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4P. A Learning Game to Improve Supply Chain Efficiency

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Abstract

Economic competitiveness and prosperity are decreased when ubiquitous supply chains suffer disruptive and costly perturbations. Statistical physics shows that both the nature of the perturbations and the effectiveness of management attempts to minimize them depend strongly on the extent of rational information exchange between the entities in the chain. A new immersive interactive learning object game is demonstrated that encourages the exploration of information technology investment strategies, and demonstrates the dramatic impact rational information exchange can have in controlling these disruptive perturbations.

Keywords

Information Technology Investments, Collaborative Management, Supply Chains, Learning Object,
Game, Statistical Physics

1. Introduction

Supply chain inefficiencies resulting from fluctuations in cost and quality have a significant negative impact on a nation's manufacturing competitiveness. As a result of the fluctuations, product output is disrupted, capital costs increase, and the associated unnecessary job disruption and hardship weaken the ability of nations to compete globally.

The purpose of this paper is to demonstrate a new game – an easy-to-use interactive and immersive learning object - that allows supply chain managers to experience how information technologies and rational collaboration can dramatically improve the bottom line. The objective of the game is to promote the widespread application of the lessons learned from earlier supply chain models and simulations.

2. Background

The problem of unnecessary supply chain perturbations has long been recognized as a serious problem for a nation's economy. Insights into these perturbations have been provided from two quite different perspectives: a business school game developed at MIT and its offshoots, and analytical models such as a statistical physics model developed at USC and CGU.

2a. The "Beer Game" and its derivatives

The beer game is widely used by business schools to demonstrate the counter-intuitive nature of supply chain management. The board game was developed over a decade ago by Sterman and Fiddaman (1993) at MIT. The game deals with a very specific inventory management problem for an imaginary beer distribution four tier supply chain. It provides an immersive experience in the ineffectiveness of intuition in inventory management decisions when operating in a 23rd order differential equation business environment. The beer game uses a single specific customer demand function and allows no feedback or repetition. The inventory manager of each tier uses a blended heuristic of (1) past experience, (2) the orders already in the pipeline, (3) the difference between his inventory level and an "ideal" level, and (4) estimation of an "ideal" level. . Thousands of trials of this board game experience have demonstrated that local intuitive management decisions are predictably irrational and lead to large wasteful inventory fluctuations. Since the introduction of the beer game, several derivatives have been developed, a good summary of which can be found in Knolmayer et. al. (2007).

The beer game results suggested that the oscillations (1) are due to managerial over-reaction to input fluctuations, and (2) that the situation could be improved by timely information exchange between the entity managers.

2b. Statistical physics and analytical models

Several analytical supply chain models have been summarized in Knolmayer et. al. (2007). In addition, statistical physics analysis has been used by the authors to examine the complex dynamic nature of supply chain oscillations and their management, from a very different general perspective (Dozier and Chang, 2004a,b, 2005, 2006a,b, 2007, 2009). The approach builds on earlier applications of statistical physics to slowly changing phenomena in neoclassical and modern new growth economics (Krugman, 1995, Thorne and London, 2000, Constanza et. al., 1977, Smith and Foley, 2002).

This work gives several new insights into supply chain fluctuations: (1) fluctuations are intrinsic to supply chains, (2) their form depends strongly on the extent of information exchange between the chain entities, and (3) their magnitude can be reduced by properly focused management control.

It may seem strange that a statistical physics methodology developed originally to describe the behavior of a large number of inanimate objects, can also be applied where large numbers of motivated people interact to achieve a desired goal. The successful application suggests there is enough randomness in the performance and specific goals of motivated people that the methods still apply.

The use of a statistical "distribution" function introduces a new perspective on inventory levels as a function of position in the chain. In the supply chain, the flow into the inventory stores in one entity depends on assumptions about inventory stores at other levels. The dependence of inventory at one level on the inventories at other levels creates a feedback mechanism that affects how inventories fluctuate both in time and with position in the chain. By taking into account in a self-consistent manner how the levels effect each other, the conservation equation for the distribution function can be used to find the form of naturally occurring fluctuations in the chain. In statistical physics, these naturally occurring fluctuations are often referred to as "normal modes" of the system.

Two cases have been examined [4,5,7,8]: (1) where information exchange by an entity is only with the two entities immediately above and below it in the chain, and (2) where information exchange is with all the levels.

In the first case, it is found that a slightly damped sound wave-like normal mode results. Inventory disturbances in such a chain propagate forwards and backwards in the chain at a constant flow velocity:

In the second case, it is found that quite different plasma-oscillation-like normal modes result, some of which are strongly damped:

A quasilinear equation can then be used to find the optimum management actions to reduce the amplitudes of these oscillations.

In spite of the importance of the conclusions from past games and analytic models about the positive impact that supply chain information exchange can have on improving a nation's economic prosperity, information resources management has not been widely adopted in supply chains. Irrationality leads to an underestimation of the risks involved in managing complex systems and this leads to underinvestment in technologies to provide the needed flexibility to deal with the increased risk

3. A supply chain learning object game

The beer game of Sterman and Fiddaman (1993), the enhanced desktop simulation by Densmore (2004), and the subsequent simulations summarized in Knolmayer et. al. (2007) suggested the value of information exchange in decreasing inventory fluctuations. At the same time, however, they left much room for improvement in incorporating effective learning or training pedagogies that interactively explore the economic benefits of information technology in damping the inventory fluctuations and on reducing total costs.

Our new simulation learning object emphasizes learning-by-feedback pedagogy. It provides an immersive interaction experience using repetition and feedback that enables the exploration of the information investment strategies that incorporate the results of the statistical physics research. As a result it more directly promotes the increased investment in information technology necessary for the application of advanced supply chain theories.

The experiment presently runs on a client-server network, i.e. the simulation runs on a "server" computer, and participants access the program from a "client" desktop or laptop computer.

A layered approach is adopted, in which each layer of the learning object is increasingly sophisticated and accomplishes more effective management control of the fluctuations. The initial layer starts in the well known beer game context. By advancing their scores, participants layer up to more challenging scenarios that require the capabilities created by a statistical approach. Players are exposed to a series of higher layer algorithms as they gain proficiency in dealing with ever increasing dynamic risk scenarios.

The player's goal in the game is to minimize the total inventory cost incurred in the supply chain for a specified total number of product units ordered by a single customer in a single business cycle. The game allows repetitive exploration of the economic impact of various information technology investment strategies.

The learning object simulation creates an interaction between four autonomous agents: The participant is the retail agent, and interacts with algorithm-driven autonomous agent cohorts representing a wholesaler, a distributor, and a factory. The participant can use various information investment strategies to influence the behavior of the other three simulated agents.

During the game, the player makes retailer inventory decisions by interactively placing orders to the wholesaler. The simulation uses various forms of feedback to communicate the effectiveness of the investment strategies and their impact on the total cost incurred by the chain.

In the game, the player makes management decisions by employing any combination of three basic techniques:

1. The first is to follow instinct.

2. The second is to invest in local IT to increase local rationality.

3. The third is to invest in global IT to increase group rationality and knowledge sharing between all autonomous agents in the chain.

There is a cost associated with each of the two IT choices, as well as a penalty cost for bad inventory decisions. The game is designed to increase the understanding of actual risk levels and the increased flexibility that investments in information technologies can provide to allow accommodation of the increased risk.

A Web version of the learning object will be demonstrated at the conference.

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