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Reducing the bullwhip effect: Looking through the appropriate lens

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Abstract

Demand amplification, now frequently referred to as ''bullwhip'', is potentially a very costly phenomenon. It can lead to stock-outs, large and expensive capacity utilisation swings, lower quality products, and considerable production/transport on-costs as deliveries are ramped up and down at the whim of the supply chain. However, the detection of bullwhip depends on which ''lens'' is used. This in turn depends on the background and requirements of various ''players'' within the value stream. To gain insight into this scenario we exploit a relatively simple replenishment model. Because new and novel analytic solutions have been derived for all important performance metrics, comparison of the competing bullwhip measures is thereby greatly streamlined. In the complex real world the likelihood is that supply chains will generate even greater inconsistency between alternative variance, shock, and filter lens viewpoints.

Keywords: Bullwhip; Variance; Shock behaviour; Resonance; Filtering

1. Introduction

Bullwhip is a relatively new phase coined by Lee et al. (1997a, b) to describe the demand amplification phenomenon which was already well known (and reportedly tackled) at Procter and Gamble as long ago as 1919 (Schmenner, 2001). Demand (or variance) amplification of orders as they pass up the supply chain from marketplace to raw materials supplier and some of the reasons for its existence were also well known to economists some 80 years ago (Mitchell, 1923). Some early OR contributions in minimising cost functions for replenishment systems by Deziel and Eilon (1967) and Adelson (1966) implicitly covered order variance problems but were not projected in a bullwhip context. Undoubtedly, the most seminal contribution to understanding the bullwhip phenomenon was that of Forrester (1958). Based on his extensive knowledge of early computer systems, and supplemented by his understanding of differential equations, he was able to simulate the bullwhip effect on various models and suggest ways of reducing it. The resultant waveform propagation curves then yield ''rich pictures'' of likely system behaviour (van Aken, 1978).

Forrester's work is additionally outstanding for two other contributions. He developed DYNAMO, one of the early simulation languages specifically developed for modelling complex dynamic systems. The second, and arguably even more important

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step, is the use of influence diagrams to describe real-world enterprises in an explanatory and communicative manner. This is an ever extending field of investigation as more and more businesses and indeed socio-economic systems are modelled in this way. Notable contributions have been made to this expansion by Roberts (1981), Senge (1990), and Sterman (2000). More recently, it has been examined in the context of a product-attribute supply chain (Vojak and Suárez-Núñez, 2004).

However, despite the undoubted enthusiasm for bullwhip as a research topic, there is a need to exercise caution. A lot depends on the observer and the assumed (or real) operating scenario. Confusion may well occur. Hence, benchmark results such as those shown in Table 1 may be quoted entirely out of context. As an example we demonstrate that for a particular system selected to exhibit no "variance" lens bullwhip, there is still significant bullwhip when observed via the "shock" and "filter" lens. The practical outcome is that bullwhip is in reality not a generic term meaning the same thing to all system users. Instead it is application specific. Fortunately, any ambiguity can be removed by evaluating proposed solutions in a wide range of simulated operating scenarios. However, we do expect carry-over of specific measures enabling bullwhip reduction to be effective in all three domains. The actual impact, however, is a variable between applications.

Table 1
Example of setting bullwhip benchmarks via simulation of information sharing

Amplification ratio	Information mode	
	No sharing	With sharing
Retailer/customer	1.67	1.67
Wholesaler/retailer	2.99	2.61
Distributor/wholesaler	5.72	3.83
Factory/distributor	11.43	5.32

Source: Dejonckheere et al. (2004) and cross-checked by Chatfield et al. (2004).

2. Bullwhip history

Demand amplification is caused by some internal mechanism or event; it is *not* due to something external to the system. So although the customer demand may be extremely volatile, it is self-induced worsening of any situation which we are studying here. At least 10 causes have been documented (Geary et al., 2003). They may be algorithmic, "player"-sourced, or due to poor system design. Furthermore, a strong business within a chain can impose a smooth order pattern for the benefit of the pipeline. In contrast a weak business can *generate fluctuating orders despite relatively constant demand.* Because bullwhip is a time-varying phenomenon, graphical representation of system behaviour is extremely helpful. We now present three examples best viewed through different bullwhip "lens".

Fig. 1 shows bullwhip occurring in the supply chain involving a European fruit juice provider. It is obvious from inspection that bullwhip is present since factory orders are substantially more volatile than the incoming demand pattern. In this particular instance it is clear that a major cause of bullwhip is the batching policy implemented by the factory (Potter, 2005). It is a scheduler response to a problem in "fitting in" the demands imposed by various aggressive customers. As Metters (1997) has indicated, this policy does carry significant on-costs.

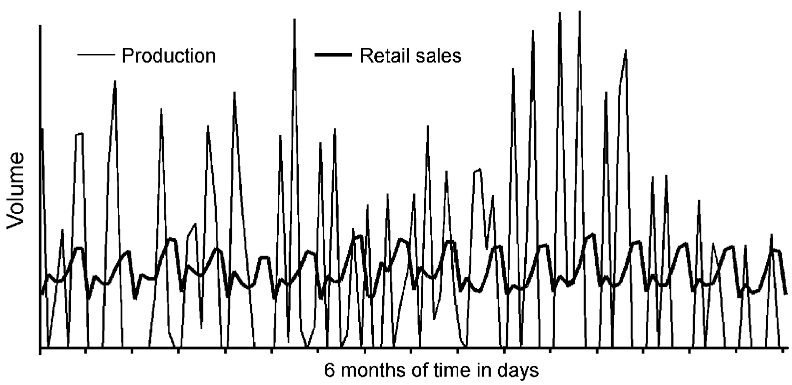

Fig. 1. Demand amplification typical of time series to be viewed through the "variance" lens. (*Source*: Potter, 2005).