



**SupplyVelocity®**

# **The Bullwhip Effect in Supply Chains**

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One of the most important phenomena in Supply Chain Management is the Bullwhip Effect. This effect was discovered by a Stanford Business School Professor and Procter & Gamble (P&G). P&G noticed that orders it received from retailers (Wal-Mart, grocery chains, Target, etc.) for diapers varied much more than the variation in demand from consumers. It then looked upstream in the supply chain and found that the orders it placed to its suppliers varied more than the orders it received from its customers.

Dr. Hau Lee from Stanford coined the term, The Bullwhip Effect, to describe the amplification of consumer demand variation the further one goes upstream in the supply chain. A ripple effect occurs when a small movement at the handle of a bullwhip creates a large movement at the end. The bullwhip effect looks like a wave with varying high peaks and low valleys. These peaks and valleys are “artificial” in that they don’t represent the real variation between the retailer, wholesaler, distributor, and the final end-customer demand.

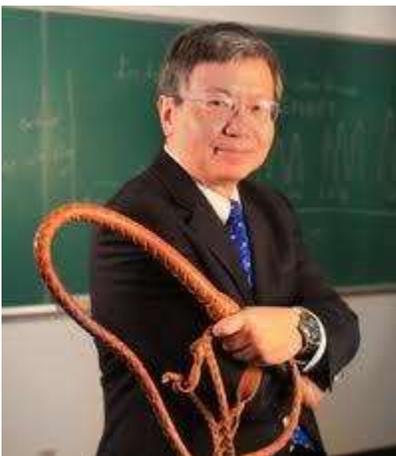


Figure 1: Dr. Hau Lee, discoverer of the Bullwhip Effect

In Figure 2 and 3 below you can see the Bullwhip Effect in action. Sales vary less than shipments in the top of figure 2. The furthest back echelon in the supply chain varies the greatest as shown in the bottom of figure 2. Manufacturing output decreased almost 15% in the Great Recession of 2007-2009, but total economic output decreased only 4.1%. This is due to the Bullwhip Effect.

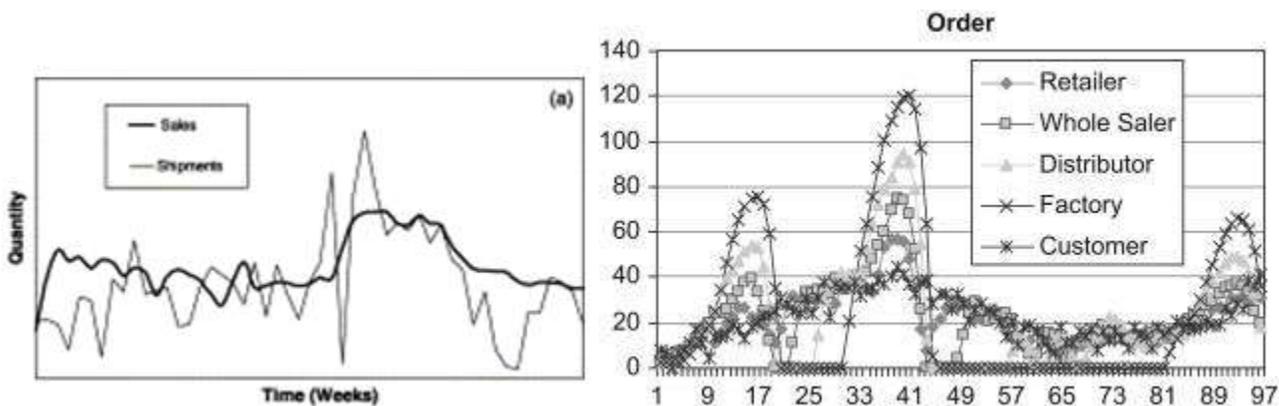


Figure 2: Examples of the Bullwhip Effect



## US Industrial Production to Gross Domestic Product



Figure 3: The Bullwhip Effect in the Manufacturing Economy

### Why the Bullwhip Effect is so Bad for Supply Chains and Companies

By creating these peaks and valleys, companies have to handle demand variability – alternating periods of high *demand* followed by low demand. This demand variation, or demand fluctuation, occurs because companies are loath to forgo sales and want high customer satisfaction scores. Therefore, they size their factories, warehouse, staff, and inventory to handle the volatility. The entire supply chain then has greater capacity and resources than what is needed to handle true customer demand variation. In other words, because of the bullwhip effect, companies have to over-size to fulfill customer orders.

A company will have to schedule overtime, followed by periods where their employees may be idle because of demand fluctuations during a bullwhip “valley”. They will sub-optimize inventory planning and inventory management (raw materials, work-in-process, finished goods), keeping higher safety stocks than what would be needed without the Bullwhip Effect. This causes companies and the supply chain to overstock, incurring inventory carrying costs such as obsolescence, and borrowing to finance inventory. The outcome also causes warehouses to be bigger, requiring additional capital investment and greater labor. The bigger the warehouse, the more people (or robots) have to move to put-away or retrieve inventory.

The net of these outcomes is profitability erosion.



## What Causes the Bullwhip Effect

Dr. Lee discovered three very common causes of the bullwhip effect. (Note, he also discovered a less common cause, which is not covered in this article.) The three common causes are:

- Over- and Under-Forecasting
- Economies of Scale in Ordering and Transportation
- Price Discounts

“Over- and Under-Forecasting” occurs when a company’s demand forecasts swings in waves that are greater than the underlying consumer or customer demand. People (being people) will react to current demand trends, even if history doesn’t support these trends *being sustained*. Who wants to risk product shortages and supply disruptions when demand is “going through the roof” or have high inventory levels when demand is “cratering”? However, doing this creates inefficiencies and disruptions in inventory, staffing, and overall supply chain utilization.

So what happens? People use the latest customer demand to adjust forecasts and orders to suppliers. In addition, people (again being people) forget to consider excess inventory they may already have on order, and will adjust order quantities above what a material requirements planning and execution system will recommend.

The next cause of disruption is Order Batching. Unfortunately, economies of scale in manufacturing and transportation is a real and important principle in supply chain management. Ordering, producing, and shipping larger quantities is a real-world way of reducing cost.

Manufacturing is particularly susceptible to Order Batching – When there is equipment set-up to change from one part to another, producing larger costs lets manufacturers recoup the set-up costs. This is commonly called an economic order quantity (EOQ) and is another important principle in supply chain management. Producing more for a given changeover allocates the set-up costs over larger quantities, thereby reducing per-unit costs. In addition, if set-up time is very long, a manufacturer has to be careful they don’t utilize more of the equipment’s capacity on changeovers than production runtime.

Transportation also can lead to Order Batching – While we would all like to have supplies shipped “just-in-time”, it is usually not practical or cost-effective. Filling up a large truck, rail car, barge or ship is the best way to lower unit costs of transportation. Freight rates for less-than-truckload shipments are much higher than truck-load because of economies of scale for the shipping company. It is much easier (and costs less) to fill up an entire truck at one site, drive it to the destination, and unload the entire truck. Procurement and logistics professionals often battle the economies of scale in transportation. For example, if a company needs 100 units to fulfill their production requirements for the next week, they may order 500 to fill up the truck and to receive truckload quantity costs, which reduces the transportation cost per unit. However, this 500 unit order becomes a peak of demand to the supplier when only 100 were needed.



## “Shortage Gaming”

Shortage gaming occurs when there is a supply chain disruption and supply cannot keep up with demand. This was readily seen during the COVID-19 pandemic of 2020 and 2021.

When companies get put on allocation by a supplier, they will naturally try to game the system to get what they need. If a customer needs 100 units and is told they can only get 80, then probably they will order 120 or even 140 next time. This over-order stacks up until the bottleneck is relieved and the company tries to fill these over-orders. Then their customers will try to cancel orders, creating a bullwhip in demand fluctuation.

The last cause and the one most controllable is “Price Discounting”. This is one of the most frustrating causes of the Bullwhip Effect, because it seems so easily avoidable. Your internal team, including sales and marketing people who create this price volatility, and your supply chain partners know that it creates temporary and fake demand spikes. However, retailers know that they need to create retail excitement or compete during important holiday seasons. Therefore, they lower their prices, moving demand from the future (or past) to the price discounting period. Customers (or consumers) purchase more than they need, or wait until the time of the year when discounting is rampant to make their purchases. This artificially creates peaks and valleys of demand shown in Figure 2.

## How to Reduce the Bullwhip Effect

There are many solutions to reduce the Bullwhip Effect

### “Over- and Under-Forecasting”

One way to easily reduce “over- and under-forecasting” is to use demand planning software and computer-tolls such as AI to set demand forecasts and order materials. When computers do demand forecasts, they don’t worry about excess inventory, customer demand, or react to current forecast demands from customers. These algorithms are more logical and don’t react with over- or under-forecasting.

### “Economies of Scale in Transportation”

As stated before, there is no getting around the fact that larger vehicles (ships are lowest cost, barges next lowest, rail next, full trucks next, less-than-truckload next, and parcel the highest cost) result in lower unit cost than smaller or partially full vehicles. The key is to get the large vehicle cost-per-unit, but not have to fill one up. How can you do this? ... by using a third-party logistics (often called a 3PL) company. These firms work with many wholesalers, retailers, and customers to fill up trucks from multiple stops that then travel a freight lane full. It is not as inexpensive as filling up a truck all by yourself, but it is a good compromise to reduce cost and, ultimately, the bullwhip effect.



## “Lean Techniques to Reduce Economic Order Quantity and Order Batching”

Another way to reduce order batching is to apply Lean to manufacturing operations. Quick-changeover or Single Minute Exchange of Dies (SMED), and 5S Visual Management, are well known methods to reduce set-up time, reducing the need to recoup long changeovers with large production quantities. The ultimate goal is to get changeovers to single minutes, or less than 10 minutes, to approach an economical order quantity to be the same as what customers normally order.

## “Reduce Lead Times”

The faster a supply chain can respond to customer demand, the less safety stock is required. Safety stock protects you from stockouts due to demand variation or forecast error. It is directly proportional to lead-time. If you can reduce your leadtime from 9 weeks to 4 weeks, safety stock will go down by 33%. Even with large demand variation, this simplifies inventory planning and inventory management. Longer lead times increase the bullwhip effect because you have to forecast over a longer period of time.

Companies that want to be the hub of a successful supply chain should work with suppliers to reduce lead times.

## “Break the Shortage Gaming by Fulfilling Demand based on Historical Purchases”

If a supply chain disruption occurs and limits your ability to fulfill customer orders, one way to break shortage gaming, and over-ordering by customers causing stockouts of limited inventory, is to allocate based on historical purchases by your customers. This allocates your limited supply to your best customers first and ensures you don't sell that limited supply to your lower importance (lower demand) customers.

## “Vendor Managed Inventory”

Letting vendors manage your inventory of their products gives them direct access to demand information. The over- or under-ordering and order batching causes of the Bullwhip Effect can be reduced with this visibility. With vendor managed inventory (VMI), your supplier replenishes inventory at your facility without you needing to place orders. The process can be set up as consignment inventory (the supplier owns the inventory until the customer uses it) or inventory the customer owns.

## “Price Discounting vs Price Fluctuations”

Wal-Mart got it right when it introduced Every Day Low Pricing (EDLP). If people know that you won't have a sale, they won't wait to purchase what they need or want. If you don't deep discount, then they won't over-purchase causing first the sharp peak and then the deep valley of demand in the following time period. Minimizing price fluctuations helps to lessen the impact of the bullwhip effect by reducing the uncertainty and unpredictability of customer demand and variability of the flow of goods in the supply chain.



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## “Gather Real-Time Data on End Customer Demand”

It may seem long ago, but in the 1990s retailers computerized store registers and gained quick access to shareable point-of-sale information. This real-time information can be shared with supply chain partners. Producing and delivering to the cadence of the customer is the ultimate goal of a Lean Supply Chain. This is a Lean Pull System and reduces the supply chain volatility mentioned throughout this article.

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