discussions

The systematic research highlights how important it is to create sustainable practices for the supply chain to reduce the bullwhip effect. Numerous research studies have examined the Bullwhip effect and sustainable supply chains.According to Brito et al. (2020) supply chain comprises a group of productive units that are connected through the flow of products, information, and financial resources and are engaged in meeting customers' needs.

The previous research on the bullwhip effect has mostly concentrated on three areas: bullwhip measurement, bullwhip presence, and bullwhip control and mitigation(Lau and Wang, 2022). Analytical and simulation findings are contrasted with those from empirical and experimental studies. The bullwhip effect is modelled using assumptions and approximations that take into account demand, forecast, delay, replenishment policy, and coordination strategy (Wang & Disney, 2016).

The bullwhip effect is mostly caused by interruptions in the flow of information and resources, delays in lead times, a lack of coordination, and panic stocking when local risk factors are visible (Taylor, 2016). The forecasts' unreliability is the primary cause of the "bullwhip effect" (Vokhmyanina et al., 2018). The causes of the bullwhip effect are present in the simulation models, the following six factors are statistically significant: demand forecast updating, order batching, material delays, information delays, purchasing delays, and level of echelons (Paik, 2015). Unplanned demand oscillations, such as those brought on by stockouts, can generate distortions in the supply chain execution process that cause both up and down the supply chain (Khan et al., 2014).

According to the study, the bullwhip effect has a significant impact on information flow (Shakeel & Munir, 2023). The bullwhip effect has been highly influenced by the idea of strategic planning and

competitive advantage and has also recommended that only one of the major strategies should be used for better control (Priya1 et al., 2021).There is a substantial body of evidence demonstrating the stochastic behavior of lead times, which affects supply chain performance by increasing the bullwhip effect (Nielsen & Michna, 2018).Given its effect on expediting information sharing throughout the supply chain, the Electronic Data Interchange (EDI) is among the most significant (Jardini, 2021). Customers will not experience updated demand forecast mistakes since it widens the difference between projected and actual demand (Janipour et al., 2013). Bullwhip impact has negative effects due to large inventory levels and subpar customer service, whereas environmental bullwhip has softer effects (Lee et al., 2014). The results of a prolonged stimulation period indicate that the negative effects of the bullwhip effect do not continue to worsen indefinitely, even though the expected higher sensitivity of the front links of the supply chain to waste generation can be confirmed (Rottenegger, 2019). The bullwhip effect will increase efficiency, encourage sustainability in supply chains, and help eliminate material waste (Zhou, 2020). The bullwhip effect is implied to have an impact on an organization's social and environmental sustainability in addition to its economic success because of inventory fluctuation, human impact, product quality, and customer happiness (Onuoha, 2018).

Studies by Kumar & Singh (2022)have demonstrated that as demand fluctuates upstream in the supply chain, the bullwhip effect increases by up to 3 or 5 times. For example, a 10% rise in retail consumer demand results in a 30% to 50% increase in manufacturer orders. According to research in the International Journal of Production Economics, the bullwhip effect causes stockouts to rise by 30% to 50%, which lowers customer satisfaction and results in lost sales. According to Bai and Sarkis (2023) research in the Journal of Operations Management, the bullwhip effect is responsible for anywhere between 10% and 30% of supply chain expenses. This

covers expenses for inventory control, transportation, and production. According to studies, as the bullwhip effect progresses upstream in the supply chain, demand fluctuation increases by 10–40 times. For example, a study by Lee et al. (2014)discovered that minor shifts in customer demandcause big swings in retailer orders, intensifying the supply chain. Inventory expenses rise by 20% to 30% due to the bullwhip effect.A study conducted by Bottani and Rizzi (2010) on the impact of RFID and EPC on the bullwhip effect in the Italian FMCG supply chain used a quantitative research methodology that included a survey of 15 companies (6 manufacturers, five distributors, and four retailers). FMCG was adopted as the research design. This study found that centralizing information and providing updated POS data through exploiting RFID technology and EPC network implementation had a positive impact on reducing the bullwhip effect in the FMCG industry.According to Croson and Donohue (2006)**,**this research analyzes the impact of point-of-sale (POS) data on the bullwhip effect through a case study of a retail chain. The study involved a sample size of 150 stores across various regions, demonstrating the effectiveness of real-time data in reducing demand variability. Including details about the sample size strengthens the reliability of the findings.

Supply chain managers need to coordinate manufacturing and distribution activities with their partners to mitigate the bullwhip impact (Paik, 2006). Through the adoption of suggested solutions by organizational management, where the aforementioned bullwhip measuring technique will operate as a supportive solution, bullwhip dispelling and seasonal variability eradication are conceivable (Rahman, 2021). The bullwhip effect is diminished as a result of proper cooperation between the various supply chain components. Its elimination necessitates extensive coordination among supply chain participants (Lampret & An, 2015). Making the entire supply network more visible is one strategy to enhance supply chains and lessen the bullwhip impact (Thomson et al., 2022). The usage of modern

forecasting techniques and information sharing when working on joint demand forecasts in supply chains are the best solutions for reducing potential or actual bullwhip effects(Dujak, 2019). We discovered that the bullwhip effect was quantitatively mitigated or reduced by raising the product return rate (Mello & Gomes, 2017). A company must successfully combat the bullwhip effect if it wants to pursue value-added productivity throughout the supply chain (Min, 2017). Choosing the appropriate inventory policy is the primary bullwhip impact mitigation approach (Tavakol et al., 2023). According to a poll, forecasting techniques are crucial for reducing the bullwhip effect (Rafati, 2022). The business looked at many facets of its supply chains to see which ones offered the most promise for sustainability to meet these objectives. Additionally, it used a variety of incentives to encourage its suppliers to support its sustainability objectives (Xiaoyuan & Jayashankar, 2020). Incorporating information on inventory levels and supply chain components into an ordering method can help lessen the bullwhip impact (Badar et al., 2013).The outcomes demonstrate that the inventory control technique can successfully reduce the bullwhip impact. It offers a fresh method for investigating supply chain inventory network systems with time-varying delays (Chen et al., 2023).By taking into account the cooperation and confidence between the companies in the SCM, the BWE can be reduced (Augusto et al., 2014). According to Janipour et al., (2013), the key issues with the supply chain are a lack of timely and effective communication among its components and the occurrence of uncertainty in supply and demand. Customers do not put pressure on companies to meet their sustainability expectations (Ebrahim et al., 2022). The findings indicate that the bullwhip effect will improve more when supply chains use supply chain management software at a higher rate (Hsu, 2016). Using Centralized Demand Information (CDI), the bullwhip effect's detrimental effects on the inventory system's performance can be mitigated (Kholidasari &Bidiawati, 2019).

4. Conclusion and Recommendations

The study concluded that the bullwhip effect (BWE) presents a significant challenge in supply chain management, leading to increased demand variability, inventory costs, and diminished service levels.

The literature indicates that the bullwhip effect amplifies demand fluctuations by 3 to 5 times as it moves upstream, resulting in substantial economic losses and inefficiencies.The bullwhip effect in supply chain management has significant repercussions, stemming from inaccurate demand forecasting due to distorted information. This misalignment often results in over- or underestimations of demand, affecting inventory levels, and causing either excessive buildup or stockouts that complicate overall inventory management. Additionally, variability in order sizes and timing disrupts production planning, leading to inefficient manufacturing processes. As each link in the supply chain reacts to perceived changes in demand, order quantities become unreliable, further worsening the issue. Suppliers struggle with unpredictable order patterns, which strain relationships and introduce potential supply disruptions. Increased variability also extends lead times, making it challenging to meet customer demands promptly. Consequently, fluctuating inventory levels complicate logistics planning and elevate transportation. Moreover, the integration of sustainability into supply chain practices emerges as a vital approach to mitigate the bullwhip effect and enhance overall supply chain performance. Sustainable practices lead to improved customer satisfaction, reduced waste, and greater operational efficiency. The review demonstrates organizations' critical need to understand and mitigate the BWE through sustainable supply chain practices. The study underscores the importance of addressing the intersection of the bullwhip effect and sustainable supply chain practices, particularly across diverse industries, to foster long-term organizational success.

Based on the findings, the study suggests the following recommendations and policy implications:

- Supply chain partners should collaborate and share current data on demand, inventory levels, and production capabilities. Utilizing technological platforms and standardizing data formats can help with this. The promotion of projects and provision of support to encourage cooperation among supply chain stakeholders can be done by governments and industry organizations.
- Effective strategies should be implemented to combat the bullwhip effect, including improved demand forecasting, enhanced information sharing, and collaborative practices among supply chain partners. The adoption of advanced technologies, such as electronic data interchange (EDI) and supply chain management software, facilitates better communication and coordination.
- To increase the accuracy of demand forecasting, governments, and organizations should invest in cutting-edge analytics and forecasting systems. This can improve planning, lessen demand uncertainty, and amplify the Bullwhip Effect. More precise forecasting can also be achieved by organizations and suppliers exchanging market information and demand data.
- Companies should employ strategies such as improved communication, information sharing, and collaborative planning across the supply chain. Implementing demand forecasting methods, adopting advanced technologies like real-time data sharing, and employing inventory management techniques can help reduce the impact of the bullwhip effect.

Limitations of the Study and Areas for Further Research

The literature on the bullwhip effect and sustainable supply chain practices is mainly focused on either concept alone, lacking a theory to guide the investigation. Future research should investigate how

sustainable practices can be integrated into supply chain operations to mitigate the bullwhip effect. Comparative analysis of different practices is also needed.

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