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Trend forecasting for stability in supply chains ☆

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Abstract

This paper revisits the use of trend forecasting to determine ordering policy in supply chains by viewing it as a part of the control process for making the supply responsive to demand. Trend forecasting is often used to assess demand — a tracked variable in the control context, which drives supply — a tracking variable. Used in this way, it is often observed to increase instability creating the so-called bullwhip effect. Trend is used on the other hand with reliability to increase stability in controller control, but with the difference that a trend of a tracking variable is used to drive correction. While both processes involve use of trend to determine policies for achieving reliable performance, the outcomes of the former are variable while those of the later can create improvement in control with certainty. The similarities and differences between the two processes are discussed and guidelines developed for applying trend forecasting to enhance stability in supply chains.

Keywords: Trend forecasting; Supply chains; Bullwhip effect; Production planning; Operations management; Policy; System dynamics; Dynamical systems; Control theory; Controller control; PID control

1. Introduction

Demand forecasting has become an integral part of supply chain management and many sophisticated tools are now available to project demand either directly or indirectly through projecting its sources (Wheelwright and Makridakis, 1985). In fact, demand forecasting has come to be used as a matter of routine rather than being focused on addressing any specific problems of supply chains it is applied to (Gung et al., 2002). Use of trends is an important part of demand forecasting and many tools and methods have been suggested to improve the accuracy of demand forecasts (Bermudez et al., 2006). Albeit, trend forecasting as a discipline has often been viewed with reservation as it ignores its own impact on systems whose structure it often does not recognize, which creates much variability in its performance (Van Vught, 1987).

Use of demand forecasts in driving supply chains is also observed to increase what has come to be known as bullwhip effect, which manifests in amplification of inventory cycles as one moves farther from demand in the supply chain. While it is widely recognized that distortions of information created by this effect can lead to tremendous inefficiencies in terms of inventory investment, poor customer service, lost revenues and misguided capacity planning (Lee et al., 1997), a clear guideline for intelligent use of forecasting does not exist and it is often used as an end rather than as a means with the expectation to improve the performance of the supply chain. Indeed, the importance of understanding complex production processes is quite widely advocated for effectively managing supply chains (Lee et al., 1997; Khurana, 1999), but how these are influenced by the widespread use of forecasting is not well understood and, driven by widespread software support, trend forecasting continues to be used without focus on problem solving.

Taking my inspiration from the use of trend in servomechanisms to create what is called derivative control, I propose in this paper that trend forecasting can be directed to reinforcing control processes also in a supply chain that should reduce instability. To accomplish this, however, the existing control processes in the supply chain must be identified and the trend of an appropriate internal corporate variable used to create derivative control to supplement them. System dynamics modeling is used to construct the control systems I experiment with pertaining both to servomechanisms and supply chains.

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2. Supply chains and forecasting in a system dynamics framework

Although the terms supply chains and bullwhip effect entered operations management vocabulary in the 1990s, the structure of supply chain (called the production distribution system) was elaborated Jay Forrester in early 1960s (Towill, 1992). Forrester also was clearly concerned with the use of demand forecasts and how they could destabilize the production distribution system (Forrester, 1961), but he called this amplification rather than the bullwhip effect.

Forrester pointed to the amplification of changing conditions created by the use of trend forecasting in policy in Appendix L of his seminal volume Industrial Dynamics (Forrester, 1961) as forecasts can be quite off the mark at and near turning points in a system. Later, Lyneis (1975) suggested that demand forecasts can also be self-fulfilling if used in production planning, since demand is often affected by the delivery delay and the quality delivered in a production and distribution system. He also investigated the destabilizing impact of use of forecasts in decision-making in further detail in Lyneis (1982). Richmond (1977) supplemented this work by developing a trend macro for the System Dynamics National Modeling Project at MIT and testing it with cyclical functions, which confirmed earlier propositions of Forrester and Lyneis about trend forecasting increasing instability while also adding to the evidence against the reliability of use of forecasting in policy. It is not surprising that trend forecasting has largely been viewed in system dynamics community as a source of instability and as a dysfunctional basis for decisions, even though trend macros are available in most software used for system dynamics modeling.

Trend information has been used on the other hand with great reliability in engineering for enhancing stability of servomechanisms, controllers or governors. Originally formalized by Maxwell (1868) almost a century and a half ago, the concept underlying such applications is based on understanding the control channels in the system and using trend information to further reinforce them. Trend manifests in derivative control, which adds a correction in response to the rate of change of error, thus further speeding up correction when error is rising (Takahashi et al., 1972, pp343–350).

Given that both trend forecasting and derivative control use the same basis for policy, it seems anomalous that the former cannot be applied with reliability while the latter can be used with complete certainty to improve performance. It should be noted, however, that while forecasting often entails use of derivative in policy without knowing other components of control in place and also without knowing which feedback loops it will create or reinforce, derivative control is fully cognizant of both these processes. Given that the control systems in engineering have inspired the application of feedback concepts in system dynamics (Richardson, 1991), it is inappropriate to categorically reject trend forecasting as a dysfunctional process and not be guided by the engineering practice to use it for improving stability also in social systems.

It is furthermore observed that, while derivative control invariably uses the trend in what is called a *tracking variable* — an entity residing within the control system as a basis for determining correction, trend forecasting may often be focused on a quantity in the market that a firm is trying to follow, which would be termed a *tracked variable* in control jargon. In supply chains, demand is often a tracked variable and supply — a tracking variable. Using a trend of demand in controlling the supply can create quite dysfunctional control processes, even though this trend may be very accurately determined. It is not surprising that the outcomes of forecasting demand in management of supply chains remain uncertain depending on what control components might accidentally form, while the outcome of derivative control in servomechanisms is always certain based on the components deliberately created in designing the corrective regimes.

In the following sections of this paper, I will first construct a system dynamics model of the classical control mechanisms used in engineering systems that involve use of trend of a tracking variable to improve tracking performance. Next, I'll construct a model of a simple supply chain management system focused on adequately meeting shipment needs by ordering to replenish inventory. Such ordering is often driven by a forecast of shipments — a tracked variable, whose use exacerbates instability. Finally, I will formulate classical control mechanisms in a simple supply chain management system using forecasts of the stock of inventory — a tracking variable, to demonstrate how trend forecasting, used as a policy tool in a supply chain, can enhance stability. In conclusion, I'll propose that we can indeed get a reliable performance from use of trend forecasting as a policy if we apply it as in derivative control. In particular, the variable forecast must be carefully selected to represent error in a tracking variable. Also, the feedback relationship it creates with the decision being affected must be controlling not reinforcing.

3. Modeling the classical control process

The classical control process, sometimes called the analogue PID control law can be expressed in the following general form:

$$M(t) = P[e(t)] + I\left[\int_{-\infty}^{t} e(t)dt\right] + D[de(t)/dt] \tag{1}$$

where, M is total correction applied, P (proportional control) is the part of total correction that is proportional to the instantaneous error e, I (integral control) is the part of total correction that is proportional to the integration of the instantaneous error e, and D (derivative control) is the part of total correction proportional to the derivative of the instantaneous error e. Instantaneous error e is invariably the discrepancy between the tracking quantity and the tracked quantity. This law controls many servomechanisms we use in every day life. An example is the power steering in automobiles which allows the wheels of a car to exactly correspond to the position of the steering wheel without the two being rigidly coupled. It is required that when the steering wheel is turned, the car wheels turn smoothly and quickly to the new position of the steering wheel without hunting for the new position and without a displacement from