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On bullwhip in supply chains—historical review, present practice and expected future impact

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Abstract

Demand amplification (or "bullwhip" as it is now called) is not a new phenomenon, since evidence of its existence has been recorded at least as far back as the start of the 20th century and is well known to economists. Yet industry worldwide still has to cope with bullwhip measured not just in terms of the 2:1 amplification which is frequently quoted, but sometimes it is as high as 20:1 from end-to-end in the supply chain. This can be very costly in terms of capacity on-costs and stock-out costs on the upswing and stockholding and obsolescence costs on the downswing. In this paper we have identified 10 published causes of bullwhip, all of which are capable of elimination by re-engineering the supply chain. We offer evidence on the present "health" of a family of supply chains, and pinpoint much good practice. This is in anticipation that such excellence will become normative in the near future as the learning experience gathers momentum and provided that human factors are properly addressed.

Keywords: Bullwhip reduction; Supply chains; BPR

1. Introduction

Jay Forrester (1958) has been rightly viewed in many quarters as a pioneer of modern day supply chain management. His seminal work on demand amplification as studied via Systems Dynamics simulation demonstrated phenomena which many practising managers had experienced. This included such events as demand waveforms being propagated upstream in the supply chain, the inducing of "rogue seasonality" in the order patterns and the consequent wrong-footing of decision makers. Such demand amplification as shown in Fig. 1 (Fisher, 1997) is not new phenomena, since evidence of its existence has been recorded at least as far back as the start of the 20th century. The situation facing much of

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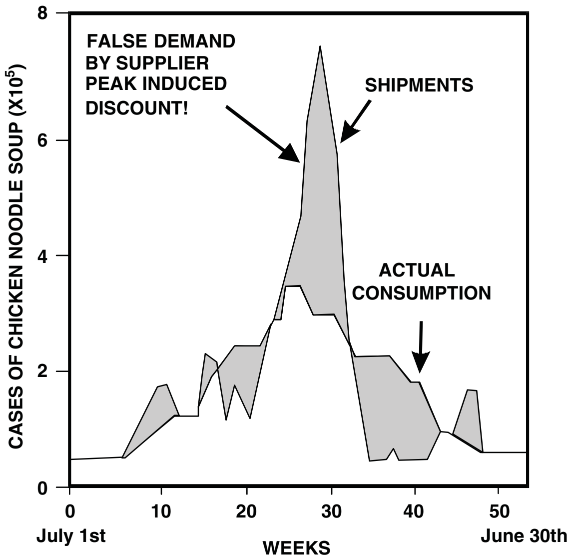

Fig. 1. Who bears the on-costs? Example of bullwhip generated via price promotion (*Source:* Fisher et al., 1997).

industry worldwide is exacerbated because "bullwhip", Lee et al. (1997), tends to be either misunderstood, or ignored (McCullen and Towill, 2002). Familiar arguments include that such "whiplash" behaviour (Hayes and Wheelwright, 1984) is someone else's problem, or it does not cost anything to this particular "player", or it is an unavoidable fact of life. But industry, in the meantime, has to cope with bullwhip measured not just in terms of the frequently quoted 2:1 amplification which is bad enough, but 20:1 and even higher (Holmström, 1997). This behaviour can be very costly in terms of capacity on-costs and in stock-out costs (Metters, 1997). Equally, because there are consequential downturns in demand stock-holding and obsolescence costs will also increase.

If effective supply chain management is now seen as a move towards "Swift and Even Material Flow" (Schmenner, 2001), then another major contributor to our present day understanding of bullwhip is Jack Burbidge, who during his lifetime was in turn an experienced production manager, consultant, and then a distinguished academic. Even prior to the "Japanisation" of much of US and European industry via the "Lean Thinking" Paradigm, he was arguing against the Economic Batch Quantity concept and in favour of the "Batch of One" supply (Burbidge, 1981). Hence, if we traditionally manufacture in large batches then his solution to queuing problems was to reduce these long set-up times, and aim for small batches as a way of life. So much so that even 40 years ago he was postulating "only to make in a week what you can use in a week". In the present operating environment we would simply substitute "day, or even hour", for "week", and his "5 Rules for Avoiding Bankruptcy" would thus have an amazing relevance to modern pipeline controls. Historically the bullwhip problem has also been of considerable interest to economists via their study of trade cycles (Mitchell, 1923). In this context the little-known paper by Zymelman (1965) provided an interesting proposal to reduce bullwhip in the cotton industry via a control law he established via analogue simulation.

Fortunately the writings of both Forrester and Burbidge considered a range of possible solutions to the bullwhip problem. These may have been brought together to form a coherent set of streamlined Material Flow Principles which have been termed the FORRIDGE approach. These have been shown to produce substantial industrial benefits, via studies of BPR Programmes. This improvement has been recorded despite the many barriers to change which may be encountered as the historically entrenched "functional silos" react to the holistic approach. More recently in a move to further improve on the FORRIDGE Principles bullwhip has become a topic for concurrent formal study. This has brought together a number of previously separate strands of research, namely OR (Lee et al., 1997), control theory (Disney and Towill, 2002) and filter theory (Dejonckheere et al., 2002). These topics underpin the essentially empirical studies of bullwhip via simulation (Forrester, 1958; van Ackere et al., 1993).

In this paper, we shall demonstrate that these approaches can be brought together via simulation packages as their focal point, thus providing diagnostic tools and design guidelines which will assist supply chain designers. The methodology has been validated on industrial data which is