Centralized - Decentralized Demand Management and the Bullwhip Effect

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Abstract

Information distortion tends to inflate from downstream to upstream, and results in demand planning errors and this is followed by inaccurate forecasting. This situation is referred to as the bullwhip effect phenomenon. Demand management is also determined based on either a centralized or decentralized distribution strategy. Both strategies will influence the accuracy of demand planning and its effect on the bullwhip phenomenon. Unfortunately, research investigating the relationship between centralization and decentralization strategies for demand and the bullwhip effect is still limited. To answer this shortcoming, this paper has two scenarios for its analysis. First, forecasting is done to determine the accuracy of demand planning, indicated by the smallest forecast error value. Based on the results of the analysis, it is known that single exponential smoothing for decentralization strategy with alpha 0.5 is the best forecasting method. The second step is to measure the bullwhip effect; the results show that the coefficient is less than one. This coefficient indicated that the company underperformed in the fulfilment of its customers′ needs. Theoretically, this paper extends the literature on demand management in the supply chain by considering centralized and decentralized strategies.

Keywords: information distortion; forecasting; bullwhip effect; demand management; supply chain; distribution strategy.

Introduction

Distorted information and demand variability, as drivers of the bullwhip effect, were critical problems for every company in the supply chain. The variability of information from one entity in a supply chain to another can create terrific disadvantages (Zhao *et al.* 2019), for example with the over-inventory of raw materials and finished goods, poor customer service, high logistics costs, and lost profits. The bullwhip effect causes every chain in the business network to stockpile because of uncertainties on the demand and supply side. In summation, various aspects of the supply chain network can suffer from low service levels (Akkermans and Voss 2013).

Taking into consideration the exposure of the bullwhip effect, we found relevant pieces of literature that have investigated this phenomenon. For example, Goodarzi *et al.* (2017) focused on the relationship between the bullwhip effect, centralization and decentralization demand strategies, and financial cash flow. Nevertheless, this research tends to simplify the situation or simplify the dynamics practically through the beer distribution game simulation model. Kadivar and Shirazi (2018) focused on measuring the bullwhip effect on distribution scenarios, namely centralization strategies, cross-docking, and direct distribution systems. Meanwhile, Giannoccaro (2018) studied the bounded rationality of the choice of centralization and decentralization strategies. The complexity of the problem and the consequences of behavior in the decision-making system (e.g., supplier relationships, forecasting, inventory, distribution, and customer relationships) is the focus of this research.

Moreover, Alvarado-Vargas and Kelley (2019) investigated the uncertainty that threatens the global supply chain and regional supply chain, both of which have consequences for the bullwhip effect. They found that risks received from the disruption of information indicated by the bullwhip effect can reduce competitiveness, which also disrupts supply chain performance. Furthermore, Tliche *et al.* (2020) measured

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forecast demand in a decentralized system. They found that the moving average method is the basis for inventory management and the bullwhip effect's mitigation. Also, forecasting errors can impact the safety stock level, where both shortages and excess inventory have negative implications for company performance. Although prior research has investigated the bullwhip effect, research that considered the impact of the distribution system on information bias, as indicated by the bullwhip effect is minimal. Thus, in this paper, we attempt to fill the gap by investigating the impact of demand management through centralization and decentralization strategies on the bullwhip effect. In addressing this objective, we used data from cement commodity sales from cement company ABC (anonymous) in Cilacap, Central Java. The company has three distribution centers, namely the X distribution center (Yogyakarta), the Y distribution center (Semarang) and the Z distribution center (Semarang). Each distribution center serves the customers in its service area.

Literature review

The concept of the bullwhip effect refers to the experience of Procter & Gamble (P&G), which faced an extreme amplitude in demand for their products. Reflecting on Figure 1, Wang and Disney (2016) explained that the demand variation increased from downstream to upstream in the short term. Even though the actual demand was relatively stable, the company relied on the sales rate from distributors or resellers in determining its production planning and inventory control (Gupta and Saxena 2020). In this sense, the company executed production using sales information as a basis for its planning, which actually is a form of temporary demand.

Customer satisfaction is the ultimate goal of any business activity and can be fulfilled by integrating procurement, production, scheduling, and distribution activities. The integration of these activities is critical with regard to the philosophy of supply chain management (SCM) (Stevens and Johnson 2016). Theoretically, synchronization is the basis of SCM, but practically it is difficult to achieve due to process uncertainty and the complexity of business relationships (Yuji, Kei, and Hua 2020). Regarding the business network as an interdependent system, a lack of performance in one company can decrease the performance of all the companies in the supply chain network. A decrease in performance will leave customers frustrated, which leads to the loss of sales for the companies (Flynn, Koufteros, and Lu 2016). According to this situation, Perdana *et al.* (2019) argue that

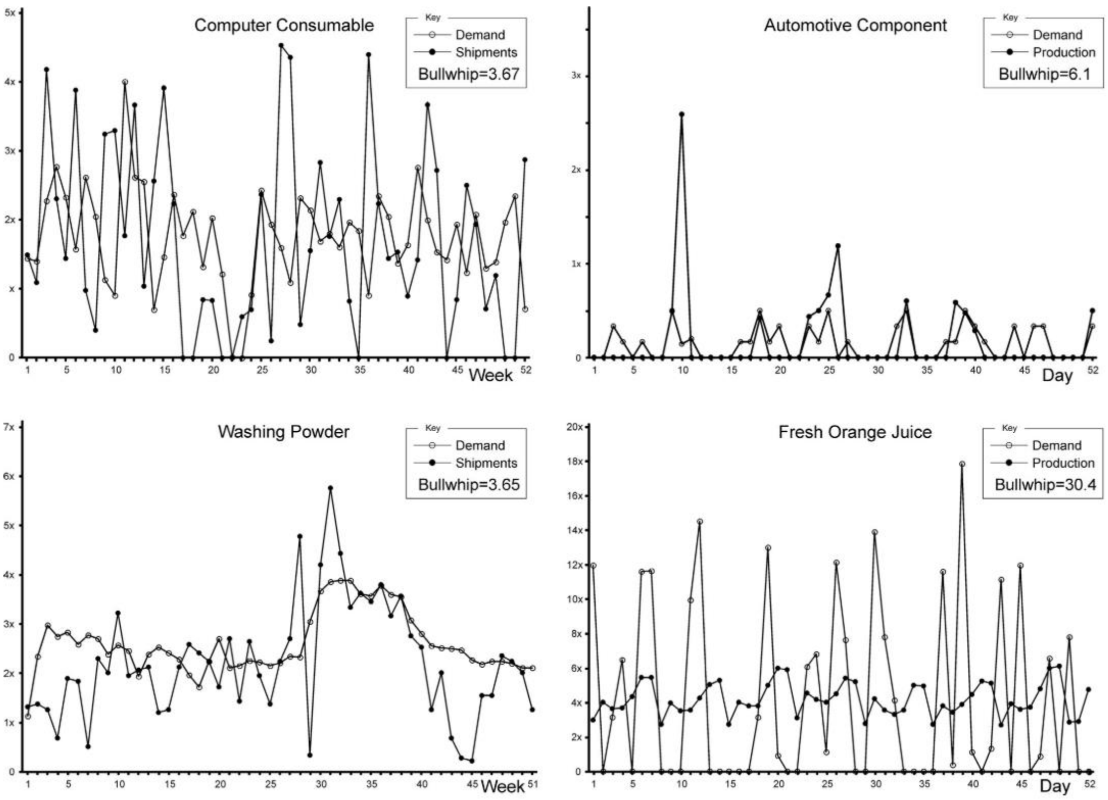

Figure 1. Bullwhip Effect
Source: (Wang and Disney 2016)

misalignment between business actors in the supply chain will lead to performance turbulence. For example, from the demand side, forecasting produces inaccurate sales predictions. Unpredictable customer behavior is the cause of forecasting errors. Another problem is the errors in reporting administrative documents that are still traditionally paper-based. Furthermore, errors in the demand acquisition on the downstream side have an upstream impact; errors in decisions reverse propagate from retail to distributors, then to producers, and to suppliers (Costantino *et al.* 2015).

Since the forecasting is calculated using the order or sales history from the company′s customers, valid and reliable data are vital for production planning. When the end customer places an order, the retailers process that information as a hint about future demand (Sillanpää and Liesiö 2018). Referring to this information, the producer will attempt to fulfill the demand and in turn, placed purchase orders for raw materials with the supplier (Jin *et al.* 2015). However, in practical terms, the variability of the information upstream (producer-suppliers) tends to be greater than it is downstream (customers-retailers). The information fluctuates more because each player has an information system that is not interconnected, meaning that there is a misalignment of information. Distorted information is the common root of the bullwhip effect (Dai *et al.* 2016). Moreover, referring to Morgan Swink *et al.* (2020), the bullwhip effect is also influenced by the design of the supply chain network's distribution system. Conceptually, the distribution system can be divided into two mechanisms, namely centralization and decentralization. Delivery through a centralized system describes the direct delivery flow from the factory warehouse to the final customer. Decentralization means delivery from the factory warehouse to the distribution warehouse prior to the end customer, in terms of service area responsibilities (Coyle *et al.* 2017). Both options have trade-offs in terms of logistics costs and service levels, as well as information deviations. Accordingly, a consequence of the centralization and decentralization strategies is the accuracy of demand planning, indicated by the bullwhip effect.

Methodology

In this paper, we aim to examine the impact of distribution strategies on the bullwhip effect in demand planning. To answer this purpose, we used the daily sales data (in tons) for six months (January-August). Data analysis were carried out through the following stages:

In this paper, forecasting employed three methods, namely the moving average technique, weighted moving average, and single exponential smoothing. These methods are time series models, which calculate the forecast demand or sales based on historical data arranged in the order of the event. Time series data are arranged in a sequence from time to time (day, month, year). Moving average, double moving average and single exponential smoothing assumed that the historical data pattern was relatively stationary (Morgan Swink *et al.* 2020). Moreover, a moving average determines a demand forecast as the average of sales over past periods (n) (Equation 1). Then, a weighted moving average (Equation 2) gives a different weight to each period′s data according to its importance, in which older data is less important than the newest. For example, data from last month has a weight of 3, data from two months ago has a weight of 2, and 1 is for data from three months ago. Next, single exponential smoothing, as shown in Equation 3, assumed that historical data is exponentially decreasing in its weight over time, the last data is being assigned a larger weight. In this model, the smoothing constants (alpha) are from 0 to 1. However, Ravinder (2016) found that there is no consensus regarding the best value for alpha. Thus, in this paper, we chose the lowest (0.1), medium (0.5), and highest alpha (0.9) to examine the best forecast value. Furthermore, from these calculations, the smallest error value referring to the mean absolute deviation (MAD) can be determined (Equation 4). Here is the equation for the moving average model, weighted moving average, single exponential smoothing, and MAD (Heizer, Render, and Munson 2017):

$$moving\ average = \frac{\sum demand\ in\ previous\ n\ periods}{n} \quad (1)$$

$$weighted\ moving\ average = \frac{\sum(weight\ for\ period\ n)\ x\ (demand\ in\ period\ n)}{\sum weights} \quad (2)$$

$$Single\ exponential\ smoothing\ (F_t) = F_{t-1} + \alpha(A_{t-1} - F_{t-1}) \quad (3)$$

Where:

F_t = new forecast

F_{t-1} = previous forecast

A_{t-1} = last period's actual demand

α = smoothing (or weighting) constant $(0 \leq \alpha \leq 1)$

$$Mean\ Absolute\ Deviation\ (MAD) = \frac{\Sigma|actual - forecast|}{n} \quad (4)$$

Referring to the smallest error value, we predicted the demand. Then, the bullwhip effect was calculated by dividing the variance of the forecast's results and sales (actual/observed data); these are described in equations 5 and 6 (Chen *et al.* 2000; Wang and Disney 2016).

$$Bullwhip\ Effect = \frac{Forecasting\ variance\ coefficient}{Sales\ variance\ coefficient} \quad (5)$$

Where the coefficient of variance is:

$$Coefficient\ of\ variance = \frac{Standar\ Deviation}{mean} \quad (6)$$

Where (Chen *et al.* 2000):

1. If the amplification ratio is equal to one, it means that the forecast (predicted demand) is the same as the actual demand, and it proved that there was no bullwhip effect. Particularly, the company was able to meet the expected customer service level.
2. If the amplification ratio is greater than one, it indicates a bullwhip effect. This value shows inaccurate demand forecasting where the amount of production exceeds the actual demand. Even though it provides a high service level to the customers, the company has to bear some excessive costs, such as inventory costs.
3. If the amplification ratio is less than one, it means less supply to fulfill the actual demand. This condition indicates that the company gives a poor level of service to the customers, this has the risk of reducing the company's competitiveness and resulting in decreased profits.

This paper used two scenarios (**Figure 2)** that show the centralized and decentralized scenarios. The first was forecasting using decentralized /segregation, which means each distribution center calculated its forecasting. The second scenario was centralized/aggregating sales data from the three distribution centers, which means that the manufacturer carried out the forecasting.

Then, the bullwhip effect was introduced, referring to both scenarios. Each bullwhip effect coefficient was compared to conclude the centralization and decentralization strategies for demand management.

Results and Discussions

Results

The analysis was performed using a moving average, weighted moving average, and single exponential smoothing. The best forecasting method was chosen based on the smallest error value-MAD. Referring to the calculations, we found that single exponential smoothing forecasting with alpha 0.5 was the method that produced estimates with the smallest error (see **Table 1**). Therefore, these results were the basis for calculating the bullwhip effect.

According to **Table 1**, decentralized forecasting (single exponential smoothing with α0.5) produces better accuracy than centralized forecasting. Theoretically, aggregation data tends to produce more accurate forecasts. In contrast, in this paper, the error value-MAD calculated by the centralized scenario was shown to be greater than that of the decentralized scenario, which indicated low prediction accuracy. Meanwhile, Jlassi (2015) argued differently, that data aggregation does not always produce a more accurate forecast than disaggregation. Also, Zellner and Tobias (2000) proved that disaggregation provided better forecasts. Simillary, Ibarra (2012) showed that disaggregated data improved the forecasting result. The explanation for the contradiction between aggregate and disaggregated data is the volatility of the data, part of which is indicated by the standard deviation. Referring to Table 2, the standard deviation of aggregate data for the three distribution centers (X+Y+Z) is greater than the

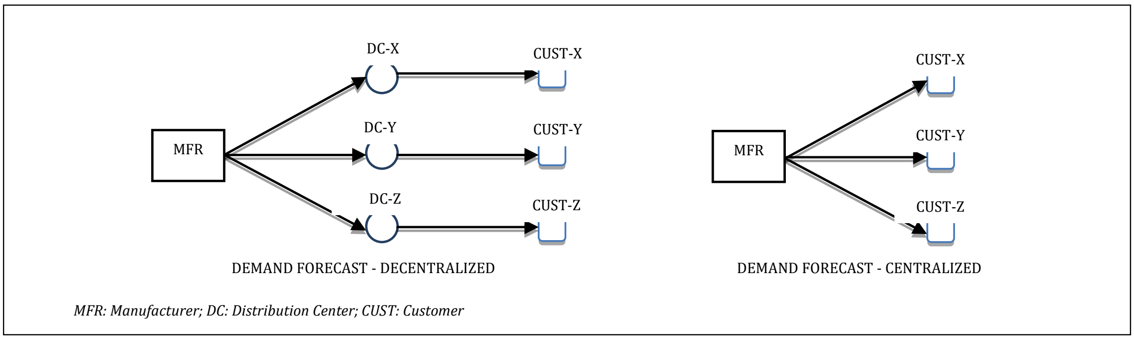

Figure 2. Centralized and Decentralized Scenarios

Table 1. Forecast Error Value-MAD

No	Distribution Center	MAD Moving Average	MAD Weighted Moving Average	MAD Single Exponential Smoothing		
				$\alpha = 0.1$	$\alpha = 0.5$	$\alpha = 0.9$
1	X	117.19	111.46	112.48	108.13	109.62
2	Y	18.66	18.10	18.16	17.46	18.90
3	Z	41.93	39.97	42.59	38.94	40.78
4	X+Y+Z	135.53	130.29	133.90	126.52	129.57

Table 2. Standard Deviation

No	Distribution Center	Standard Deviation
1	X	208.30
2	Y	31.00
3	Z	87.61
4	X+Y+Z	290.07

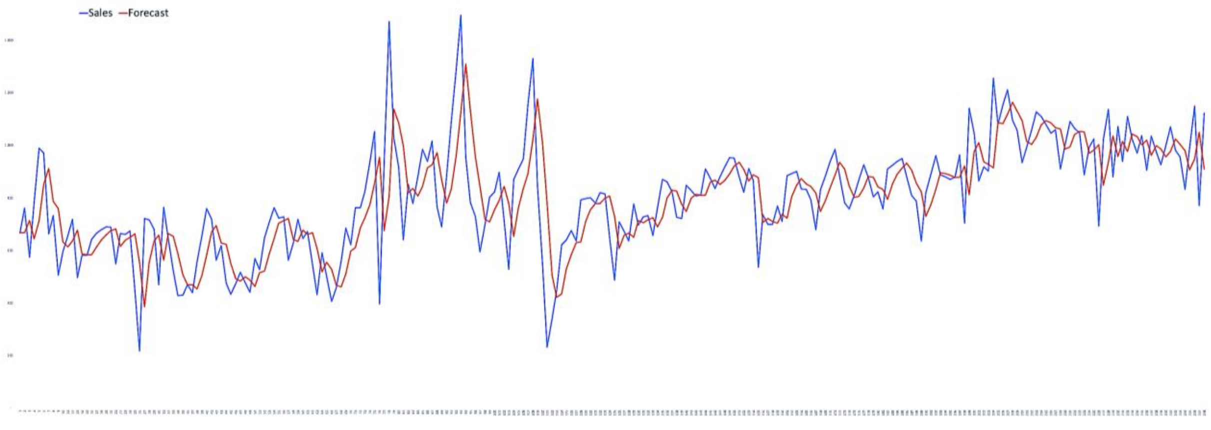

Figure 3. Comparison of Observed Sales and Forecasting at Distribution Center X

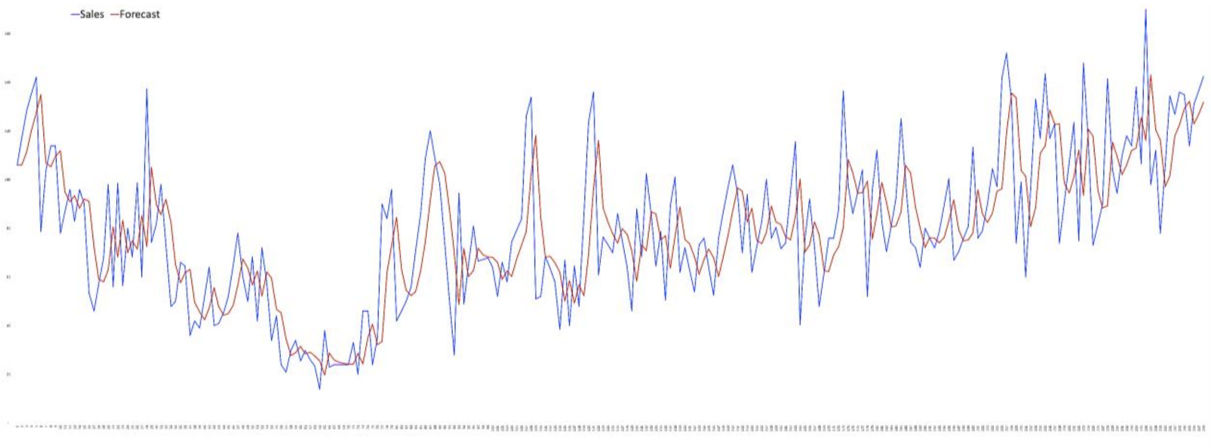

Figure 4. Comparison of Observed Sales and Forecasting at Distribution Center Y

disaggregated data, so this implies that disaggregated data results in better forecast performance.

Subsequently, the comparison between the actual value of sales and the forecast is illustrated in **Figure 3-6**. **Figure 3** shows Comparison of Observed Sales and Forecasting at Distribution Center X, **figure 4** shows Comparison of Observed Sales and Forecasting at Distribution Center Y, **figure 5** shows the comparison of Observed Sales and Forecasting at Distribution Center Z, while **figure 6** shows the Comparison of Observed Sales and Forecasting at Distribution Center X+Y+Z (Aggregation).

With regards to the single exponential smoothing (alpha 0.5) forecasting method

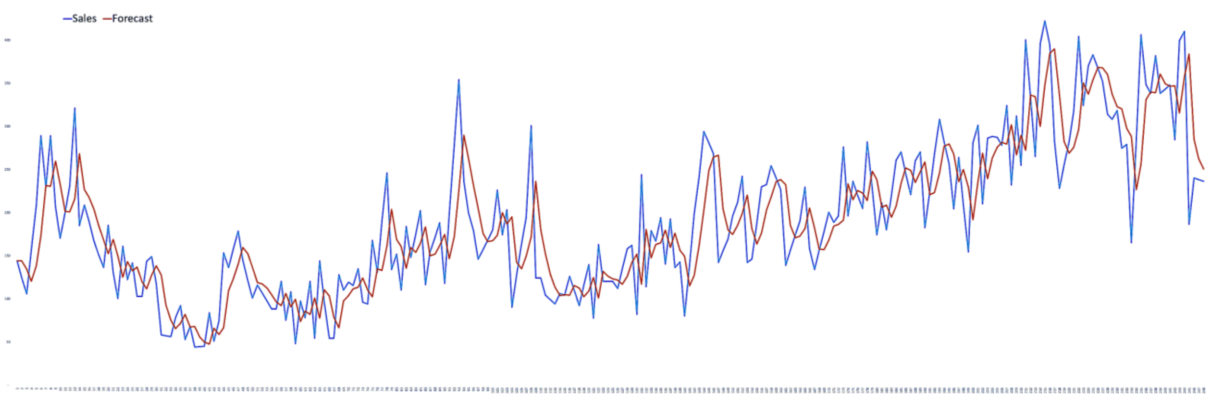

Figure 5. Comparison of Observed Sales and Forecasting at Distribution Center Z

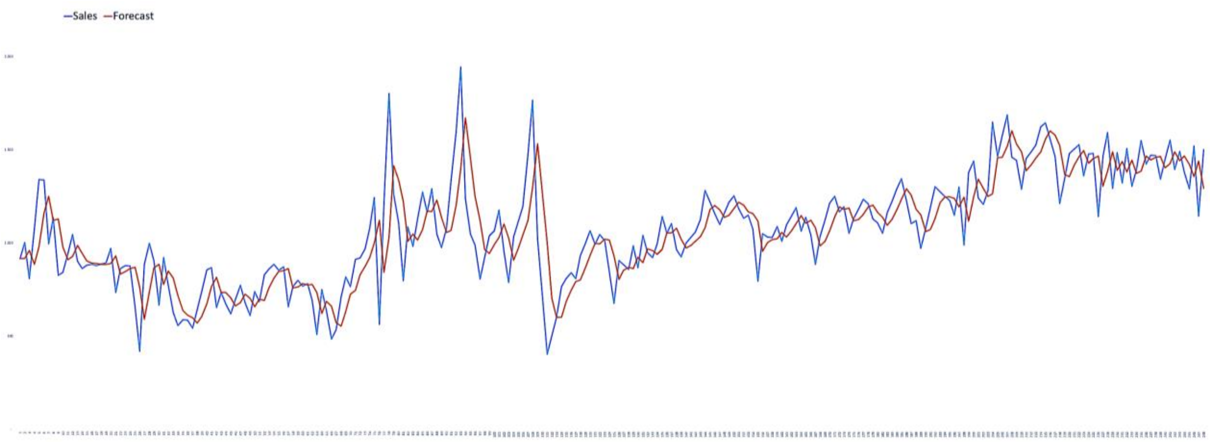

Figure 6. Comparison of Observed Sales and Forecasting at Distribution Center X+Y+Z (Aggregation)

Table 3. Bullwhip Effect Coefficient

No	Distribution Center	Bullwhip Effect - Single Exponential Smoothing α = 0.5
1	X	0.86
2	Y	0.84
3	Z	0.92
4	X+Y+Z	0.90

produces the smallest error, the next step was to measure the bullwhip effect. The measurement results tabulated in Table 3 shows that the amplification ratio value was smaller than one, which means that the company had a poor ability to meet the demand

Discussions

Demand management through centralized and decentralized strategies has a different impact on forecasting accuracy. The results of this study found that demand forecasting with decentralization resulted in better accuracy than centralization did. Accordingly, the volatility of the data has implications for the standard deviation and error forecast values. Referring to this result, it can be a helpful insight for the company, which is critical for identifying the consumption behavior of cement products for each sales area as well. Forecasting is the key to production planning activities. More accurate forecasting will result in better-executed production. Forecasting inaccuracies have harmful implications for service levels to consumers. The measurement results show that the bullwhip effect coefficient was less than one, which indicates that the company has not been able to meet customers' needs. Fluctuations in customer demand force companies to be careful in determining production plans. A shortage in supply can make customers run to other cement products, and the company does not expect this. Companies must make accurate predictions, if they do not want to experience a decline in performance, by identifying variants or trends in cement sales in each marketing area. In addition, companies need to forecast by considering external factors other than sales data, such as regional economic growth and the number of infrastructure developments, using an associative forecasting model.

Cement sales figures are evidence of customer behavior and when these are measured by the forecasting method they act as a predictor in demand planning. Taking this into account, the value of the bullwhip effect's coefficient is a description of the variance in using cement, which is caused by many factors. For example, there are trends in infrastructure development by the private sector, housing growth, and the implementation of government projects. Likewise, as an internal factor, the company must also control aspects of its administration and discount decisions. Manual sales records carry a risk of data input errors (Drakaki and Tzionas 2019). Meanwhile, retailers' discount programs, undertaken without coordinating with the distributors and company, will result in temporary sales volatility (Ponte *et al.* 2020). Both of these factors lead to information bias, and that leads to response errors. This situation must be validated by the decision-makers, especially in planning the demand. Conceptually, centralization has advantages, in terms of the ease of control of logistics administrative activities and low inventory costs. On the other hand, decentralization is more effective in its distribution to consumers and in lowering transportation costs. Both have trade-offs for decision-making. Of course, the purpose of decisions in a business context is to produce an effective and cost-efficient process without sacrificing customer satisfaction, to gain a competitive advantage. Therefore, companies need to understand and respond appropriately to consumer behavior as indicated by demand amplification (Perera, Fahimnia, and Tokar 2020). The bullwhip phenomenon occurs due to information bias, leading to dramatic errors in decision-making from retailer to distributor, distributor to the producer, and producer to the supplier. Consequently, along with the supply chain system, each entity could make estimation errors or faulty decisions, which result in underperformance (Ojha *et al.* 2019). Therefore, companies need to evaluate the process of the documentation of sales data, data sharing procedures between companies' networks, and the decision-making process. Taking into account that bullwhip is due to unsynchronized data, information, and decisions, collaborative forecasting, and a replenishment system are needed to produce better forecasts.

The high cost of inventory, transportation, and administration (logistics costs) as a consequence of miscalculations, make the supply chain network underperform. Accordingly, there is an interdependent relationship between companies in the supply chain network (Yan and Azadegan 2017). Contextually, producers in their demand planning require accurate information from retailers and distributors and then assign it to the supplier to provide the raw materials. Accurate information is the key; indeed, this is generated through a valid analysis process and by using the correct data (Singhry and Rahman 2019). Unfortunately, not all companies in the supply chain have the same perspective. Also, asymmetric resources and power could lead to exploitative behavior by the supply chain members (Naiding *et al.* 2020). This is in contrast to the substance of supply chain management, which emphasizes harmonization between its members. Paluri and Mishal (2020) stated that trust and mutually beneficial relationships are essential to produce excellent supply chain performance. Moreover, an integrated information system is one of the solutions to mitigate misinformation (Hofmann and Rutschmann 2018). In this sense, integration can be successful if there is an alignment of the processes, planning, implementing, and evaluating.

Conclusion

This paper answers the absence of research investigating the relationship between centralization and decentralization (demand management) strategies and the bullwhip effect. This study showed that the decentralization strategy resulted in better forecasting accuracy than the centralized strategy. The value of demand estimation was calculated by forecasting methods, consisting of the moving average, weighted moving average, and single exponential smoothing; the results showed that single exponential smoothing has the lowest error. This paper theoretically extends the supply chain management literature, particularly in demand management. What needs to be underlined is that the centralization and decentralization strategies have trade-offs, especially for demand forecasting. The error value is an indicator of the forecasting method; the lower the error value, the higher the demand estimation's accuracy.

In the context of the bullwhip effect, the low coefficient value of less than one indicates that the company cannot meet its customers' demands. These findings can be used as input for decision-making in the company to carry out more accurate production planning. Misidentification and misinterpretation of the customers' demand can trigger supply chain network disturbances. Consequently, the supply chain's stakeholders, who consist of suppliers, producers, distributors, and retailers, would show poor performance. Hence, supply chain integration is needed to mitigate this error. Supply chain integration is characterized by sharing data and information, collaborative planning, mutual relationships, and trust.

This paper only examined the bullwhip effect on the producer and distributor tier. The results showed the bullwhip effect on distribution strategy but in a partial way. Practically, the supply chain is an interconnected business network, which consists of multiple tiers. Therefore, further research is needed to investigate the bullwhip effect on a multi-tier network, namely the supplier, retailer, and logistics service providers. Meanwhile, the availability of sales or demand historical data is the key to measuring the bullwhip effect.

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