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The analysis of the bullwhip effect in Chinese medicine supply chain

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THE ANALYSIS OF THE BULLWHIP EFFECT IN CHINESE MEDICINE SUPPLY CHAIN

By

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China

A research paper submitted to the World Maritime University in partial Fulfillment of requirements for the award of the degree of

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Research paper**:** **The analysis of the bullwhip effect in Chinese medicine supply chain**

Degree**:** **MSc**

The structure reforming of the medicine industry in China has made the medical logistics faced huge changing. However, compared to the quickly developed hardware construction, the software construction for medicine logistics is greatly lagged whatever from professional human resource or theory research. The characters of the medicine supply chain make it will be more sensitive for the bullwhip effect. Therefore, this paper should examine the BWE in pharmaceutical industry in detail, which would have more reality meanings.

First part of this paper examined the mechanism and principles of the bullwhip effect (BWE) in Chinese medicine supply chain, and discussed the impact of BWE on logistics and the customer service level for pharmaceutical company. Then using a spreadsheet based program to simulate the mechanism of bullwhip effect, illustrated how the replenishment policy and the different forecast techniques influence the bullwhip effect. And the discussion would tradeoff between inventory cost and customer service level, to find an optimized solution. Through the analysis above, summarized several countermeasures and solutions to decrease and alleviate the bullwhip effect in medicine supply chain.

Finally, it discussed the impact of bullwhip effect by case study, which represented three different levels of situations in current Chinese medicine supply chain. It showed that the modern supply chain management construction in China is still under a primary level. Although the bullwhip effect is not obvious in the daily operation, but as soon as the market fluctuation happened, the impact of BWE is very serious.

Keywords: bullwhip effect, medicine supply chain, logistics, simulation, inventory, replenishment policy, spreadsheet application

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LIST OF ABBREVIATIONS

3PL	Third Party Logistics
BWE	Bullwhip Effect
CAO	Computer Assistant Order
CDC	Centers for Disease Control and Prevention
CMSC	Chinese Medicine Supply Chain
CRM	Customer Relationship Management
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EDLP	Every Day Low Price
ERP	Enterprise Resource Plan
ES	Exponential smoothing forecast
MRP	Material Requirements Planning
MA	Moving average forecast
MD	Mean demand forecast
MMSE	Minimum Mean Squared Error forecast
OTC	Over the Counter
OUT	Order Up To
POS	the Point of Sale
SARS	Severe Acute Respiratory Syndrome
SCM	Supply Chain Management
SC	Supply Chain
VMI	Vendor Management Inventory

Chapter 1 Introduction

The first chapter will outline a general view of my dissertation. First part introduces the research background that includes the background of bullwhip effect (BWE) and the current situation of Chinese medicine supply chain (CMSC). Then approach the problem and state my aims and objects for this paper. The last part is my research methodology and working model for this dissertation.

1.1 Background

1.1.1 The Bullwhip Effect

The concepts of supply chain and supply chain management now have widely been adopted by most of enterprises' logistics department. Christopher (1998, 2000) had said that the competition is no longer among firms but instead by the competition between supply chain and supply chain. That is why the supply chain management has become more and more important for modern enterprise management.

Supply chain management is a kind of a dynamic decision task. It involves different factors, which will influence the decision-making, such as lagged feedback and multiple decision-making. This feature makes it very difficult to be implemented in reality. According to Sterman (1989), when decisions have indirect and delayed feedback affects decision makers, it would be difficult to control the dynamic situation. Further, when multiple agents are involved in the chain, each member's performance would depend on all other members' decision and performance. Therefore, it is subject to coordination risk that may bring instabilities in the system (Croson et al., 2005).

One of well-known peculiar phenomenon caused the inefficiency in the supply chain is the bullwhip effect. There are a number of literatures showed that there always exists the distortion of the demand information, when it transferred along the supply chain, and which should misguide the upstream members for their inventory and

production decision-making. In a typical single-item two-echelon supply chain model, it means that the variance of order received by the manufacturer normally will be greater than the variance of real demand observed by the downstream final retailer.

In China, many domestic researchers have done a lot of study and research work on the supply chain management and the bullwhip effect, but compare to the foreign research in this field, that is still under a primary stage.

1.1.2 The current situation of Chinese medicine supply chain

By the quick development of Chinese economic, the living level of local residences is also fast developed. The implementation of basic medical security policy and the promotion of the drug separation management, continues increase the requirement for medicine industry. That gives the domestic pharmaceutical retailer and medical logistics industry a good opportunity for fast development. The survey[1] shows that, at the end of 2005, the requirement for medicine in whole country would reach 218 billion RMB. Up to 2010, it is estimated that Chinese domestic medicine market value will be 60 billion USD, and will exceed the United States market. China would become the biggest medicine market in the world, by 120 billion USD in 2020. Those figures outline a great outlook for Chinese medical logistics industry in future.

The other important fact is that the structure of Chinese medicine supply chain is under great changing. Up to 2006, there are 800 raw material suppliers, 6300 pharmaceutical manufacturers, 16500 distributors and 180,000 retailers in China mainland. By the separation of prescribing from dispensing of drugs, the hospitals would gradually out of the traditional medical distribution network. Private owned fair-price drug store quickly opened and become one of independent medicine distributor against traditional state-owned drug store. The chain drug stores have right to order the medicine directly from pharmaceutical manufacturer and reduce many intermediates between retailers and manufacturers, which is prohibited before.

[1] China Association of Pharmaceutical Commerce: ww.capc.org.cn

Those changing force the Chinese medicine supply chain to take a huge reform. Now, under the support of local governments, many new medicine distribution centers were constructed and many modern logistics technology were quickly adopted in some medical logistics centers, such as EDI or RFDI.

However, the reality is not so optimism, the high logistics cost has become major problem in front of each Chinese pharmaceutical enterprise. According the professional survey[2], currently, the logistic cost occupy about 30~40% of total cost in pharmaceutical industry in China. But in developed country, this figure is only 4%. The foreign medicine distribution company achieved very high efficiency by carrying out uniform scientific supply chain management.

In addition, the performance of logistics and supply chain management in medicine supply chain is greatly lagged, for example, compared to the fast-consumption commodity or automobile manufacture industry. Moreover, within the industry, development of hardware construction is relatively quicker and more attended than the software construction, whatever from basic theory study to human resource cultivation. The detailed research and study combined both supply chain management and medical logistics is even little. The limited research paper is mainly focused on the new technique application, such as new information technology using in supply chain management. There is less professional theory study, for example, the bullwhip effect in supply chain management in medical industry. That is the reason why I choose to make the study on this subject.

1.2 Aims and objectives

The features of medicine supply chain, such as long period and fixed capacity manufacture, professional and high cost inventory and transportation make the medicine supply chain is very sensitive for the bullwhip effect. In addition, the more and more serious industry competition make the cost reduction become one of most important task for domestic pharmaceutical companies. The benefit of

[2] China Pharma Information Net: www.cpi.gov.cn

minimizing the logistics cost is not only the key point for alleviating the cost for production but also the increasing of profit. It has become one of most important methods to improve the domestic medicine company's competitive ability. Therefore, this paper will examine the BWE in pharmaceutical industry in details, which would have more reality meanings.

The main problem and sub-problems researched in this thesis is summarized as follows:

Main problem:

How to alleviate and dampen the bullwhip effect in Chinese medicine supply chain?

Sub-problems:

1. What is the mechanism and principle for bullwhip effect in CMSC?
2. How to calculate, simulate and analyze the bullwhip effect in CMSC?
3. What kind of countermeasures can be used to alleviate and dampen the BWE?
4. How to improve the supply chain management in CMSC?

Aims and objects:

The aims and objects of my study are to explore some solutions for Chinese domestic pharmaceutical firms to minimize the impact of the bullwhip effect, and generally improve the whole supply chain management level. That would include:

A) Identify the causes for the bullwhip effect in the Chinese medicine supply chain

B) Use a more practical simulation model to help Chinese Pharmaceutical firms to easily understand and analyze the bullwhip effect in supply chain.

C) Broaden the solutions to improve inventory and replenishment performance.

D) Examine the impact of the reforming of Chinese medicine industry and discuss the consequent changing and opportunity.

1.3 Methodology

In this paper, first part will examine the mechanism and principle of the bullwhip effect (BWE). Especially, further explore how the organization structure, information structure, decision mechanism and human behaviors influence the bullwhip effect, in medicine industry.

Secondly, it will analyze and discuss the impact of the bullwhip effect on both capital cost and the customer service level in medicine industry.

Thirdly, through the formula deduction and simulation method illustrate how the replenishment policy and the different forecast techniques influence the bullwhip effect and the different performance in supply chain. Some valuable guidance and indication achieved from the result of simulation.

Through the analysis above, several countermeasures and solutions to alleviate and dampen the bullwhip effect would be carried out, from both strategy level and tactic level.

Finally, use empirical study on bullwhip effect to examine the BWE in real case situation. Three different level real cases, which include a real drug manufacturer firm, the vaccine industry and the SARS incident, used to illustrate how the bullwhip effect influence the Chinese medicine supply chain.

Based on the study all above the paper got some conclusion and recommendations for the industry to improve the performance and competitive ability.

1.4 Scope and limitation

The scope of my dissertation is mainly focus on the impact of BWE on the pharmaceutical manufacturers in the Chinese medicine supply chain. That is

because the manufacturers as the upstream members in the supply chain are easier and more seriously be influenced by BWE. Secondly, the simulation model studied in the paper is under many assumptions to simplify the situation, it is just a two-echelon model. Compared to the complex reality, the result of the simulation although is valuable and reasonable, but still need improvement and adjustment before introducing to the real work. For the limited condition, I only get limited information from only one real drug manufacturer as the case study for real pharmaceutical manufacturer. However this company is a very representative domestic corporation in current, but still could not represent the whole industry, especially for many foreign joint venture pharmaceutical company, in China. The later one most time have better supply chain management performance and experience.

1.5 Working Model (General outline of the thesis)

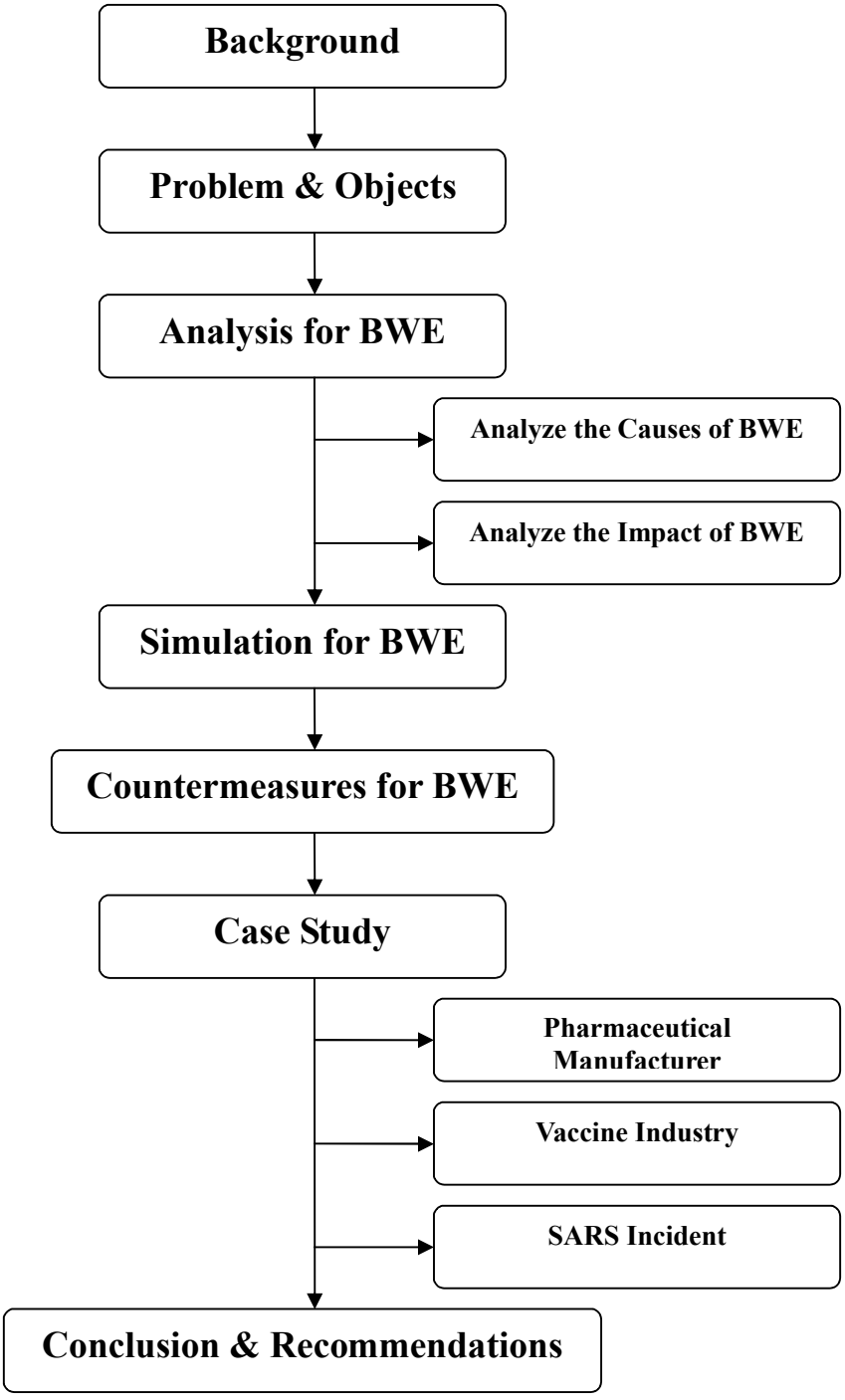


Figure 1.1 Working model of the thesis

Chapter 2 Literature Review

2. 1 Supply Chain and Supply Chain Management

The concepts of supply chain and supply chain management now have been adopted by most of enterprises' logistics management department worldwide. If look back for the history of the development of modern logistics industry, we could clearly found that the supply chain, just like the blood for human is the vital factor for the company, has gotten more and more attention.

The early concept of logistics, physical distribution, mainly refers to including the flowing process follow the physical materials and service in distribution, from the site of manufacture to the destination of consumer site. Later, the concept of logistics appeared. The logistics management is first delivered since the period of the World War II. The American army implemented the logistics management process for the ammunitions supplying. Logistics deals with the flow and storage of goods and related information, as defined by the Council of Logistics Management. All the processes consisted planning, implementing, controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point-of-origin to point-of-consumption are for conforming to customer requirements. During that time, the study object is narrow logistics, which just include the logistics activity related to the commodity distribution, is the activity of the entity of products in flowing process. The information and information flow had not been concerned.

According to Ballou (1992), logistics management, as a discipline in management science and practice has its root back in the United States in the 1950-60s, when the potential of efficient material distribution for decrease companies' direct product costs was realized. The oil crises happened in the 1970s, made both transportation costs and interest rates became huge pressure for enterprises. Then, the importance of logistics to a company's profits was really understood by top management (Ballou, 1992).

At the mid-1980s, Professor Michael Porter from the Harvard Business School said that a company is able to gain a competitive advantage over its rivals in the same markets only by providing more value to its customers. Moreover, in his famous book, *Competitive Advantage* (Porter, 1985), introduced a new concept of value chain. This term and concept then quickly be adopted and studied worldwide. In the value chain concept, that each activity in a company should add value to the value chain for customer and, similarly, each company in a particular industry should add value to the value system (Porter and Millar, 1985). People understood that the logistics is the center for company to create value for the customer. Both inbound and outbound logistics are primary activities in this value chain and they could greatly improve the value for customer, not only the cost-efficiency within the company itself.

Based on the concept of value chain, in the later 1980, the terms of supply chain management started to be used in literatures. The modern concept of supply chain management is very similar with the logistics management, but the former has more broaden scope than the later one within company. The definitions of supply chain management are different in the different literatures. Christopher (1998) defined supply chain management as follows:

The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole.

This has been widely accepted by many researchers, but there are many other similar but different explanations too.

Although the history of SCM is only less than 30 years, but now this concept has to be widely used in manufacture management system, and become a new management model. By the development of globalization and intensive competition between enterprises and the homogeneity of products, more and more enterprise recognized

that strengthening the cooperation and coordination between the partners along the industry could improve the competitive ability of enterprise. That could become an important contributor to its market success. Enhanced competitiveness forced companies ceaselessly integrated within a network of organizations. This integration of companies within a network system has led to put more emphasis on Supply Chain Management (SCM).

Supply chain management (SCM) is the term used to describe the management of the flow of materials, information, and funds across the entire supply chain, from suppliers to component producers, to final assemblers, to distribution (warehouses and retailers), and ultimately to the consumer. In fact, it often includes after-sales service and returns or recycling. In contrast to multiechelon inventory management, which coordinates inventories at multiple locations, SCM typically involves coordination of information and materials among multiple firms.

SCM is the management of upstream and downstream relationships in order to deliver greater customer value with less cost to the supply chain as a whole. The integral value of the SCM philosophy is total performance of the entire supply chain, and is enhanced when we simultaneously optimize all the links in the chain (Burke and Vakkaria 2002). In order to achieve this coordination/integration of all the parts in the whole supply chain, information system is most important. Recent quickly developed technology in information systems and information technologies have the potential to meet the requirement for realizing that integration.

Christopher (1998, 2000) has said that: Competition is no longer among firms but instead is becoming supply chain to supply chain, and moving beyond that to competition among supply networks.

2.2. Bullwhip Effect (BWE)

Supply chain management is an example of a dynamic decision task, which involves different factors would influence the decision-making, such as lagged feedbacks and

multiple dependent decision makers. This makes it very difficult to be implemented. According to Sterman (1989a), when decisions have indirect and delayed feedback effects decision makers, find it difficult to control the dynamics. Further more, when multiple agents are involved in the chain, each one's performance depends on the quality of other supply chain members' decisions and performance, and therefore is subject to coordination risk that may trigger instabilities in the system (Croson et al., 2005). One of well-known inefficient phenomenon in supply chain management is the widely studied bullwhip effect. There is a number of literatures indicate that the information of orders transferred along the chain tends to be distorted, and which could misguide upstream members in their inventory and production decision-making. In a typical single-item two-echelon supply chain model, it means that the variability of the orders received by the manufacturer normally will be greater than the real demand variability observed by the downstream final retailer.

The bullwhip phenomenon was first noted by M.I.T. Prof. Forrester (1958), who used industrial dynamic approaches to demonstrate the amplification in demand variance, and popularized this phenomenon. Forrester's work has inspired many researchers in this field to quantify the bullwhip effect, identify possible causes or consequences, and suggest various countermeasures to tame or reduce the bullwhip effect. For example, Hewlett-Packard found that orders placed to the printer division by retailers have much bigger fluctuations than the real customer demands, and the orders to the company's integrated circuit division have even worse swings (Lee et al., 1997). Many industries, including computer memory chips (Fisher, 1994), grocery (Fuller et al., 1993), and gasoline (Sterman, 2000), has experienced similar symptoms. It seems that the bullwhip effect exists with the supply chain by natural, in every industry.

A number of researchers have designed different models to illustrate the mechanism of bullwhip effect. One of the most famous and popular one is the "Beer Distribution Game", which is simply simulation and be widely used game in many

situations. A lot of business education school used this game to demonstrate the concept of BWE, and the result of the game was always similar, however the participators are from different country and with different background, which exactly indicated the existence of BWE. Nowadays, this model has been developed to many different versions ranging from manual to computerized. Simchi-Levi et al. (1998) developed a computerized version of the beer game; Machuca and Barajas (1997), Chen and Samroengraja (2000) and Jacobs (2000), developed different web-based versions.

D Steman (1989) analyzed the bullwhip effect through the beer distribution game, concluded that the BWE was caused by the participators' systematic unrational behavior and the wrong comprehension for the reflect information. In his view, some behavior factor, especially those influence of unreasonable decision, make the decision-making process is base on partly observation and absence cooperation even is under the entrusted each other status. Towill (1996) through simulation and case study discovered that, the range of variance of demand information would be doubled when through every echelon. When the manufacturer gets the order from agent, the fluctuation of the forecast for the demand information is almost the eight times of the market original signal. Richard establish a quantify model to analyze the anamorphic information and the relationship with BWE. Another, some researcher through the method such as simulation to analyze the BWE, approve the impact of inventory policy on supply chain information. However, H L.Lee (1997&1998) is the man who first made a completed and correct analysis for this phenomenon. He considers that the participators in system are rational and make optimal decision, and the BWE is the result of the co-influence from rational system participators' strategic behavior.

According the studies, the demand forecasting and the type of ordering policy used are two key causes lead to the bullwhip effect (Lee et al. 1997). Lee also provides a mathematical proof that variance amplification takes place when the retailer adjusts his ordering decision based on demand signals. Dejonckheere et al. (2003) use model

demonstrate that the use “non-optimal” forecasting schemes, such as the exponential smoothing and moving average forecast, would always lead to bullwhip effect, which is independent and have no relation with the observed demand pattern. After that, an increasing number of studies high on the effects of demand signaling, improper forecasting and the replenishment rules used in supply chain(e.g. Watson and Zheng 2002).

To present, the study about bullwhip effect is mainly focus on these several directions:

1. the existence of BWE

2. the quantitative analysis of BWE

3. reducing and taming the BWE

There is a lot of work to be done to prove the existence of BWE. In addition, the quantitative analysis of BWE is mainly concern to quantify the changing of ordering from supplier, manufacturer and distributor. People also raise some solutions and countermeasures to reduce the BWE. The information sharing is one of most important method. The limitation for this literature review is that there is less special research literature on the medicine supply chain or bullwhip effect concerned study on medicine supply chain were found and listed in this section. That’s also the reason why this paper chose to study the bullwhip effect in this specific area in further discussion.

Chapter 3 The mechanism and principle of the bullwhip effect in medicine supply chain

In this section, the mechanism and principle of bullwhip effect would be examined in details, especially under the current situation for Chinese domestic medicine supply chain.

3.1 Medicine supply chain

If we sort the sequence of the different logistics according the technical requirement and the barriers for entrance, the medical logistics would be as one of most difficult and complex logistics system, with company in the IT/Electronic and automobile industry. The reason for the medical logistics needs so strong logistics technique and big capital investment support is that medicine logistics as a special logistics area, which would under the control of the strict regulation for health and safety from governmental administration. These rules and regulations control the whole process in supply chain, every step need be tracked and recorded, and the requirement for trace back ability is expand to the whole supply chain. The unexpected distribution, recall or return in medicine industry will make tremendous impact for public health and social obligation. Therefore, any mistake in medical logistical operation will cause huge opportunity cost and is not permitted.

3.1.1 The features of medicine supply chain:

1. The medicine manufacture period is long and the manufacture capability is fixed relatively.
2. The transport frequency is high, but quantity is small.
3. Storage condition is high and professional, and inventory or holding cost is very high.
4. The validity time is limited and need strong information system to support.
5. High operation quality required and whole logistic process is traced and monitored.

6. The demand is fluctuated according natural situation, such as epidemic or natural disasters etc.

3.1.2 Chinese medicine supply chain

China, as a country with the biggest number of population in the world, has a very big domestic medicine market. Especially, in recent years, by the quickly developed economic, the mainland medicine industry also got a quick development. In the end of 2006, the total sales volume for medicine in mainland is about 13.4 billion USD, increased 13.12% than last year; the profit was 41.3 billion RMB increased about 11.1%. Otherwise there were 1168 pharmaceutical enterprises are to the bad, occupy the 22.62% in the whole industry. The main reason is the cost increasing for the raw material and other resources, such as water, electricity, gas and oil. To limit the total cost becomes one of most important task for many pharmaceutical companies to keep their positive profit. More and more enterprises had realized that the supply chain is one of most important key point for this object. Nevertheless, the current situation for Chinese domestic supply chain is not optimism.

Features of Chinese medicine industry:

- There are too many pharmaceutical enterprises in the market.
  (Up to 2006, there are 800 raw material suppliers, 6300 pharmaceutical manufacturers, 16500 distributors and 180,000 retailers in China mainland.)

- The scale for distribution enterprises is relatively small and dispersed. (There are only 10 distributors' sales volume is exceed one billion RMB)

- There are four layers state owned medicine distributor control the most market for long history, the efficiency is very low.
  Four levels state owned medicine distributors:
  First Level:
  Beijing, Shanghai, Tianjin, Shenyang, Guangzhou

5 major Medicine distributors

Second Level:

1000 City level medicine distributors

Third Level:

3000 County level medicine distributors

Fourth Level:

Other local small medicine distributors and wholesalers

The medicine distributed according the state owned distribution network from first level to next level, and final delivery to fourth level.

- The medicine distribution market was not opened to foreign enterprises for a long history, the regulation had just been changed in 2003.

In China, the medicine supply chain system normally is continuing the old planned economy structure. Pharmaceutical manufacturers could mainly through the state owned provincial medicine distribution company as main distribution network, to sale their product, especially for the prescription drugs (because of the market control ability, in fact the private and foreign distributor has very limited influence compare to state owned medicine distributor to get the distribution channel to final hospital customer, although the market is free for everyone.). Between the medicine manufacturers and final drug retailers, there exist many different layer intermediates (different level state owned or private distributors or wholesalers), such as figure 3.1 showed. Only some OTC drugs could be directly distributed to big final chain drug-stores (they also play the role of wholesaler for themselves) by pharmaceutical manufacturer themselves.

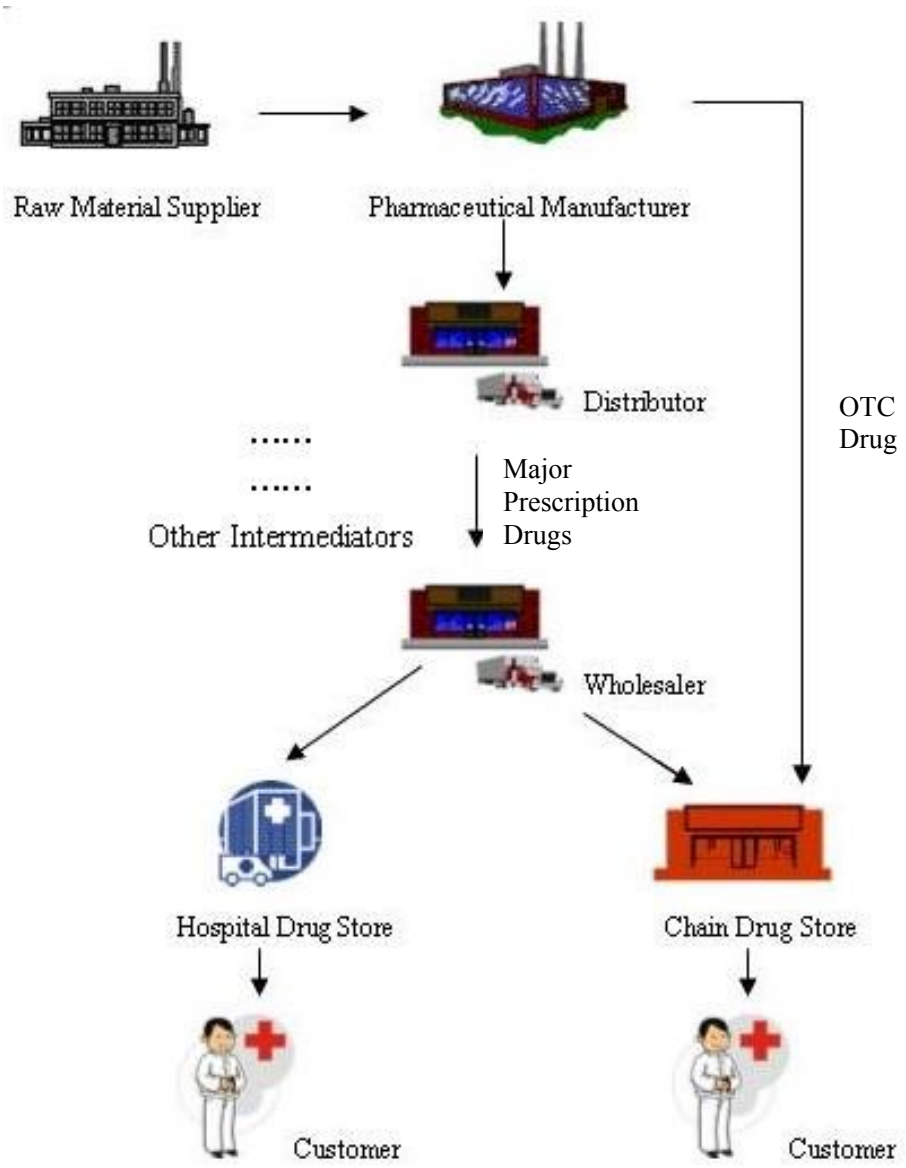


Figure 3.1 The structure of Current Chinese medicine supply chain

This kind of distribution channel make the whole supply chain become very complex and low efficiency. The latest market information could not be feedback to manufacturer in time, bullwhip effect easy to happen, and the multi-level inventory and distribute system make the logistics cost would be very high.

The causes for the bullwhip effect

There are many researchers had made full and detailed study on the bullwhip effect.

Lee had used the quantitative analysis method to study a multicycle inventory system (Lee 1997) and gotten four reasons caused the bullwhip effect:

1) The limited capacity supply and the shortage game
2) Different demand signal handling processes for different enterprises
3) The batch ordering method of the retailer
4) The fluctuation of the product price

As we all known that the bullwhip effect is a special phenomenon exists in the supply chain. Therefore, the causes for the BWE must also exist in the supply chain system. The structure of the supply chain, the decision-making mechanism and the human involved in the SCM are all most important aspect related to the BWE. In this section the discussion for the causes of the bullwhip effect would closely around those three aspects.

3.2 The structure of the medicine supply chain

3.2.1 Physical structure

The structure of supply chain could be recognized as formed by three different aspects: The horizontal layer, the vertical scale and the center position.

- The horizontal layer means the layer quantity of the main members in the whole supply chain. It comes to decide the length of the supply chain.
- The vertical scale is in reference to the main members in each same layer, it comes to decide the width of the supply chain.
- The center position is in reference to the core corporation's position relative to the end consumer in the whole supply chain.

Considering the different length of horizontal layer and scale of vertical layer in SC, we could divide the physical structure of the supply chain into four types as below:

1. The whole tree structure supply chain: there is more horizontal layer and larger scale of vertical layer, its shape is like the big tree has exuberant branches and leaves and integrity beards and roots, the core corporation owns many and different layer suppliers and the consumers.

2. The thin and long structure supply chain: the horizontal layer is many but vertical scales is small, although there are many layers but entity quantity of each layers is little.

3. Short and thick structure supply chain: the horizontal layer is little but vertical large-scale, layer quantity is little but vertical layer is many.

4. The chain shape structure supply chain: the horizontal layer and vertical scale is both small, this kind of supply chain is the most simple.

In the convention supply chain structure, the horizontal layer and vertical scale is bigger, the echelon for agent relationship would be increased. And then the information processing frequency would increase, the bullwhip effect would easy be happened. Therefore, the simple chain shape structure brings smallest BWE, and the whole tree structure would have big opportunity to bring serious BWE.

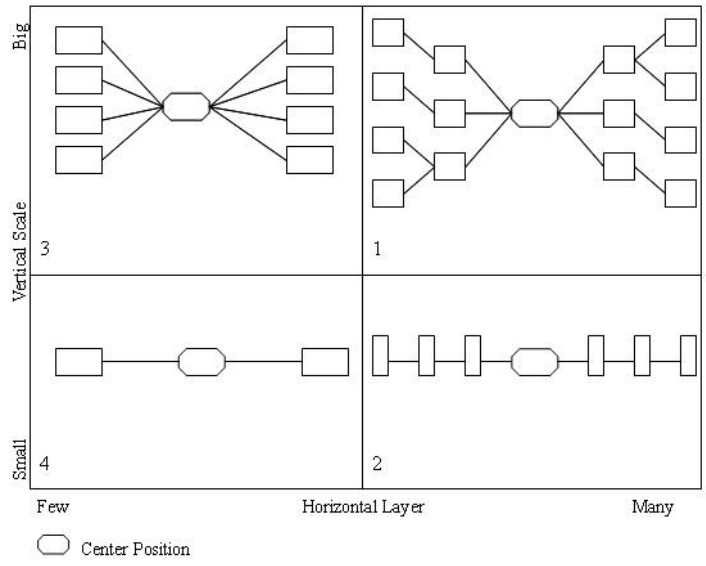


Figure 3.2 Four kind of Supply Chain Structure

Currently in the Chinese medical supply chain system, whatever from raw material suppliers, the pharmaceutical manufacturers, medicine distributors and wholesalers, and final retailers are all numerous and redundancy. In addition, the scale of each enterprise is relatively small and less market dominant ability. There is no bigger and monopoly domestic distributor in the supply chain such as in developed country. The whole industry's structure is a kind of whole tree structure, under a primary level and the bullwhip effect would be serious in theory.

3.2.2 The center position

The center position means the position of core enterprise in the whole supply chain. Cool and Henderson(Cool, Henderson,1993) had discussed the enterprise's authority and it's influence for profit-acquiring ability in supply chain, which is not simply refer to the company's impact on other members, such as bargaining power, but the fundamental core competitive ability. The core corporation more close to the end consumer would control more final market and demand information, the authority is bigger in the supply chain. The different position of the core corporation brings two kind of different SC types: the forecast driving type and demand driving type. Because of long distance from end consumer for the core business in the forecast driving type supply chain, the manufacturers are planed according the forecast; the demand driving type supply chain could effectively identify the market demand because they are close to the end market, make use of demand pulling power to move the operation of supply chain. Because of the uncertainty of the multi-forecasting, the fluctuation of bullwhip effect for forecast driving type supply chain is bigger than those for demand driving type supply chain. In medicine industry, these two kind of supply chain are both exist according different situation.

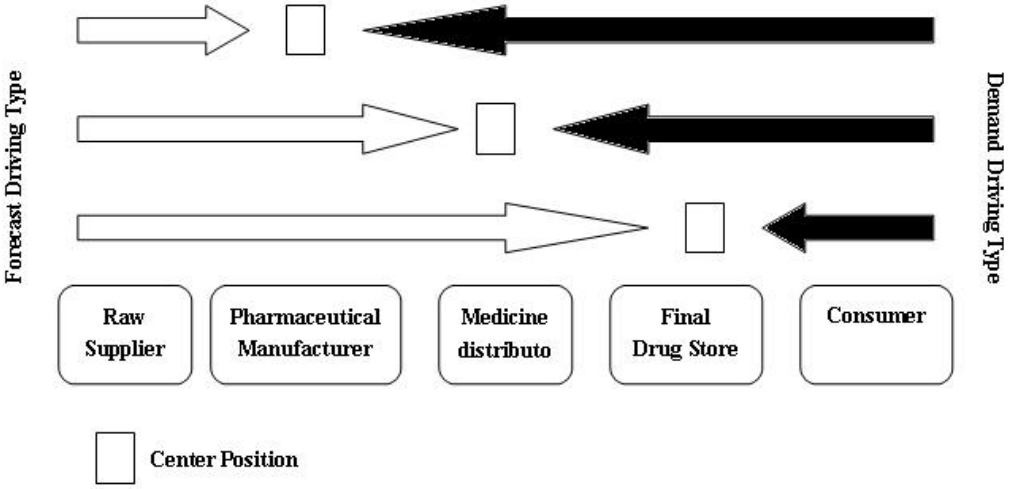


Figure 3.3 Different types supply chain according the center position

3.2.3 Information structure

In the supply chain, the relation between the node enterprises could be divided into three types: complete cooperation, partial cooperation, independent decision-making. Therefore, there are three kind variant information structure types: The complete information sharing, partial information sharing and information not sharing. Complete cooperation is the cooperation at the strategic level, through merger, annex and shares control methods to realize organization horizontal cooperation. Partial of cooperation is the cooperation at the operation layer that concerns some operating flows between enterprises only partial information is shared. For instance, the ordering flow, the procurement flow and information management flow is the partial information sharing. This type of cooperation is the main kind cooperation in the supply chain information structure. The independent decision-making means each entity has no cooperation intention, according the self-forecast information, to reach the maximum profit for them, there is no information sharing completely.

The impact of different information structure for bullwhip effect is also different. The complete cooperation reaches completely information sharing on the information structure. The uniform central control for manufacture arrangement, schedule implementing, inventory allocation, and market forecasting, make the information

processing and identifying become easily. So, the impact of bullwhip effect will be minimized. Partial cooperation has no cooperation base on the organization structure, just the information sharing on information structure level. If the cooperating field is closely related to ordering and main operation flow, the impact of fluctuation from the supplier order would be alleviated. Otherwise, the bullwhip effect will still exist. After many times repeated cooperation and gaming, reciprocal reliance will also decrease the bullwhip effect. For the independent decision-maker, because without any information sharing, the result is the bullwhip effect will be maximized. Especially under the situation of product is shortage, the delivery time is long, and the market fluctuation is big, the supplier will face a huge demand undulation.

3.3 The impact of the decision-making mechanism on the bullwhip effect

The bullwhip effect is closely related to the decision-making operation, so in this section the impact of decision-making mechanism would be discussed in details as below.

3.3.1 Demand forecast processing

In the supply chain, the upper stream manager, obtain the demand forecasting based on the demand information from downstream, and arrange the manufacturing, procurement or other supply scheme. It is thought that the result of this demand information is one of the proximate causes that lead the bullwhip effect. For instance, when a manager decides the order quantity, would use a kind method to do the future demand forecasting, such as the exponential smoothing method. When the daily new figure showed, the demand will present continuous variance in the future. The order send to the supplier not only reflect the requirement to satisfy the inventory quantity for demand, but also reflect the necessary safety stocks volume. The future demand and relevant safety stocks are realized by smooth technique. During the delivery time, that is normal to keep several weeks of safety stock, the result is the changing of the forecast order quantity will be larger than the demand

quantity. In the supply chain, as the upstream supplier, if also use exponential smoothing to calculate the demand forecast number and safe stocks, so the order of supplier will have a huge undulation. The order quantity from distributor to manufacturer will bigger than the real market demand. A flood of safety stock would lead the bullwhip effect. As a result the delivery time more long in supply chain, the fluctuation will be more acuteness.

3.3.2 The batch order

The batch order could be divided into the period cycle batch and the instant batch two kinds. Theoretically, customer could make order according the real-time demand, however in fact, because of the existence of the physical space distance and the repugnance for the time between the supplier and customer, the completely continuing real time order is almost impossible. In addition, the cost and time for handling single order is sensitive, the supplier impossibly responds to each instant order just in time. The other fact is that many drug manufacturers have implemented the Material Requirements Planning (MRP) system, normally make order toward the supplier according monthly requirement. In Chinese domestic medicine supply chain, usually each echelon will have their own stock, and they send new order to upstream enterprise just when the inventory is used up or under safety stock. Therefore, decision-makers used to make order with a certain interval time. The problem is that, in the partial interval time, the demand quantity in a certain period is stable, but at the rest times, the demand maybe decreases or increases suddenly. The implementation of periodic order policy will extend the demand variance probability and cause the bullwhip effect. Another common problem must be paid attention is the economics aspect for the continual ordering. The difference of cost between the full burden transportation and carrying capacity lower than the minimum transportation requirement is substantial. That is more obvious for the medicine physical distribution cost in the past Chinese plan economic management period. Thereupon, when distributor order drugs from the supplier, they really want to meet the full burden transportation, in the meantime, the supplier offer most

concessional price to the bulk or batch orders, which stimulate the long interval time and more quantity batch orders for future. The result is that the fluctuation of the demand volume occurs, and the probability for the bullwhip effect phenomenon appearing becomes bigger and its impact is amplified.

3.3.3 The price fluctuation

According to the estimate, in the retail trade between the manufacturer and the agent, 80% is being pre-traded under the demand forecasting. This usually is because the manufacturers purposely offer an attractive price to achieve order for the next period in advance. Nevertheless, it will also cause more inventory by the in advance purchase in the retail trade. In the medicine market, the rate fluctuation mainly caused by the manufacturer and retailer's periodic use special promote policy, such as the rate rebate, volume discount and special reward etc. This is particularly familiar in newly arising fair-price drugs chain store in china. In addition, the manufacturers also offer retailers and wholesalers trade privilege, such as special discount, the rate clause etc; they are all a kind of indirect rate rebate. These special promotions would bring the future stock, although it would stimulate the consumer amount buying in advance. This kind of promotion is closely related to the supply chain management, if the in advance purchase becomes one kind of routine policy. It could foresee that, when the drugs rate is low, consumer will intend to buy more than actual requirement quantity (especially for those OTC drugs and common used prescription drugs) which is much similar to other commodity. When the rate is at medium or high level, the consumer would stop buying until the stock use up. The result is, the purchase mode for the consumer could not reflect the real consuming mode, and quantity variance of purchasing is bigger than the quantity variance of consuming. The bullwhip effect appeared. Although this phenomenon still very limited in Chinese domestic market currently, but by the more and more OTC drugs and fair-price drug stores expand their market shares, this phenomenon will become gradually widespread. Many fair-price drug stores consider the high-low price cross strategy as a kind of competitive advantage to stimulate the purchasing, but less

awareness for its negative effect. In fact, because of the existence of the bullwhip effect, in the supply chain, the difference from order between customer and manufacturer is huge. When facing this significant variance of order, the drug manufacturer, on the one hand, is forced to over manufacture and delivery within a particular time, and in other time, idle sans matter; on the other hand, the manufacturer has to keep high volume inventory to meet the potential demand fluctuation. The impact of this kind of marketing strategy would spread to the whole supply chain, not for manufacturer only.

3.3.4 The rationing and the shortage gaming

When the manufacture capacity is limited, manufacturer usually will use the rationing schemes to allocate product according the ratio of the order quantity, the result will come a bullwhip effect to amplify. Such as, assume the total order amount received from distributor by manufacturer is Q, but if the supply ability for manufacturer is only Q/2, under this kind of rationing scheme, each distributor or retailer will receive the half order quantity of what he had ordered. If manufacturer carry out this kind of rationing scheme in practice, so each distributor or retailer would intend to enlarge his own order quantity.

The one hand, at this time, manufacturer according the order information received to make demand forecast, will amplify the demand seriously. That would lead manufacturer to make two kind serious wrong decisions with high probability: sending excess order for upstream supplier, or allocating excess manufacture resource for the production. Once the demand backs to normal level (sometimes only a little demand drop evidence in the market would cause the decline of demand), the manufacturer will undertake all cost including the inventory cost and resource allocate mistake cost (the loss cost).

The other hand, the retailer could hold several repeated orders from the different supplier in the same time, and buy from the first supplier finally, then cancel the left order while the demand is satisfied. We could imagine, the gap between the

pre-ordered quantity and the actual consumption quantity is very big, and the bullwhip effect would appear immediately. Under the situation of order fluctuated, manufacturers are hard to recognized whether it is real growing demand or only is one kind overmuch forecast from distributor. Usually the final result is the manufacturer pays the price for all cost.

3.3.5 The lead-time

The lead-time between the each node in the supply chain also has close link with the bullwhip effect in the supply chain. We could take in to explain with a simple mathematical model:

Suppose two lead time T_0 and T_1 for the same manufacturer, and $T_1 > T_0$, and the average variance as Va for the downstream distributor. In the supply chain, decision-maker usually use the average demand variance in unit time to commit an demand forecast, that's the average demand variance in unit time multiply the lead time to get the forecast order variance, then

The order variance for lead time T_0: $V_0 = Va * T_0$

The order variance for lead time T_1: $V_1 = Va * T_1$

When $T_1 >> T_0$, so the $V_1 >> V_0$

Thereupon, the length of lead-time is direct ratio relationship with the demand variance, and the influence on the bullwhip effect is obviously.

3.3.6 The time delay

In the supply chain, there exist the problem of time delay, which including the information delay and material delay.

1. Because the client's order information normally could not get by manufacturer directly and immediately, which need through the handling and processing from

the retailer and the wholesaler, this result in the information Delay. The information delay has three kinds:
<1> order business handle delay, such as when retailers received order, need time for order-handling;
<2> ordering delay, such as retailer need time to accord the customer's order to make new order for supplier;
<3> post delay, so the order on the post way also need time.

2. Similarly, the product manufactured by manufacturer also needs several medium nodes to deliver to customer's hand, such as wholesaler etc, therefore will result in the material delay. The material delay has two kinds:
<1> delivery delay, the time between the supplier got the order to the cargo to be prepared for delivering;
<2> transportation delay, the time spend on the way for transportation.

Above-mentioned both make the supply chain could not respond to the market demand variance synchronously, and potentially influence the bullwhip effect, just as the impact of lead-time. The respond time longer for the supply chain, the reaction from market would be more serious. The fluctuation of the order quantity for each member would be gradually amplified along the supply chain upwards. The degree of time delay is closely related to the length of supply chain, the participant enterprises are more, the bullwhip effect would be more obvious.

3.3.7 The absence of coordination

Because of each member in supply chain always exists definite interest conflict, between corporations, regardless the relationship is how close, there are some commerce information could not be shared mutually. This kind of "in-fighting" influences the operation efficiency and competition ability for the whole supply chain greatly. In addition, there is no supervision and punishment mechanism for coordination that cause the real time information concern customer's demand can't be feedback to the supply chain in time and completely. Result in the delay and

distortion for responds to customer's demand. This is also one of the important causes the bullwhip effect. For instance, medicine final retailer would not like to let the upper stream supply chain control the true sales information, in order to prevent the competitor or latent rival to obtain confidential commerce information through the supplier. However, under the environment of the global economic integration, each member in the medicine industry has recognized the importance for developing cooperative supply chain between members. They had started emphasizing mutually reliance and cooperation to realize the common object and face future more serious competition, especially in Chinese medicine market.

3.4 Human behaviour amplify the bullwhip effect

The role of human behavior played in the supply chain and the relationship with the bullwhip effect is another important reason. Nienhaus (Nienhaus, 2006) had described and discussed about this aspect in his paper. In his study, it was showed that if someone compared all human participants' performance with the computer-controlled participant, in the simulation of the beer distribution game. The decision made by the computer is the best solution, which policy is always holding the current inventory position. However, it is disappointed that the majority participants always, in the simulation, try to optimize operation by their solution, but the result would come to the contrary and even worse. Their average cost is far high about 2-3 times than the best solution, and the extreme worst condition is even more than 10 times. The reason that leads the personal performance far worse than the simple and best computer's strategy is the existence of two kinds the extreme behavior:

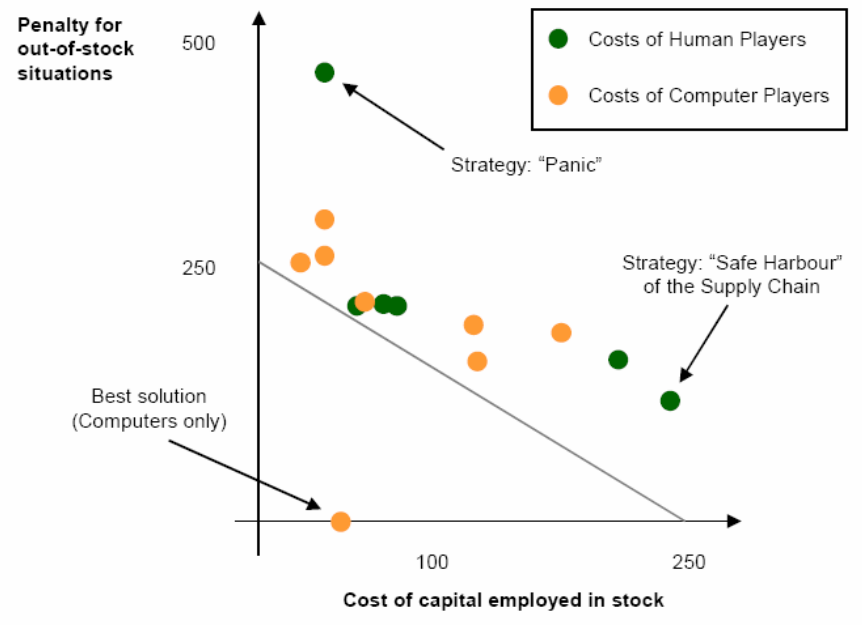


Figure 3.4 Performance of human co-makers vs. agent-based strategies

Source: Joerg Nienhaus, Arne Ziegenbein, Christoph Duijts (2006). How human behaviour amplifies the bullwhip effect – a study based on the beer distribution game online. Production Planning and Control, 17, 547-557

1. ***Safe harbor*** - Some bodies always try to assume excessive conservative decision-making in the supply chain. For instance, they send more order than the actual demand to raises safe stocks. Do like this, they not only lead their partner's inventory increased, but also force the suppliers to raise their order volume. Once, there is one participant adopt the safe harbor strategy, the whole supply chain would all be subjected to the negative impact.
2. ***Panic*** - Another drastic strategy is excessive panic, emptying the stocks before final client's demand increasing. The negative impact at first stage is limited. However, once the order from the final client starts persist growing up, the panic participant would have to follow the current situation to send more orders, which include the real demand increasing and his own safety stock, to next echelon. That would make all next echelon members amplify the demand forecast and increase their safety stock, the negative impact for the whole supply chain spread just like the safe harbor strategy.

The behavior of those participants is deviate from the best solution. Incline to any one of these two extreme behaviors regardless, will result in more cost. Moreover, other cooperated participants would under the impact of his behavior immediately.

The next harm impact of human behavior is the ***underestimate for the value of information***. There is a research (Nienhaus J. et. 2003) had further studied and analyzed about that. In the survey for about 1000 European corporations, the executive managers were asked how to evaluate the value of clients' information for arrangement their production plan and how often those client information would be gathered, the answer mostly is very important, and information that is more important would be transferred more in time.

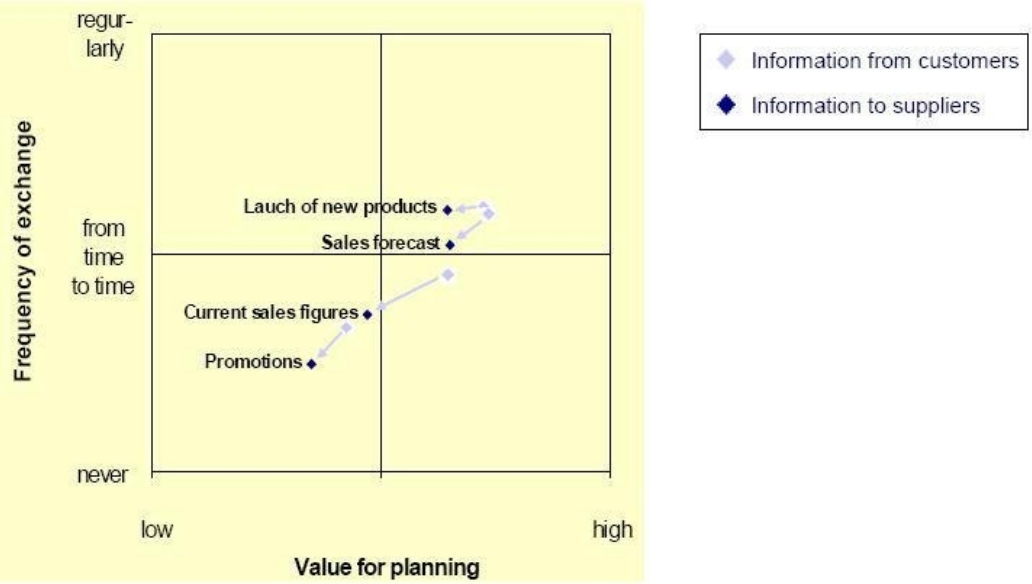


Figure 3.5 The value of information for co-makers is under-estimated
Source: Joerg Nienhaus, Arne Ziegenbein, Christoph Duijts (2006). How human behaviour amplifies the bullwhip effect – a study based on the beer distribution game online. Production Planning and Control, 17, 547-557

When the executive managers are questioned about how evaluating the value of the same information for the production plan arrangement for their upstream suppliers. The answers showed that they prevalent thought that information for their upper stream suppliers was not as important and direct as for themselves. According to this notion, they usually will deliver the information that they receive from the client

to their upper-stream partner with low frequency. Therefore, each participant becomes an obstacle in information flow, regardless is upwards or downwards transmission. As above said the transmission time of the information and materials is the main reason for the bullwhip effect's creation. Therefore, the underestimate for the value of information for their cooperators is similar effect for lengthening the transmission time of information. That would also amplify the bullwhip effect.

Chapter 4 Impact of the bullwhip effect

The analysis result in chapter 3 has proved that the bullwhip effect is caused by very different complicated reasons, and it would be more serious for the upper echelon than downstream member in the supply chain. Most time the manufacturers would subject to the most influence relatively. The impact of the bullwhip effect normally would exceed the prediction of common managers, which exists on both the cost and service level for suppliers. Therefore, in this chapter, I will discuss the impact of the bullwhip effect listed in Table 4.1, especially for the manufacturers in the medicine supply chain, in detail.

Table 4.1: The impact of the bullwhip effect in medicine supply chain

Impact on Cost	Impact on Service Level
■ Production Cost	■ Replenishment Period
■ Inventory Cost	■ Supply Level
■ Transportation Cost	■ Relationship between Members
■ Labor Cost	■ Social Stability
■ Lost Revenue Cost	

4.1 The impact on the cost

The most obvious impact of bullwhip effect is the impact on the cost in the daily operation in the supply chain.

4.1.1 Increasing production cost

The bullwhip effect will increase the production cost of the pharmaceutical manufacturers. Such as mentioned previously, in the process for the bullwhip effect delivering along the supply chain to the upstream, the biggest sufferer always is the

upper stream manufacturer. For better meeting the variance demand from the customer, the retailers and distributors always make a more fluctuated order to upstream. To cope with this kind of amplified fluctuation, the manufacturers only have two kinds of choices. The one is to allocate more production resources to promote productivity, which would enlarge the unit production cost. Moreover, especial in pharmaceutical manufacture industry, the capacity is strictly limited by the production facility, and the capital cost for purchasing additional facility for production is larger than other general industry.

4.1.2 Increasing inventory cost

To cope with the amplified demand variance, the manufacturers in addition to strengthening the capacity only could choose method is to keep holding higher-level safety stock, even when the demand is at low level. The increasing of the inventory not only enhance the holding cost for the productions, in the meantime, but also increase the cost for the essential warehouse space and related operation. In particular, some drugs' expired time is very shorter and need higher standard store condition in warehouse, which would make the increasing of the inventory cost become more serious.

4.1.3 Increasing transportation cost

The requirement for the transportation between the manufacturer and supplier is closely related to the order quantity. Because of the existence of the bullwhip effect, the transport demand will drastically fluctuate during the different time. Therefore, it is necessary to keep holding the rest transport capacity to meet the potential demand in high peak, which would also increase the total transportation cost.

4.1.4 Increasing the labor cost

The exporting or importing work force demand for the manufacturer and its supplier would also fluctuate follows the fluctuation of the order quantity. It is also the same for the work force demand for the distributor and retailer. To meet the labor

requirement in the different enterprise in the supply chain has different choice. Someone choose holding the surplus labour, someone choose changing the work force to other department, regardless to choose which one, it will increase the total labor cost.

4.1.5 Cost for lost revenues

Another kind of cost is the lost revenues, which due to the shortages in the variance caused by the bullwhip effect. Each member in the supply chain has the risk to take the influence of lost revenue in the shortage.

4.2 The impact on service level

Compared to the visible and countable capital cost for the operation, the falling service level is another kind of invisible and immesurable cost for the upstream supplier, which would decrease their competitive advantage and bring potential risk for loosing future business.

4.2.1 Prolonging the replenishment period of the supply chain

Because the bullwhip effect amplify the fluctuation of the demand, comparing with the usual demand, the production plan for the manufacturer and their material supplier in BWE become harder to arrange. Most time, it will appear the situation that the current capacity and inventory could not satisfy the order demand, which cause the prolonging of replenishment period for the manufacturer and downstream members in the supply chain.

4.2.2 Lower the supply level in the supply chain

The bullwhip effect cause more risk of shortage. The significant fluctuation of the order quantity make the manufacturer could not delivery goods to all distributors and the retailers in time, which would cause the increasing of frequency for the production shortage, happened in the retailer side.

4.2.3 Bring negative impact on relationship between the each node in the supply chain

The bullwhip effect brings negative influence for the operation of each member in the whole supply chain. That hurt the relationship between each member enterprise. Everyone in the supply chain thought that themselves is perfect, and put all responsibility to other member corporations. Hence, the bullwhip effect cause the distrust between different echelon corporations in supply chain, making the potential coordination work becomes more difficult.

4.2.4 The impact on social stability

The medicine is different from other common commodity, which is a very special kind of merchandise, because it is related to the healthy of the peoples. The impact of bullwhip effect would influence the social stability. For example, the bullwhip effect would cause the reduction of output which is caused by the previous small decreasing demand orders quantity. Once the epidemic or other natural disaster happened at that time, the shortage of inventory and reduction of output would cause the panic in society or even more serious social problem.

In conclusion, the bullwhip effect and the dissonance caused by it, brings many negative influences on the operation of supply chain. The bullwhip effect not only increases the capital cost, but also lowers the response ability and causes the declining of profit for the whole supply chain. Especially in medicine supply chain, the impact of BWE would concern the serious social stability instead of the simple economic problem that would make us pay more attention and keep awareness for it.

Chapter 5 The simulation model for the bullwhip effect

In the previous chapter, many theory analyses have been done to study the causes and impacts of bullwhip effect in the medicine supply chain. To look for a reasonable and practicable solution for alleviating and taming the BWE is the final object for all researchers. Simulation as one of most popular method used in BWE analysis has been more and more attended by researchers. Next the paper would through a simple spreadsheet based simulation program to study the parameters and conditions, which would influence the performance of supply chain. In addition, examine the relationship between the demand forecast techniques and the bullwhip effect. Try to illustrate a practicable method to study and analyze the bullwhip effect.

5.1 The classic Beer Distribution Game model

When we talk about the model for the bullwhip effect, the most famous and earliest one must be the Beer Distribution Game (Sterman, 1989). Sloon business school professor Mr. Sterman first designed it as a kind of class experimentation. Four-participators form a simulated supply chain, each one represent the beer retailer, wholesaler, distributor, and manufacturer. These four roles make the decision of procurement, inventory and replenishment independently, and which all base on the information from the related participant as only information resources. In that model, the most important reality is that there exists the delay for beer movement between each echelon. Therefore, each participator had to think about the factor of delay time and the related demand forecasting during the decision-making. The result of simulation shows that under the linear cost structure, the order quantity fluctuated and amplified through the supply chain from downstream retailer to upstream manufacturer. The beer distribution game proves the existence of bullwhip effect, and help people to get know and explore the mechanism of the BWE. The next simulation would also follow the standard setup of the Beer Distribution Game.

5.2 The assumption and notation for the simulation model

5.2.1 The hypothesis and suppositions for the simulation

1. The Two-stage supply chain model
   In the reality, the whole supply chain network always is very complex. In most time, it is too difficult to establish a theory model to study. Here, it will assume the supply chain network is a kind of one to one supply relation. One manufacturer and one retailer form a basic two echelons supply chain model.

2. In each period, for the manufacturer, there are three events:
   A. Receive the incoming shipments from the upstream supplier and placed into stock.
   B. Receive the incoming orders from the downstream retailer and be treated either filled (if inventory is available) or backlogged.
   C. Place and deliver the new order to the upstream according OUT replenishment policy.

3. At the end of each period, the retailer makes the next period demand forecast according the history sale volume and by certain forecast technique, which represented by X_t. Then compare the forecast result with the current inventory position, according the inventory policy calculate out the order quantity. Then send order to upstream manufacturer.

4. At the end of each period, the manufacturer base on the history order volume from retailer, forecast the future potential order quantity. Same to the retailer, compare the forecast result with the current inventory quantity, and according the inventory policy calculate out the order quantity for upstream raw material supplier or production department.

5. To simplify the analysis, here suppose the retailer control the market demand and the manufacturer do not know the market demand condition, and could only make use of forecasting tool to acquire an actual market demand.

6. Suppose the retailer or manufacturer could acquire all ordered cargo from upper-stream supplier, there is no out of stock condition.

7. Suppose the unit holding cost per period as h, the unit backlog cost per period as b, and the unit switching cost for changing the production level per period as sw.

5.2.2 The meanings of the notation in the model:

Average Demand	d	
Demand forecast at time t	X_t	
Inventory backlog cost	b	(unit per period)
Inventory holding cost	h	(unit per period)
Inventory on order (in pipeline)	WIP_t	$= WIP_{t-1} + O_{t-1} - O_{t-(Tp+1)}$
Inventory Position	I_t	$= NS_t + WIP_t$
Net Stock	NS_t	$= NS_{t-1} + O_{t-(Tp+1)} - D_t$
Net Stock Amplification	NSAmp	
Order-Up-To Level Stock	S_t	$= X_t + SS - (NS_{t-1} + WIP_{t-1})$
Replenishment Order	O_t	$= S_t - IP_t = S_t - (NS_t + WIP_t)$
Physical Lead Time	T_{PL}	
Real demand at time t	D_t	
Round Period	T_p	
Safety factor	sf	
Safety Stock	ss	
Switching cost	sw	(unit per period)
Total Lead Time (risk period)	L	$= T_P + T_{PL}$

5.3 The demand forecasting methods used in the simulation

The demand forecast process is one of causes for the bullwhip effect. In the Lee's (1997a, b) research, he recognized the forecast and forecast value handling these two processes together as "forecast process", and put it in further research. In this paper, it divides the demand forecast behavior to information forecast, information

processing and information delivering three different processes, and discusses the bullwhip effect in the different process respectively.

5.3.1 Four kind demand forecasting methods

Here, four kinds of popular demand forecasting methods are chose to be studied. They are mean demand forecast, moving average forecast, exponential smoothing forecast and minimum mean squared error forecast. The next section would mainly focus and evaluate the performance of these four forecast techniques. The Table 5.1 shows the main features and formulas for these four methods.

Table 5.1 Four main demand-forecasting techniques

	Name	Forecasted lead-time demand	Features
1	**Mean demand forecast (MD)**	$O_t = S_t - (S_{t-1} - X_t) = X_t$ $X_t^L = Ld$	1. The simplest forecast method 2. If the demand is IID, then the best forecast of all future demands is the long-term average demand.
2	**Moving average forecast (MA)**	$X_t = \frac{1}{p}\left(\sum_{i=1}^{p} D_{t-i}\right)$ $p = T_m+1$ $X_t^L = LD_t$.	Demand forecasts are continuously updated in face of new demand realizations.
3	**Exponential smoothing forecast (ES)**	$X_t = X_{t-1} + \alpha(D_t - X_{t-1})$	The one period-ahead demand forecast is adjusted with a fraction of the forecasting error.
4	**Minimum Mean Squared Error forecast (MMSE)**	$X_t^L = Ld + \frac{\rho - \rho^{L+1}}{1-\rho}(D_t - d)$	1. The forecast error is minimized 2. explicitly takes the correlative demand structure into account

5.3.2 The impact of the demand forecasting and processing

The demand forecast processing is one of major causes for the bullwhip effect. In this section, the bullwhip effect performance in different process for the demand forecasting, handling and delivering would be discussed respectively.

5.3.2.1 In the process of demand forecasting

Here only choose the moving average (MA) method and the exponential smoothing forecast (ES) method as sample to illustrate the impact of the demand forecasting

process on the BWE, because they are mostly popular in research and practice.

Here suppose the market demand process is AR(1) process , for simplified the deduction process. And this kind of market demand assumption also used in many supply chain and information sharing research literatures. Moreover, assume the lead-time is out of consideration to focus on the forecast process. So, it could get:

$$D_t = d + \rho D_{t-1} + \varepsilon_t \quad (1)$$

Here, D_t means the demand at time t; t=1, 2, 3$\cdots\infty$, refers the different order period; d is a constant figure bigger than zero; $-1<\rho<1$ is the autoregressive coefficient for two close period demand variable. ε_t indicates the fluctuation error of demand variable, mean value is zero, variance is σ^2 and according the IID random distribute. It assume the $\sigma<<d$, then $D_t>0$. Therefore, it could get:

$$E(D_t) = d/(1-\rho) \text{ and } Var(D_t) = Var(D_{t-1}) = \sigma^2/(1-\rho^2) \quad (2)\ (3)$$

A. For exponential smoothing forecast (ES)

$X_t = X_{t-1} + \alpha(D_t - X_{t-1}) = \alpha D_{t-1} + (1-\alpha)X_{t-1} \quad (0 \le \alpha \le 1)$

The D_{t-1} mean the real demand at time t-1, and X_{t-1} mean the forecast at time t-1, and α is smoothing factor.

$$Cov(X_t, D_t) = Cov\left(\sum_{k-1}^{\infty} \alpha(1-\alpha)^{k-1} D_{t-k}, D_t\right) = \frac{\sigma^2}{1-\rho^2}\frac{\alpha\rho}{1-\rho(1-\alpha)} \quad (4)$$

then: $Var(X_t) = Var[\alpha D_{t-1} + (1-\alpha)X_{t-1}]$ (5)

$$= \alpha^2 Var(D_{t-1}) + (1-\alpha)^2 Var(X_{t-1}) + 2\alpha(1-\alpha)Cov(D_{t-1,}X_{t-1})$$

$$= \frac{\sigma^2}{1-\rho^2}\frac{1+\rho(1-\alpha)}{1-\rho(1-\alpha)}\frac{\alpha}{2-\alpha}$$

Because, $-1<\rho<1$, $0<\alpha<1$ and $Var(D_t) = \sigma^2/(1-\rho^2)$,

So, $\frac{Var(X_t)}{Var(D_t)} = \frac{1+\rho(1-\alpha)}{1-\rho(1-\alpha)}\frac{\alpha}{2-\alpha} < 1$ (6)

The conclusion is that the fluctuation of the demand forecasted by the ES is

smaller than the fluctuation of the real market demand. Therefore, the ES forecast method would not cause the BWE during the forecast process.

B. For moving average forecast (MA)

$$X_t = \frac{1}{p}\left(\sum_{i=1}^{p} D_{t-i}\right)$$

$$\begin{aligned} Var(X_t) &= \frac{1}{p^2} Var\left(\sum_{i=1}^{p} D_{t-i}\right) \\ &= \frac{1}{p^2}\left[p + 2\left((p-1)\rho + (p-2)\rho^2 + \cdots + \rho^{p-1}\right)\right] Var(D_t) \\ &= \frac{2\rho^{p-1} + p - p\rho^2 - 2\rho}{p^2(\rho-1)^2} Var(D_t) \end{aligned} \qquad (7)\ (8)$$

Because: $p^2(\rho-1)^2 - \left[2\rho^{p-1} + p - p\rho^2 - 2\rho\right] > 0$

So, when $-1 < \rho < 1$, $p \geq 2$, $\frac{Var(X_t)}{Var(D_t)} < 1$

Similar to the former, the conclusion is that the fluctuation of the demand forecasted by the MA is smaller than the fluctuation of the real market demand. Therefore, the MA forecast method would not cause the BWE, during the forecast process.

It could get the similar result for mean demand forecast or minimum mean squared error forecast, too. Therefore, here, we could get the conclusion that the demand forecast technique itself is not the reason to cause the BWE, in the process of demand forecast.

5.3.2.2 In the demand information processing

When in the demand information processing, assume that:

$$Q_t = S_t - (S_{t-1} - D_t) = D_t + (S_t - S_{t-1}) \qquad (9)$$

Here, Q_t means the quantity of order from retailer, assume $Q_t > 0$, S_t means the highest quantity of inventory.

So, $Q_t = D_t + \frac{\rho(1-\rho^{L+1})}{1-\rho}(D_t - D_{t-1})$ (10)

When the lead time L=0, $Q_t = (1+\rho)D_t + \rho D_{t-1})$ (11)

$$Var(Q_t) = (1+\rho)^2 VarD_t - 2(1+\rho)\rho Cov(D_t, D_{t-1}) + \rho^2 VarD_{t-1} = [1+2\rho(1-\rho)]VarD_t$$

$$\frac{Var(Q_t)}{Var(D_t)} = 1+2\rho(1-\rho) > 1$$

(12) (13)

Here, it could found that during the demand information processing, when choose the standard OUT replenish policy, even when the lead-time is out of the consideration, the BWE is always existent.

5.3.2.3 In the whole process for the demand information delivering

From above discussion, it have proved that in the process of information forecast, the fluctuation of the demand information is smaller than that of the real market, and in the process of information processing, the fluctuation of the demand is amplified. Therefore, the next it would analyze the bullwhip effect in the whole process for the information processing. For easy to the compare the conclusion, here, it is supposed that retailer and manufacturer make use of same forecasting technique and the replenishment policy.

1> For the retailer

It is using the ES method to make forecasting as example. The inventory position is S_t, $S_t = X_t + z\delta$, z refers the safety factor of retailer, the $z\delta$ means the safety inventory position of retailer. The standard deviation for retailer in the demand forecasting is $\delta_t = \sqrt{[Var(X_t - D_{t-1})]}$, which could be achieved by the history data. The retailer would use the OUT replenishment policy to handle the information. Then,

$$Q_t = S_t - (S_{t-1} - D_{t-1}) = X_t - X_{t-1} + D_{t-1} + z(\delta_t - \delta_{t-1})$$ (14)

(Here, it is supposed that if the last inventory position is bigger than the current OUT inventory position, the exceeded inventory cargo could be returned to

manufacturer without any cost)

$$Var(Q_t) = Var\left[(1+\alpha)D_{t-1} - \alpha X_{t-1}\right]$$
$$= (1+\alpha)^2 Var(D_{t-1}) + \alpha^2 Var(X_{t-1}) - 2\alpha(1+\alpha)Cov(D_{t-1}, X_{t-1})$$

$\because\ Var(D_t) = Var(D_{t-1}) = \sigma^2/(1-\rho^2)$,

So, $Cov(X_{t-1}, D_{t-1}) = Cov(X_t, D_t) = \frac{\sigma^2}{1-\rho^2}\frac{\alpha\rho}{1-\rho(1-\alpha)}$

And $Var(X_t) = Var(X_{t-1}) = \frac{\sigma^2}{1-\rho^2}\frac{1+\rho(1-\alpha)}{1-\rho(1-\alpha)}\frac{\alpha}{2-\alpha}$

So could get : $\frac{Var(Q_t)}{Var(D_t)} = 1 + \frac{(1-\rho)4\alpha}{\left[1-\rho(1-\alpha)\right](2-\alpha)} \geq 1$

(15) (16) (17)

2> For the manufacturer

When manufacturer also use the ES method to forecast the ordering quantity (O_t) of retailer.

$$O_t = \beta Q_{t-1} + (1-\beta)O_{t-1} = \sum_{k=1}^{\infty} \beta(1-\beta)^{k-1} Q_{t-k} \qquad (18)$$

β (0≤β≤1) is the smoothing factor for the manufacturer, implies the weight for the real data, determined by the experience. When I let the Q_{t-1} refer the real demand at time t-1 for retailer, and M_{t-1} represent the forecast value at time t-1 for the retailer. Then:

$$M_{t-1} = \sum_{k=1}^{\infty}\left[\frac{-\alpha^3}{\beta-\alpha}(1-\alpha)^{k-1} + \left(\frac{\alpha\beta^2}{\beta-\alpha} + \beta\right)(1-\beta)^{k-1}\right] D_{t-k-1} \qquad (19)$$

$\because Var(M_t - Q_t) = Var(M_t) + Var(Q_t) - 2Cov(M_t, Q_t)$

$Cov(M_t, Q_t) = \frac{1}{2}\left[Var(M_t) + Var(Q_t) - Var(M_t, Q_t)\right]$

So, we have: $Var(M_t) = \beta^2 Var(Q_{t-1}) + (1-\beta)^2 Var(M_{t-1}) + 2\beta(1-\beta)Cov(Q_{t-1}, M_{t-1})$

Then : $Var(M_t) - Var(Q_t) = -(1-\beta)Var(M_t - Q_t) \leq 0$

(20) (21) (22) (23)

And, according the OUT level calculate the next period's inventory position for manufacturer $S_{m,t}$, get $S_{m,t} = M_t + z_m\delta_{m,t}$. Here, $z_m\delta_{m,t}$ implies the safety stock for manufacturer. When I assume the order quantity from manufacturer to the

supplier is Q', then, at time t:

$$Q_t^{'} = S_{m,t} - (S_{m,t-1} - Q_{t-1}) = (1+\beta)Q_{t-1} - \beta M_{t-1}$$

$$= (1+\alpha)(1+\beta)D_{t-2} + \sum_{k=1}^{\infty}\left[\left(\frac{\alpha^3\beta}{\beta-\alpha} - \alpha^2\right)(1-\alpha)^{k-1} - \left(\frac{\alpha\beta^3}{\beta-\alpha} + \beta^2\right)(1-\beta)^{k-1}\right]D_{t-k-2}$$

Then have:

$$Var(Q_t^{'}) = Var(D_t)\times(-4\alpha - 6\alpha^2 - 4\beta - 8\alpha\beta - 3\alpha^2\beta - 6\beta^2 - 3\alpha\beta^2 + \alpha^2\beta^2 + 8\alpha\rho + 8\alpha^2\rho + 2\alpha^3\rho^2$$
$$+ 8\beta\rho + 8\alpha\beta\rho + \alpha^3\beta\rho + 8\beta^2\rho - 3\alpha^3\beta^2\rho + 2\beta^3\rho + \alpha\beta^3\rho - 3\alpha^2\beta^3\rho - 4\alpha\rho^2 - 2\alpha^2\rho^2 - 2\alpha^3\rho^2$$
$$- 4\beta\rho^2 - \alpha^2\beta\rho^2 + \alpha^3\beta\rho^2 - 2\beta^2\rho^2 - \alpha\beta^2\rho^2 + 7\alpha^2\beta^2\rho^2 - 2\beta^3\rho^2 + \alpha\beta^3\rho^2 + \alpha^3\beta^3\rho^2)/$$
$$[(2-\alpha)(2-\beta)(\alpha\beta-\alpha-\beta)(1-\rho+\alpha\rho)(1-\rho+\beta\rho)]$$

$$\because\ Var(Q_t) = Var(D_t)\left(1 + \frac{(1-\rho)4\alpha}{[1-\rho(1-\alpha)](2-\alpha)}\right), \text{and} 0 \le \alpha \le 1, 0 \le \beta \le 1, -1 \le \rho \le 1$$

So, $Var(Q_t^{'}) - Var(Q_t)$

$$= \frac{\left[4\beta(1-\rho)\left(2\alpha + 3\alpha^3 + 2\beta + \alpha\beta - \alpha^2\beta - 2\alpha\rho - \alpha^2\rho - \alpha^3\rho - 2\beta\rho + \alpha\beta\rho + 2\alpha^2\beta\rho + \alpha^3\beta\rho\right)\right]}{[(2-\alpha)(2-\beta)(\alpha+\beta-\alpha\beta)(1-\rho+\alpha\rho)(1-\rho+\beta\rho]} > 0$$

(24) (25) (26) (27)

From the deduction above, it could get the conclusion that when the retailer and the manufacturer both use the ES method to forecast the market demand and the downstream requirement, and adopt the fixed interval time OUT level as replenishment policy without any information sharing, the fluctuation of the order quantity for the upstream supplier from manufacturer would be further amplified.

5.3.3 Insights

Through the above deduction, I could get the following conclusions:

1. In the information forecasting process, the fluctuation of the forecast demand from the forecast method is smaller than the real demand of the market. In another word, the demand forecasting technique is not the reason to cause the BWE.

2. In the information processing process, the amplifying effect is mainly caused by the replenishment policy. Nevertheless, the accuracy of each forecast method is

different. Therefore, we get the conclusion that the information processing process is one of the step would cause the BWE and choosing a better forecasting method is necessary for avoid serious deviation.

3. In the information transferring process, the multi-forecasting is one of the major reasons for the bullwhip effect. Because of the source of information is different, the decision-maker more far away from the final market, the fluctuation and amplification for the information they achieved would be more serious.

5.4 The inventory replenishment rules

The inventory replenishment rules could be divided into two types, they are:

a) Fixed order quantity system, means the ordering is in the same quantity and at varying time intervals.

b) Periodic review system means the ordering is at a regular and repeating intervals but the quantity is variable.

In the common practice for medicine retailer, the replenishment is very frequent and the manufacturers tend to produce medicine at a regular interval, so the periodic review system is more popular. Thereupon, it will just study the review system replenishment rule, in this paper.

5.4.1 Standard order-up-to policy on the bullwhip effect

The standard order-up-to (OUT) policy is one of simple and popular replenishment policy used in reality. That is making an order equal to the deficit between the OUT level and the inventory position. The OUT level Stock at time t covers the forecasted average lead-time demand and a safety stock:

$$S_t = X_t^L + ss \tag{28}$$

Here, X_t^L represent the forecasted demand over L periods and SS refer the safety stock (SS= zσL). There are two methods to calculate the forecasted demand over

the lead-time L, X_t^L.

a) *One-period ahead forecasting*, the demand forecast for one period ahead and multiplying it by the lead time, i.e., $X_t^L = L \times X_t$, where X_t represents the forecast of demand in period t.

b) *Lead time demand forecasting*, the forecasting demand equal to the sum of the demands over the lead time, the formula is $X_t^L = \sum_{i=1}^{L} X_{t+i}$, where X_t also refer the forecast in period t.

In the first method, the lead-time L is explicitly appeared in the function. Whereas in the second one, the lead-time is implicitly hide in the function (Kim et al. 2006). In this paper it would use the one period ahead forecasting method to calculate the inventory position.

5.4.2 The generalized order-up-to policy

It is illustrated in previous section, when using the standard OUT replenishment policy, the bullwhip effect may always exist. It is rational to find a smoothing replenishment policy to replace it. Here introduce the generalized order-up-to policy, which intends to dampen the order variance and smooth the order pattern. Here:

$$O_t = X_t^L + ss - I_t = LX_t + ss - I_t = (T_p + 1)X_t + ss - I_t = X_t + (T_p X_t + ss - I_t) \quad (29)$$

Where $(T_p X_t + ss - I_t)$ is the inventory deficit between the desired and actual inventory.

When introduce a proportional controller β for the inventory deficit, so the formula changed to

$$O_t = X_t + \beta \times (T_p X_t + ss - I_t),\ (0 < \beta < 2) \quad (30)$$

Above is the formula of generalized order-up-to policy. Forrester (1961) had referred the 1/β as the "adjustment time".

- When β > 1, implies overreaction to the inventory deficit.

- When $\beta < 1$, refers partially recovery for inventory deficit.

This fractional adjustment may generate a "smooth" ordering pattern and finally alleviate the bullwhip in the process of information processing.

5. 5 Exploring the bullwhip effect by means of spreadsheet simulation

There are many different software could be used in the stimulation and statistical analysis, but the Microsoft Excel is one of most popular and relative easy to be achieved than others. Therefore, here choose a spreadsheet based bullwhip effect exploring program[3]which developed by Robert and Marc (Robert et al 2007) to do the analysis and simulation for the BWE in this paper.

5.5.1 Spreadsheet simulation

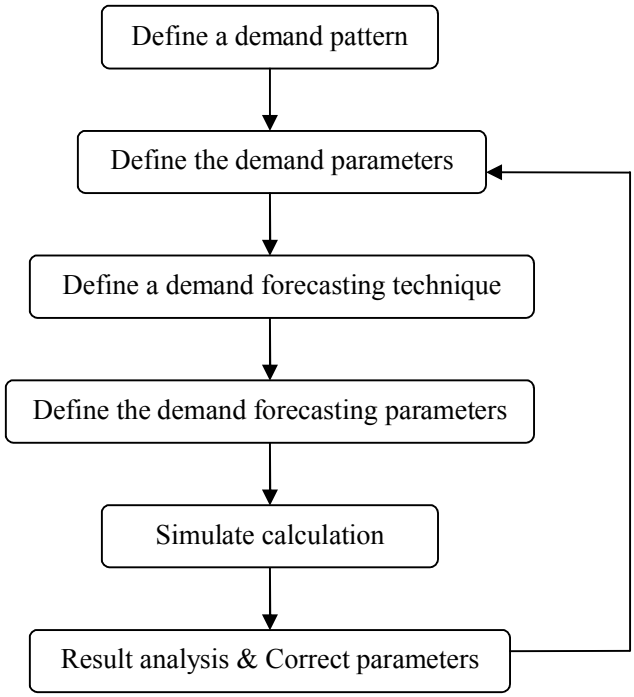


Figure 5.1 The flow of simulation

(1) Parameters input

[3] Robert N. Boute and Marc R. Lambrecht 2007 could be download from: http://www.econ.kuleuven.be/public/NDBAA78/BullwhipExplorer.xls

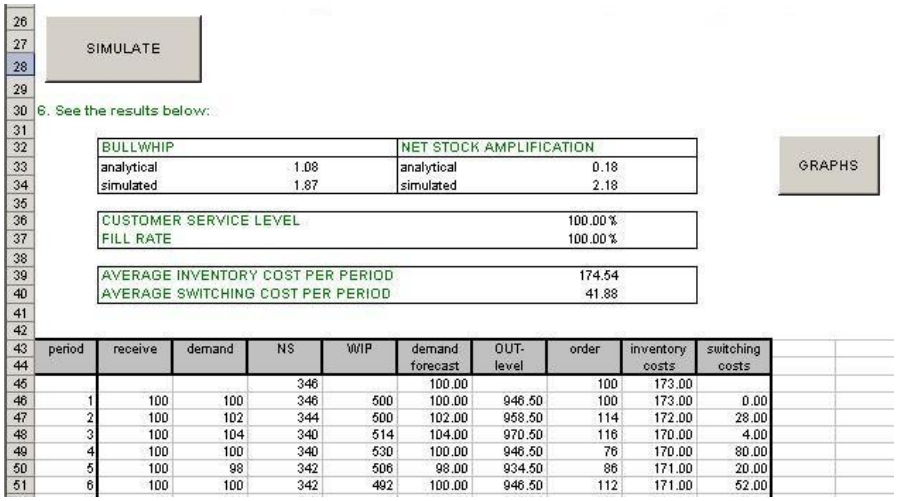
Firstly, user select the demand pattern (IID or AR) and demand forecast method, then, according their requirements choose and define the parameters (see table 5.2) for demand forecasting.

Table 5.2 the parameters could be set in the spreadsheet simulation model

Mean Demand	d
Autoregressive Coefficient	ρ
Variance of error term	σ^2_ε
Physical Lead Time	T_{PL}
Review period	R_p
Stddev Lead Time Demand	σ_L
Safety Factor	z
Number of Periods	T_m
Smoothing Parameter	α
Signaling Factor	χ
Unit holding cost per period	C_h
Unit backlog cost per period	C_s
Unit switching cost per period	C_{sw}

(2) Simulation

To run the program by click the button *simulation*, a 500 period simulation will be automatically generated.



period	receive	demand	NS	WIP	demand forecast	OUT-level	order	inventory costs	switching costs
			346		100.00		100	173.00	
1	100	100	346	500	100.00	946.50	100	173.00	0.00
2	100	102	344	500	102.00	958.50	114	172.00	28.00
3	100	104	340	514	104.00	970.50	116	170.00	4.00
4	100	100	340	530	100.00	946.50	76	170.00	80.00
5	100	98	342	506	98.00	934.50	86	171.00	20.00
6	100	100	342	492	100.00	946.50	112	171.00	52.00

Figure 5.2 The simulation for bullwhip effect

(3) Result output

1. The variance amplification ratios

$$\text{BWE} = \frac{\text{Variance of orders}}{\text{Variance of demand}}$$

a. When the BWE equal to one implies that the order variance is equal to the demand variance, the same words, there is no BWE or variance amplification.

b. When the BWE larger than one means the amplification and BWE exist.

c. When the BWE smaller than one indicates the orders are smoothed and not variable as the variance of demand.

2. The customer service level

The program gives the amplification of net stock to determine the service level, which could reflect the respond speed for customer's demand variance.

$$\text{NSAmp} = \frac{\text{Variance of net stock}}{\text{Variance of demand}}$$

3. The average inventory and switching cost per period

$$C_t^{INV} = \begin{cases} C_h * NS_t \text{ if } \text{NS}_t \geq 0 \\ C_s \times (-NS_t) \text{ if } \text{NS}_t < 0 \end{cases}$$

$$C_t^{INV} = C_{SW} \times \left| \text{O}_\text{t} - \text{O}_\text{t-1} \right|$$

The high BWE measure refers a widely fluctuating order pattern, indicates that the production level has to change frequently, resulting in a higher average production switching cost per period. An increasing inventory variance results in higher holding and backlog costs.

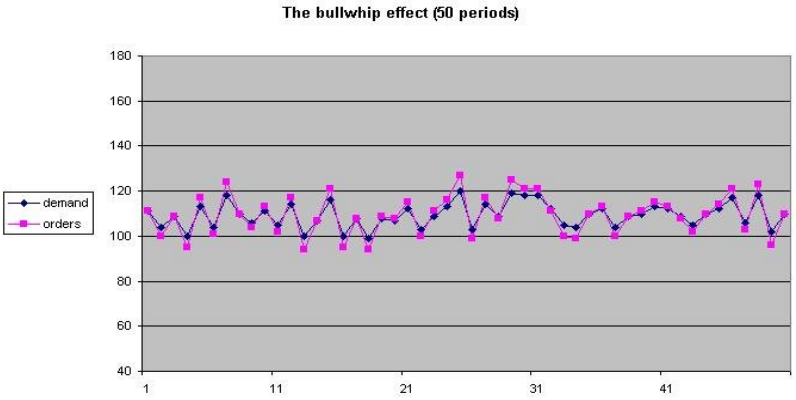


Figure 5.3 Bullwhip effect (50 periods)

Finally, the program provides the customer service level and fill rate result from the simulation analysis, and gives the bullwhip effect graph as figure 5.3 showed. The customer service level represents the probability that customer demand is met from stock. The fill rate is measured by the proportion of demand been immediately fulfilled from the inventory.

5.5.2 Data analysis

Compared these four demand forecast methods in simulation, it could get the following result in table 5.3 and table 5.4.

Table 5.3 The bullwhip effect and Netstock amplification for four different forecast methods according different lead time.

	Lead Time	L=0		L=1		L=2		L=3		L=4	
Demand Pattern	Forecast Method	BWE	NS Amp	BWE	NS Amp	BWE	NS Amp	BWE	NS Amp	BWE	NS Amp
IID	MD	1.00	0.00	1.00	1.00	1.00	2.00	1.00	3.00	1.00	4.00
	MA	1.00	0.00	1.48	1.20	2.12	2.80	2.92	4.80	3.88	7.20
	ES	1.00	0.00	1.44	1.11	1.98	2.44	2.60	4.00	3.31	5.78
	MMS	1.00	0.00	1.00	1.00	1.00	2.00	1.00	3.00	1.00	4.00
AR(1)	MD	1.00	0.00	1.00	1.00	1.00	3.00	1.00	5.50	1.00	8.25
	MA	1.00	0.00	1.47	1.06	2.09	3.62	2.86	7.47	3.79	12.46
	ES	1.00	0.00	1.37	0.93	1.81	3.04	2.33	6.08	2.93	9.90
	MMS	1.00	0.00	1.75	0.75	2.31	2.44	2.88	4.65	2.82	7.37

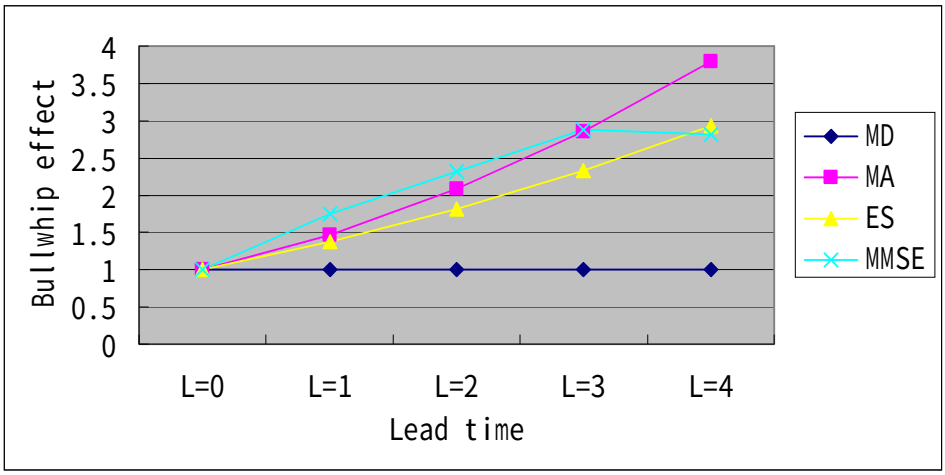


Figure 5.4 The bullwhip effect for four different forecast methods according different lead time.

Table 5.4 The bullwhip effect and Netstock amplification for four different forecast method according different autoregressive coefficient ρ value

	ρ	0.1		0.3		0.5		0.7		0.9	
Demand Pattern	Forecast Method	BWE	NS Amp	BWE	NS Amp	BWE	NS Amp	BWE	NS Amp	BWE	NS Amp
AR(1)	MD	1.00	2.20	1.00	2.60	1.00	3.00	1.00	3.40	1.00	3.80
	MA	2.12	3.03	2.12	3.45	2.09	3.62	1.93	3.22	1.46	1.60
	ES	1.96	2.63	1.90	2.91	1.81	3.04	1.67	2.81	1.35	1.64
	MMS	1.22	2.19	1.76	2.45	2.31	2.44	2.56	1.98	1.93	0.88

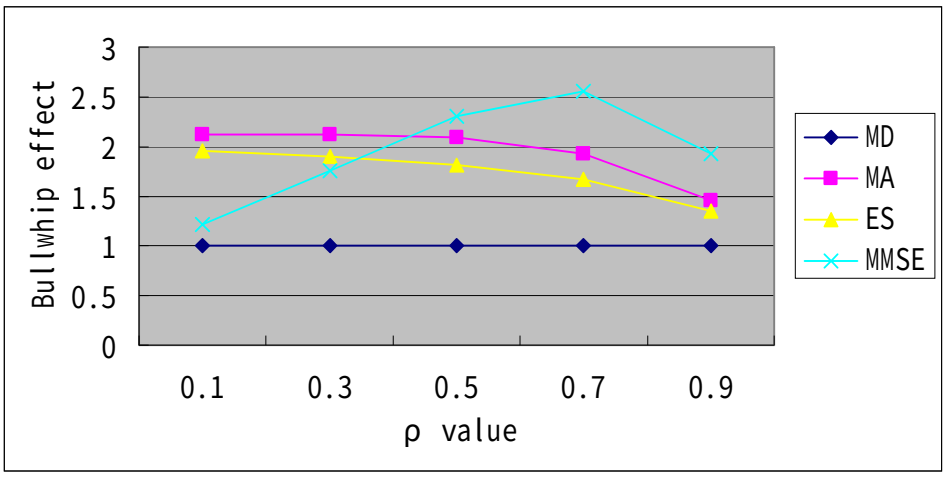


Figure 5.5 The bullwhip effect for four different forecast method according different

autoregressive coefficient ρ value in AR(1)

Through the simulation test above, when other related condition is fixed, and just change the value of the ρ and L separately, we observed the different impact of four kinds of different forecast methods on bullwhip. Could get the conclusion as below:

1. When ignore the information handling process, when Lead-time is zero, just as the result of formula deduction in previous section, whatever for IID or AR(1) demand, there is no bullwhip effect and netstock amplification caused by any kind of demand forecast method. The simulation results confirm the conclusion that the forecast method is not the reason for the bullwhip effect.

2. When the Lead-time is not zero and other condition is not changed, for four kind of forecast methods, except the MD forecast, the bullwhip effect and netstock amplification effect would all be amplified.

3. For the MMSE, for the IID demand, the result of MMSE forecast and MD forecast is completely same. But for the AR (1) demand, for MMSE forecast method, although the bullwhip effect is not least, but the netstock amplification effect is lowest, which could effectively reduce the inventory cost.

4. For MA method, when $Tm=\infty$, and $\rho=0$, it is same to MD method, having no BWE.

5. For ES method, when $\alpha=0$, it is same to MD, having no BWE

6. When other condition keep constant, making ρ gradually increased from 0 to 1, the bullwhip effect of the MA and ES gradually reduced, but the MMSE then have a heat up at first then lower of process, its inventory amplification effect always less than the other two kinds of forecast method.

Through the simulation analysis, it is proved again that as long as the OUT inventory position keep constant, regardless what kind of forecast method to be used, there is always no bullwhip effect. If adopt the standard OUT replenish policy, the

bullwhip effect would certainly exist. Moreover, adopting different forecast method in the supply chain, the result of bullwhip effect is also different. Therefore, to select a proper and precise forecast method is one of most important step to alleviate the bullwhip effect. Among these four kind forecast method, the MMSE forecast method is the best choice in general consideration, for the IID demand it equal the result of chase sale policy, for the AR(1) demand, it could provide the lowest inventory cost.

Because of the characteristic of information processing with the standard OUT policy, which would always cause the bullwhip effect, the simulation spreadsheet offered another optimized solution as generalized OUT replenishment policy. Through setting the value of parameter β, could adjust the impact of the bullwhip effect. For example, if choose β=0.5, for IID demand and using MD forecast method, the BWE could be reduced to 0.33, compared to the BWE=1 in standard OUT policy. That is a better choice for supply chain manager to consider alleviating bullwhip effect.

5.6 Impact of bullwhip effect reduction on customer service

The original meaning of wiping-out or alleviating the bullwhip effect is not only for the bullwhip effect itself. Its final object is through reducing the extra or additional cost or influence caused by the BWE, to achieve higher effective and efficient supply chain management performance. And all these are based on meeting the requirement for operation and satisfying the needs from final customer by high quality of product or service.

The thing always has its two sides. When we focus on the taming or alleviating the BWE, we also have to consider the subject of customer's satisfied level, in the meantime. While we pay more attention on the inventory cost, also have to take consideration on the customer service level, and these two aspects always are conflict. Therefore, in the simulation, the program not only gives the value of BWE, but also gives the value of net stock amplification. That value is a ratio of the inventory variance over the demand variance, and the net stock could be used to calculate the

fill rate (when the net stock value is negative, means the customer's requirement could not be satisfied). In the simulation, suppose for IID demand and use mean demand forecast, when set Tp=2 and β=1, could get the result of BWE=1 and NS AMP=3; but when change the β to β=0.5 and other condition is constant, then could get the result of BWE = 0.33 and NSAMP=3.3. Just as Robert (Robert and Marc 2007) states that : "*we are able to smooth the order pattern, but pay the price of higher inventory fluctuations and more inventory costs."* We could not satisfy the both side at same time, and have to face the trade off between the bullwhip effect and the customer satisfaction rate. Disney (Disney and Towill 2003) thought that the question is how to alleviate the additional cost for the extent production and at the meantime avoid increasing inventory cost too much. The traditional and classic golden ratio theory seems to one of the best solutions for that. (Robert et al 2007) For IID demand, adopt mean demand forecast method, if let the β = 0.618, the value of the BWE and NSAMP all can be minimized. Certainly, in more sophisticated situation, we would need more complex method to reach the solution, in this paper, it would not do further study on it.

It has to be remembered that all of above simulation and analysis is based on the two-echelon supply chain model assumption. The result summarized above is important and suggestive, but in multi-layer supply chain model or more complex real situation, these suggestions and experience need further validation and discussion.

Chapter 6 Countermeasures for the bullwhip effect in Chinese medicine supply chain

The existence of bullwhip effect is caused by structure of supply chain, the decision-making mechanism and human behaviour, which discussed in chapter 4. Therefore, to dampen and alleviate the bullwhip effect, we have to take into study the causes exist in these three aspects, in the same time. Next, it will discuss the countermeasures against the bullwhip effect from two layers, from strategic and tactical layer.

6.1 Strategic layer

Similar to other industry, the corporations in the medicine supply chain are always under the situation of that both benefit and conflict coexist in same time. Because of the incoordination on basic object, the scarcities of available motivate and supervise mechanism make the information sharing and decision-making simplification are not realistic under the conventional supply chain structure. Therefore, a strategy could ensure all internal members in the supply chain keep the coordinated benefit object is the key point and the foundation for a perfect supply chain.

6.1.1 Coordinating the benefit object for corporation

From the view of the coordinating company's benefit object, one of the simplest ways is to through the finance management to achieve the supply chain internal completed integration. Its essential is to turn the agent relation into inner relation within the corporation. Then this is the vertical integration for the supply chain. In China, the Sanjiu Pharmaceutical Co. is a typical vertical integration enterprise in medicine industry. They now have owned sub company concern the distribution, raw material supplier, pharmaceutical manufacturer, and even chain drug stores. However, most time, because of the internal resource restriction and dissimilarity in the main core competencies, complete supply chain internal integration, in a short

time, is not easy to carry out for most companies.

Another available way is the cooperation between member companies. To setup a somewhat similar to the alliance partner relationship, as well is an effective approach to perfect the information and decision-making structure within the supply chain. This kind of cooperation is setup at the foundation of the mutual trust. The trust is based on the long-term cooperation and game, normally it is very difficult to be acquired. In addition, the tradition competition theory makes the firms used to regard the other members in the same supply chain as their rivals. As a result the cooperation in conventional supply chain is hard to hold. This is because their contractual relation is lax, and is hard to establish available cooperation supervision mechanism.

For coordinating the benefit object of the supply chain member has a third kind of approach, that is the part of stock equities exchanging. The beneficial result of stock equity exchanging is that could quickly achieve the coordination on the benefit object for members. That does not need via long-term cooperation and gaming to get the common object. On the one hand, the specialization of the assets and flow process would stimulate the interest of stock equity exchanging, but the differentiation of the scale and authority of the firm would make the effectiveness of stock equity exchanging become complicated. On the other hand, the effective cooperation could not be achieved only by simple stock equity relation, but rely on the cooperative object, the ability of reciprocity and the same expectation for the ability of the cooperation. The best sample is that Shanghai Pharmaceutical Co., and China Nation Pharmaceutical Group Corporation as two biggest medicine groups in China, is not only playing the role of state owned medicine distributor, but also have put a lot of investment in local pharmaceutical manufacture and Research & Development project. Now, they are both become biggest integrated pharmaceutical group in China.

6.1.2 Optimizing contract

In some sense, the benefit within the same benefit group is also self-contradictory sometime. While there is no outside incentive term, no participants will open their own information first. For reducing the impact of the bullwhip effect, it is necessary to find an effective way to manage and control the linkage between members. Therefore, to build up a perfect contractual system is one of the premises for the stable cooperation. And it is especially important for the partial cooperation and the independent decision-making relationship. The optimized contract as lawful agreement is a kind of valid tool.

6.2 The tactics layer: from the viewpoint of the decision management

6.2.1 Optimizing supply chain structure

Since improper supply chain structure will make the supply chain inefficiency, to alleviate the bullwhip effect should start from the optimization for the supply chain structure firstly. More participants involved in the horizontal and vertical level in the supply chain, more frequency of information processing and information distortion will exist. Therefore, to limit the number of participator in both horizontal and vertical is important and necessary. For example, pharmaceutical manufacturer could choose to cooperate with only one but having perfect distribution network distributors as unique agents in a certain region. Then, the participators can cut in both horizontal scale and vertical layer in downstream, which could reduce the information processing and probability of distortion and let manufacturer could achieve the market demand more quickly and easily.

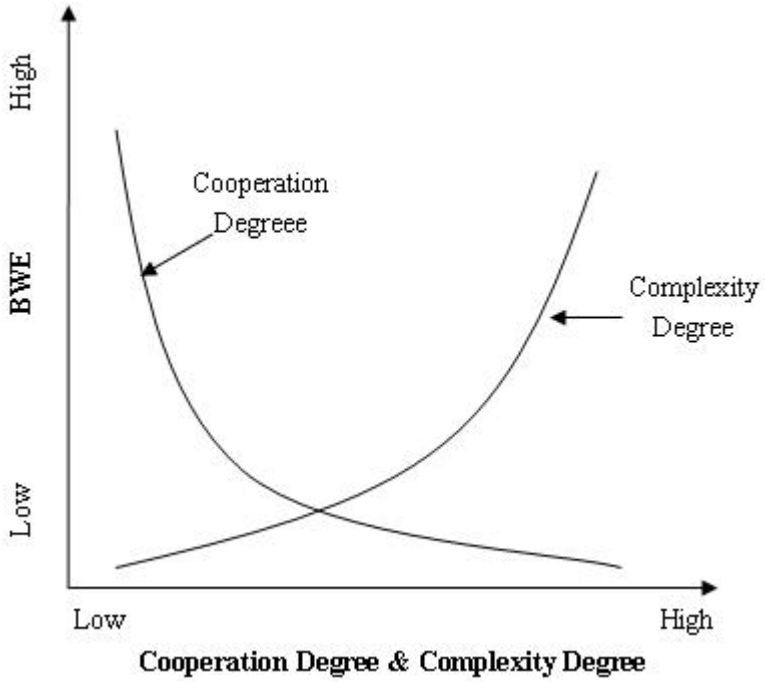


Figure 6.1 The relationship of cooperation & complexity Degree vs. BWE

The simple supply chain structure can also make the linkage between the supply chain members become closer, strengthen the trust between participators, and improve the efficiency at same time. It also could make information sharing become more open-heart and high efficient, and indeed realize the value and advantage of supply chain management. The relationship between the BWE with cooperation degree and structure complexity degree is showed in figure 6.1.

6.2.2 Avoiding the amplification of demand

For a company, to make an accurate demand forecasting is one of most important thing. Because that is the foundation to make the decision for the procurement and production be more close to the real market demand. Under normal condition, the demand forecasting information is transferred between the members of supply chain according a certain rules. Most time, the demand forecasting for the upstream member is based on his downstream member's demand forecasting. For preventing the distortion of consumption figure transferred along the supply chain, the key point is to keep the demand parameter in united, when delivered from the downstream to

the upper stream. One kind of effective method is to gather the customer demand information directly from end retailers, and opening those completed first hand demand information to each echelon in the supply chain. That would depend on the new communication technology, such as the internet or electronic data interchange (EDI). It is possible for everyone in the supply chain, could update its own forecasting according to the same raw data. The reinforcement for raw information delivery could avoid multiple demand forecast, and notable dampen the bullwhip effect, although it could not wipeout the bullwhip effect completely. For example, now some medicine manufacturers have realize achieving and making the demand forecast base on the real-time sales figure from the distribution center of the distributors, some one even try to get sale figure from POS (the point of sale) directly, that make the time of information processing is greatly reduced. This kind of measure can effectively contract the difference in demand forecast between upstream and downstream member.

Another avoid multiple forecast method is direct to cooperation with final retailer via the vendor management inventory (VMI) to cut medium linkage, and to acquire straight and first hand customer demand information. For example, the pharmaceutical manufacturers could evade the traditional distribution network and face to the final chain drug store or hospital drug store directly. However, this strategy is only suit for those bigger medicine suppliers. For small suppliers, whose supply quantity or the production line is limited, this method will raise their replenishment and logistics cost. Another limitation for this method is that there still have some rules and regulation problem for implementing.

6.2.3 Breakdown the batch order

The big batch order will prolong the demand forecasting time and lead the bullwhip effect, so the supply chain member should try to adjust their order strategy to implement smaller quantity and more batches supply policy. The firm could adopt the real time inventory replenishment mode, which could avoid not only the

fluctuation of demand but also high safety stock cost, in the meantime.

The obstacle to realize this strategy firstly is the increasing of the order cost. To solve this problem, company could depend on new information communicating and processing technology. For example, the Electronic Data Interchange (EDI) or internet website technology could not only help the order deliver and accept become more efficient, but also, such as CAO (Computer Assistant Order), could make the cost for labor greatly cut down. In addition, the easy operation for order making would also encourage the downstream customer to order various kinds of products same time, which make the vehicle could load enough cargoes under most economic volume. The result is that for each kind of product, although the order frequency is increased, but the economy for each batch transport is still under a reasonable level. For example, in other industry, the P&G Company would give certain rate rebate to the customer who could accept hybrid order. Moreover, the British distributor Tesco uses the freight car with different temperature boxes to deliver the fresh and frozen food in the meantime.

Another problem for breakdown the batch order is the increasing transport cost, one of the solution is mix transportation mentioned above. The other way to alleviate the transportation cost is outsourcing the physical distribution business to professional third party logistics provider (3PL). The 3PL company could offer better logistics service and scientifically arrange the product transportation with lower cost than enterprise could. However current, in China mainland, the qualified and professional 3PL company for medical logistics is still little and the market needs further development and cultivation.

6.2.4 Stabilize price

The temporary promotion or simply according the sales volume to evaluate the sales achievement marketing solution would make the price fluctuated in final market and then lead the purchase in advance. The result is that the purchasing quantity would slump in the future, or because of a great deal of order cancellation, bring the

fluctuation and disorder into production and procurement plan. The best solution to control the BWE caused by purchasing in advance is avoiding the sudden or temporary promote strategy and replacing it by a long-term and continuous rebate or promotion policy for distributors. The manufacturers should through stable prices strategy to minimize the motivation for purchase in advance behavior. For example, the medicine supplier only gives discount to the retailer, who could fix their 80% of ordering quantity in advance. Currently, some medicine supermarkets implement the "every day fair price" strategy, which effectively alleviate the hoarding phenomenon for consumer and stabilize the total sales volume. That is also important and helpful for the accurate demand forecasting and correct decision-making.

6.2.5 Avoiding shortage game behaviour

When the production capacity is strain in the supply chain, the manufacturer need choose a certain repartition mechanism to allocate the limited products. For alleviate the bullwhip effect, on one hand, the manufacturer should choose the direct distribution method named "encourage-respond", which could maximize the profit for whole supply chain, and not choose the "motivate- expand" mechanism which would cause the bullwhip effect. The history distribution mechanism, linear distribution mechanism and the proration distribution mechanism are all will encourage distributor to make overmuch order. However, uniform distribution mechanism, random repartition mechanism and confirm distribution mechanism etc. will not cause that kind of undulation. The clients in downstream have no intention to extend the quantity of order under this mechanism.

In other hand, reinforce the sharing and mutual communication of the capacity information is important. Usually, when the downstream member could not get the manufacturer's real product capacity information, the "game" phenomenon would reach the highest peak. Manager should try to as far as possible avoid anything could cause artificial guess, which would lead to illusive shortage phenomenon.

Sharing the inventory and production information with customer will help to alleviate consumers' uneasiness, reduce the demand in game. If the manufacturers do not want share the actual capacity information, they could choose to sign contract with the medicine distributor in advance, according the history sales volume. Then, they could regulate capacity in advance and arrange production plan better.

In addition, manufacturer should have restraint for sales return from distributor, which will enlarge the game phenomenon. Under the situation of that there is no any punishment policy for order cancellation or sales return, the retailers will intend to expand the ordering quantity firstly and cancel the order, when the demand is satisfied, later. So it is necessary to implement and establish some restriction or punishment policy for order-canceling behaviour, which will be helpfully for alleviate the bullwhip effect.

6.2.6 Shortening lead-time

In the beer game model, we could discover that when lead-time longer, the bullwhip effect would be more serious. The length of the lead-time and the impact degree of the bullwhip effect is direct ratio relationship. If could shorten the lead-time, it will help both retailer and supplier to hold more economic inventory and replenishment policy, in the meantime, decrease the forecast cycle and increase the forecast accuracy. However, this method is greatly limited by the real situation in reality.

The countermeasures to alleviate the BWE have been studied and discussed in many literatures before. All above mentioned are only part solutions which chose for they are more close to the Chinese medicine supply chain. For more related information could reference the paper by Souza (Souza 2000) and Lee (Lee 1997), there is more detail discussion in them. At end, it is summarized these countermeasures in table 6.1, make it more easy and convenient to reference.

Table 6.1 Countermeasures for the bullwhip effect

	Reason	Reason Analysis	Countermeasures	Techniques
1	Organization structure	Too many horizontal and vertical members in supply chain, Less cooperation	Simplify the organization structure Keep key participator and Reduce unnecessary participator	
2	Demand forecast	Using distorted demand information Multiple demand forecasting	Control the inventory and replenishment policy Reduce lead-time and forecast period Achieve and share real demand information	**VMI** **POS**
3	Price fluctuation	Market promotion Supply quantity is different with purchase quantity	Every day fair price policy and stabilize price Long-term discount contract	**EDLC** **CRP**
4	Batch order	Order cost is high Unit transportation cost is high	Implement electronic order-making network Small batch transportation plan	**EDI, CAO** **3PL**
5	Shortage game	Allocate the product according the order ratio Information communication is limited The order canceling is unlimited	Share sales volume, inventory, capacity information Allocate the product according history order volume Improve the flexibility for production and inventory	
6	Time delay	Information delay Transportation delay	Implement electronic Information sharing network Reduce the Lead-time and break batch delivery	**VMI, EDI** **3PL**
7	Less coordination	Benefit conflict	Strengthen trust and cooperation Optimize contract Coordinate beneficial object of corporation	
8	Personal human behavior	Safe harbor & Panic strategy Under estimate the value of information	Emphasize establishing fixed policy and countermeasure for market variance to avoid the human behavior mistake. Enhance simulation and forecast evaluation Enhance information communication and cooperation	

Chapter 7 Case study

Through the detailed analysis about the causes, impact, simulation and countermeasures for bullwhip effect in the previous four chapters, in this chapter, it will illustrate how the BWE impact the Chinese medicine supply chain, by three real cases each represents a certain situation in the industry. They are in the routine operation in a medium size domestic pharmaceutical company, in the special vaccine supply chain industry and in the incident of SARS in China 2003.

7.1 Case study for pharmaceutical company SBCPC

7.1.1 Background of pharmaceutical company SBCPC

SBCPC is a famous modern joint venture with sixty years history, Located in Shanghai. That is regarded as one of the high-tech enterprise by Shanghai Municipal Government, consists of several branch factories, one joint venture and one municipal R&D institute. SBCPC has over 1000 employee and about 100000 square meter factory, and the register capital is about one hundred million. SBCPC mainly produce biochemical pharmaceuticals, chemical pharmaceuticals, and Chinese traditional herb and so on. Their product mainly is prescription drugs and the major direct customer still is state-owned big drug distributors in different province, in China. That company is very representative in current Chinese medicine industry.

7.1.2 Data analysis

Here, it is very fortunately get some raw data concern production plan, production volume and the final delivery volume of some products from one of branch factory in

SBCPC. In the real case, the situation is more complexity than that assumed in the simulation. SBCPC as a medicine manufacturer faces the demand and market from several different distributors in different regions of China. For the privacy reason, detailed information about the structure of distribution network, the production capacity, or the demand forecast methods etc. could not be recognized here. Therefore, it could only through the limited information from the following table to analyze the potential bullwhip effect and other problem in supply chain in this typical Chinese domestic pharmaceutical company. The table 7.1 and table 7.2 are the production and delivery record for medicine A and B, which both are prescription drugs. The distribution channel is through the conventional medicine distributor network deliver to the hospital drug store. These two medicines are mainly distributed within China mainland.

Table 7.1 The production and delivery record of medicine A in 2005 and 2006

Product Name: Medicine A				
Time Year/Month	Plan Production volume (Box)	Production Volume (Box)	Inventory Volume (Box)	Delivery Volume (Box)
2005/01	170000	64567	65520	0
2005/02	80000	176550	112553	129517
2005/03	0	0	953	111600
2005/04	0	0	953	0
2005/05	80000	71410	63713	8650
2005/06	48000	47581	111294	0
2005/07	48000	0	3353	107941
2005/08	72000	75105	18080	60378
2005/09	80000	98120	49760	66440
2005/10	100000	133810	87840	95730
2005/11	60000	65760	114080	39520
2005/12	80000	0	0	114080
2006/01	40000	11710	2400	9310
2006/02	40000	53810	4800	51410

2006/03	70000	80970	15120	70650
2006/04	60000	56260	960	70420
2006/05	60000	58820	0	59780
2006/06	70000	80057	0	80057
2006/07	80000	83407	0	83407
2006/08	120000	137480	0	137480
2006/09	120000	129801	0	129801
2006/10	120000	138006	17040	120966
2006/11	120000	138030	51840	103230
2006/12	30000	48480	55200	45120
Variance	1551275362	2539628703	2399280190	1985688725

Source: SBCPC Company 2006

Table 7.2 The production record of medicine B in 2005 and 2006

Product Name: Medicine B				
Time Year/month	Plan Production Volume (Box)	Production Volume (Box)	Inventory Volume (Box)	Delivery Volume (Box)
200501	240000	5800	56880	0
200502	460000	397100	130560	323420
200503	720000	512460	0	643020
200504	360000	620250	26880	593370
200505	500000	473130	29280	470730
200506	720000	743830	0	773110
200507	672000	478220	1920	476300
200508	850000	0	0	0
200509	600000	522830	5280	517550
200510	360000	342600	0	347880
200511	500000	536340	240	536100
200512	520000	539880	480	539640
200601	700000	432810	0	433290
200602	480000	500770	21780	478990
200603	400000	480040	0	501820
200604	700000	730778	3600	727178
200605	180000	295623	21780	277443
200606	700000	677912	9600	690092
200607	380000	544043	19200	534443

200608	650000	632719	21600	630319
200609	550000	429338	4800	426938
200610	500000	599368	4800	596968
200611	400000	424814	0	427214
200612	600000	775350	4800	770550
Variance	27693210144.93	37040419327.39	797661991.30	39691668412.46

Source: SBCPC Company 2006

Here we know, in the table, the delivery volume is equal to the final sales volume, which represent the volume of medicine be transported to the next downstream members, this figure is regarded as the real demand of the market. The production volume is the final real production volume of that month, which is direct accord the final orders get from the downstream. So, the bullwhip effect could be determined by the variance amplification ratios as:

$$\text{Medicine A:}\quad BWE = \frac{\text{Variance of orders}}{\text{Variance of demand}} = \frac{\text{Variance of production}}{\text{Variance of delivery}} = 1.28$$

$$\text{Medicine B:}\quad BWE = \frac{\text{Variance of orders}}{\text{Variance of demand}} = \frac{\text{Variance of production}}{\text{Variance of delivery}} = 0.93$$

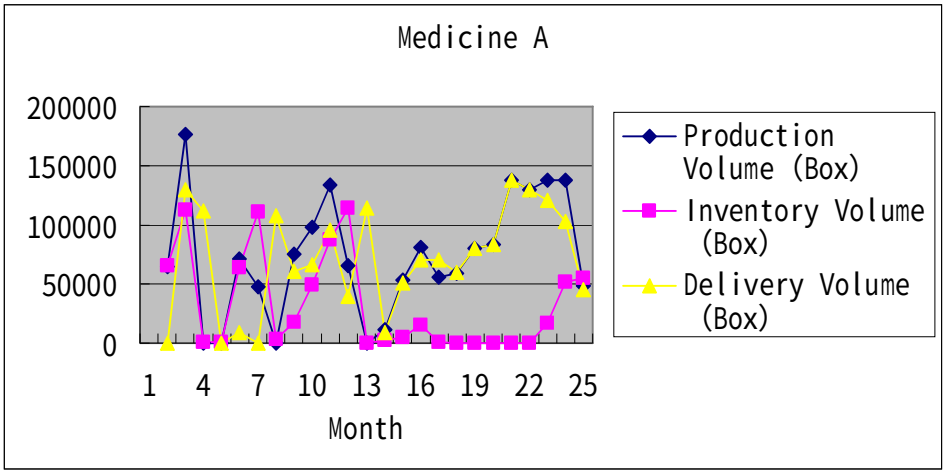


Figure 7.1 The Production, Inventory and Delivery Volume for Medicine A

Source: SBCPC Company 2006

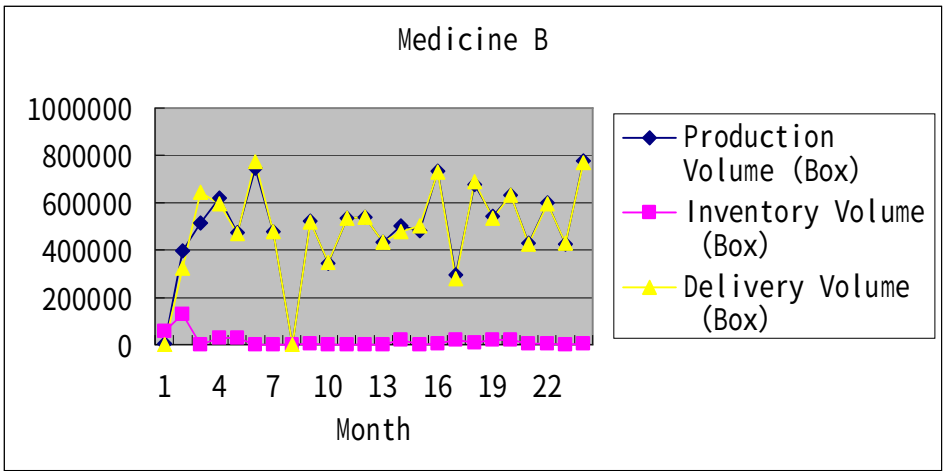


Figure 7.2 The Production, Inventory and Delivery Volume for Medicine B

Source: SBCPC Company 2006

Therefore, from above two tables, we could found several features in this company's operation management.

1. About the future demand forecast method: when I tried to found out the potential relationship between the production volume and the delivery volume, there is no some certain regulation. Most time it looks like that the forecast method was following the "chase sales policy", the production plan-maker try to manufacture the productions equal to the real demand or orders from downstream.

2. There is no clear inventory policy, sometime the inventory volume would be very high and later within one or several months the inventory volume would be reduce to zero. There are many times, we could find that when they delivered all products, the inventory position down to zero for several months. I could not know whether the customer's demand was all met or not. At least, the

inventory policy is not considering the fluctuation of the market or the fill rate, and service level is very limited.

3. There is huge difference between the plan production volume and the real production volume, and the later one was more close to the final demand (delivery volume). The production plan looks like just a crude forecast for the future market.

4. The result of the BWE calculated by the variance-amplified ratio is not obvious. For medicine A, there is 20% amplification, and for medicine B, there even got a dampening effect. I think the reason for that is mainly because their inventory policy, which do not pursue the "safe harbor" and do not care more about the service level. Since that, the data shows that the production plan is just following the orders from downstream customer as close as possible.

7.1.3 Conclusion

From the analysis above for the SBCPC, it could find that, the implementation of supply chain management is still under the beginning and primary level. Because of some of the domestic pharmaceutics company still close following the "Chase sale policy", the bullwhip effect in those kind of cooperation is not obvious (such as in the case of SBCPC). Currently, in China, at least in many medicine companies the BWE is not a very significant problem in normal situation. Nevertheless, the poor and low level supply chain management policy should make them be more sensitive for the bullwhip effect as soon as the market gets any change.

7.2 Case study for domestic vaccine supply chain

7.2.1 Background of Chinese vaccine supply chain

Chinese vaccine cold chain is conventionally monopolized by the state health administration, and under the plan economic status. Current, in china, the whole vaccine cold chain is primary formed by vaccine manufacturer, distributor and different level CDCs (Centers for Disease Control and Prevention). The supply chain structure is as the figure7.1 showed:

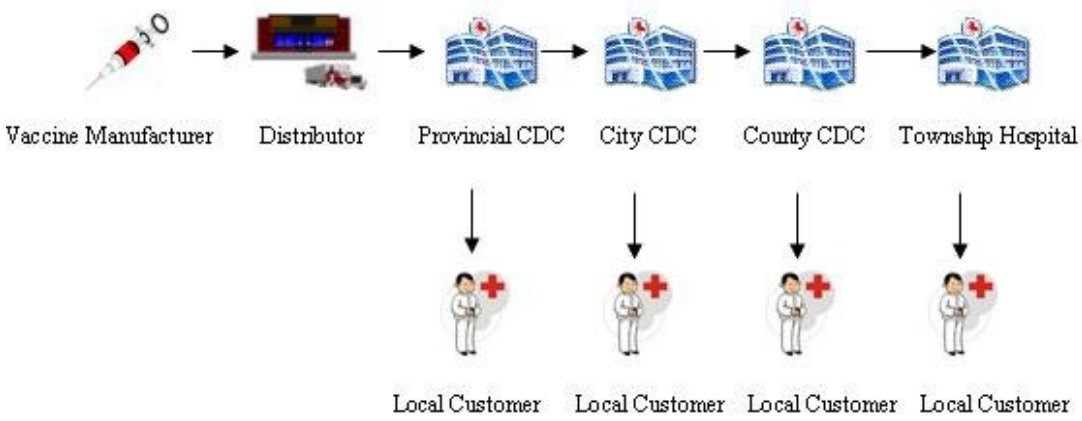


Figure 7.3 – the distribution network for Chinese vaccine supply chain

The distributor mainly carry out the business support and some financial support , the relationship with manufacturer is very close. Most time the inventory of distributor is under the control of manufacturer, so there is no bullwhip effect in this level.
The town CDC could be looked as the customer of county CDC, and same time they have their own end customer. It is also the same situation for the county CDC and city CDC.

The feature of vaccine cold chain

- There is no completed inventory management policy.
- Some vaccine, such as flu vaccine, the demand is very uncertainty.
- To meet the requirement of macro control, when the downstream CDC wants to

order the vaccine, which must through the upstream CDC. So, if the town CDC want purchase the vaccine, it would need through eight steps to get it. It includes four steps for the order information delivery and four steps for the vaccine delivery.

- The vaccine itself is very special merchandise. The vaccine production period is very long. For example, the flu vaccine need almost half year to production. In the short term, the supply quantity of vaccine is limited.
- The demands for vaccine normally occur in a short time.
- The expired time for the vaccine normally is short, therefore, the shortage is very easy to happen.
- The demand order of vaccine from different regional CDC is always happened in the same period. The other word, the distributor would receive the order from many CDCs in a relative shorter time.
- Because of each level of CDC is controlled and managed under the plan economic for a long-term, the management team of vaccine cold chain is unstable and is lack of the professional training, so the management level of vaccine cold chain is worse.

The bullwhip effect in Chinese vaccine supply chain

Causes for BWE

Because of the special characteristic of vaccine, the reason to result in the bullwhip effect is also very special.

Short-term game

Because of the supply quantity of vaccine in short-term is unchanged, therefore,

when the epidemic happened, the supply would be shortage easily. It would allocate vaccine according the ratio of the order quantity, when it is found that the supply is not enough. To get more allocation, the CDCs have to amplify the quantity of order. Then, when the supplies recover, the order volume would back to the original quantity, the bullwhip effect occurred. In addition, the upstream CDC would expand the order quantity according certain ratio as preparation for urgent situation that would also increase the bullwhip effect. Such as the flu epidemic happened in 2003, because of the shortage of 3 million of flu vaccine, each level of CDC amplified their order volume; the final order quantity received by the distributor is estimated about 30% higher than the real market demand.

The fluctuation of price

Because of the shortage of the vaccine supply, the provincial CDC would increase the price to limit the order from downstream to meet themselves' requirement. It is also same for each other level CDC. Therefore, from the upstream to downstream, the price of vaccine would increase according the supply chain. For example, the price from distributor for flu vaccine is only RMB 60, and the price for town CDC would be RMB 80. The same time, some CDCs would pre-order more than the real demand quantity of vaccine, which also enhance the bullwhip effect.

Other reason

For the ordering of vaccine normally happened in a short period, each level of CDC would make repeat order. Therefore, any small fluctuation from either town CDC, would introduce huge fluctuation in the distributor side. In addition, there is no restriction policy for the order cancellation behavior, which lead the CDC would make order unreason, also cause the increasing of bullwhip effect.

The impact of bullwhip effect

- **Increase the total cost:** include the inventory holding cost, labor cost, transportation cost and other related cost.
- **Lower service level:** the fluctuation of order make the manufacturer could not supply the distributor and CDCs in time, and increase the frequency of shortage. Moreover, the CDC always want get the vaccine as soon as possible, but when the real demand is uncertainty, the supplier would delay the delivering. The both situation would decrease the customer value and lower the customer service level.
- **Influence on the society stable**. As a kind of special merchandise for the health safety of people, when the large-scale epidemic situation happened but the vaccine is not enough, it would cause the instability of society and other potential huge serious influence.

Possible solutions for alleviate the BWE

1. Reduce the horizontal layers in supply chain

   The more participants involved, the more information processing would be done, and the degree of distortion would be bigger. Therefore have to reduce the horizontal layer in the whole supply chain. If could let the county and city CDCs directly order the vaccine from distributor, it would both alleviate the bullwhip effect and still achieve the macro-control.

2. Change the structure of CDC in vaccine supply chain.

   Allow the professional vaccine distributor to manage the stock of CDC and the facility for cold chain, could decrease the operation cost for CDC. For distributor, this method could expand the market share for their product, and could decrease the cost for transportation and inventory management. It could be a kind of VMI (vendor management inventory) model that let the manufacturer and distributor make correct inventory policy for the real market

demand.

3. Optimize the allocation policy.

   The vaccine supplier should consider the number of human population, history sales volume and the forecast according morbidity model to allocate the vaccine supply. That could reduce the gaming behavior.

4. Strengthen the administration of government

   The vaccine as a kind of special merchandise, the state government should strengthen the administration for it. Through scientific forecasting and financial supporting, to assure enough supply inventory and coordinate the supply allocation, when the supply shortage appeared. The government would also strengthen the administration for the price of the vaccine in the supply chain.

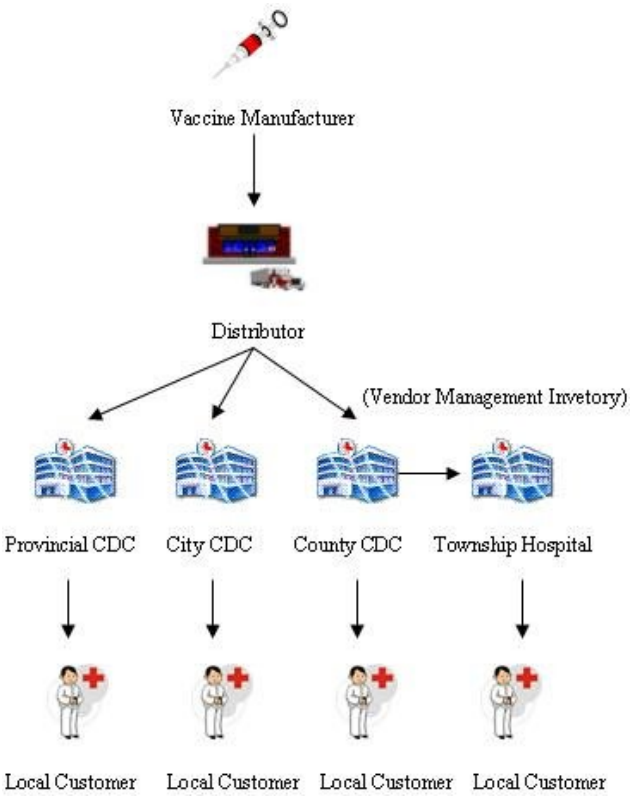


Figure 7.4 Optimized vaccine supply chain

7.2.3 Conclusion

The vaccine cold chain is a very special and important case in the medicine supply chain. Because of the special characteristics of it make the demand fluctuation easily happen and the supply quantity is very sensitive. Therefore the bullwhip effect is frequently appearing and brings serious effect in this industry, which attracts many governments and manufacturers attention and need further study.

7.3 The medicine supply chain in the SARS incident

7.3.1 The background of SARS incident

In 2003, there happened a serious epidemic crisis in China, a kind of lethal virus called SARS (Severe Acute Respiratory Syndrome) spread from south to north of mainland in China. By the developing and changing of the epidemic situation, the demand for related medicines and sterilization products are also up surging. Nevertheless, when the epidemic is finished, the hot sold medicines lost the market, such as disinfector, thymus peptide etc. The inventory of this kind of commodity in some drug stores is excessive supply, and almost all anti-SARS related merchandises are overstocked in all medicine wholesalers in Beijing. Therefore, in this case, I would discuss the detail situation of each echelon in the medicine supply chain during the SARS epidemic period.

The drug store

As the end retailer directly faced the market, drug store had the most quick and precise reaction. In the middle of April 2003, by quick spreading of SARS epidemic, the market for commodity like clinical thermometer, disinfector, respirator

and antivirus medicine was upsurge. Faced the sudden changed market demand, the reaction of drug store could be divided to three types:

1. Actively preparation

   Because of the epidemic had appeared in Guangdong province at begin of year, small part of big and foresighted drug store had predicted the changing of market, prepared the inventory for the related medicines and other merchandises. However, this kind of store was very little.

2. Well sale but have less profit

   Because of the sudden changing of market, the upstream procurement cost was increased. Many drug stores could do the business with less or even negative profit just for keeping the reputation.

3. Quit the market

   Some small and independent drug store faced the market, because had no resource to achieve the related merchandises, so could only quit from this market.

The hospital

Compared to the drug store, the situation of hospital was very special. Because when the epidemic spread, people avoided going to the hospital, therefore, there was no amplification in the hospital drug store.

Medicine distributor

Similar to the drug store, drug distributors also suffered the fluctuation of the market. Because of the longer distance to the final market, the loss was bigger. When the related drugs were sold out, although some kind of medicines were hot sale, but the sales volume of most other unrelated medicine was fell, which made them still loss money. At that time, the different drug stores and hospitals according the different demand make different orders to distributors. However, when all merchandises

were arranged ready for delivery to the market, the market had changed. Almost all medicine distributors were overstocked the anti-SARS merchandises in Beijing, only the degree was different.

Pharmaceutical manufacturer

The situation of pharmaceutical manufacturers were different, some corporations had their own sales team, so could monitor the market in time. According the investigation from Huicong Medicine Information Research Institute, the marginal of some manufacturers were doubled during the SARS period. However, some other companies, mainly achieved market information from agent distributors and wholesalers, got the information was delay and with big error. Such as the respirator in April 2003 was shortage, but the supply was enough in May, and many factories still over manufactured it. The result was many manufacturers and distributors all overstocked.

7.3.2 The bullwhip effect in SARS

Analysis for the causes for the BWE

The slow responding of supply chain was the main reason.

1. The information separation between manufacturer and retailer
   The downstream retailer did not know the real inventory and capacity of upstream manufacturer, so they would amplify the order. And the manufacturers did not know the variance of market demand. In addition, the upstream suppliers raised up the price, which make the bullwhip effect increased.
2. The turn over speed of chain drug store was slow
   The chain drug store control and keep the inventory, then the market information delivery was delayed.

3. The layer of distribution network was too many

   Too many suppliers, lead the problem of information responding system.

Possible solutions

1. Promote supply chain management

   The supply chain management could strengthen the competitive ability and coordinate the operation and information sharing in supply chain. The members share the information, benefit and risk, which could effectively alleviate the BWE.

2. ECR (Efficient Consumer Response)

   ECR refers that distributor and supplier through information system to cooperate realizing efficient customer response for reducing or eliminating unnecessary cost and expend and bringing more profit to customer. To implement the ECR, it needs integrated automatic code recognizing, POS system and EDI technologies. Construct a paper-less information transfer system, to sure the information could flow in the opened supply chain. That method could limit the information delay and distortion and speed up the customer response.

3. VMI (Vendor Management Inventory)

   Let the pharmaceutical manufacturer directly manage the inventory in the final retailer. That could not only reduce the inventory cost both for retailer and manufacturer, and help the manufacturer achieve the direct market demand, greatly alleviate the bullwhip effect.

Although the SARS case is an extreme example in the medicine supply chain, but many potential serious epidemics still threaten the public health system, the Avian Flu is one of example. What's performance of Chinese medicine supply chain in the next epidemic is what we have to serious face for.

Conclusion and Recommendations

The bullwhip effect is a hard problem in supply chain management, solving it is the essential. This dissertation focus on discussing and analyzing the impact and influence of bullwhip effect in the Chinese medicine supply chain, try to find some reasonable and practicable solutions for this industry.

First, the paper introduced the background and current situation about research for the supply chain management and bullwhip effect. In addition, gives the aims and objects of this study.

Second, it mainly discussed the causes and impact of bullwhip effect, especially associated with the features and characteristics in current Chinese medicine supply chain industry.

Third, the paper used a basic spreadsheet based simulation program to analyze the relationship between the condition setting with bullwhip effect and performance of supply chain. It proved the result of formula deduction that the forecast technique is not the cause for BWE. And give the discussion about the trade off between inventory cost and customer service level. That model is a very useful and practicable method for decision-maker in the analysis for bullwhip effect.

Fourth, based on the previous research, paper gave some solutions for alleviating the bullwhip effect in medicine industry.

The last part of paper gave three case studies. It discussed the impact of bullwhip effect in three different kinds of situations in current Chinese medicine supply chain. It could find out that, there are many problems in the medicine industry. It showed

that although the bullwhip effect is not obvious in the daily operation, but how to improve our management level and performance to make good preparation for the next SARS or Avian Flu etc is a serious problem need to be serious faced.

In accordance with the study, it could get some conclusions and recommendations as below:

1. Although the bullwhip effect is companied with the supply chain and could not be eliminated completed, but there still have many solutions could be used to control and alleviate its impact and influence. The most important fundament for BWE alleviation is the scientific supply chain management, and the qualified manage human resource is the basic footstone. So, cultivating the professional supply chain management human resource is one of most important things.

2. To solve the problem of bullwhip effect, it has to concern the whole supply chain. The BWE would be alleviated, only when every member in the supply chain had involved in the action, and had realized the importance of cooperation and be aware of the impact of bullwhip effect.

3. The modern new information technology is the key and most effective solution to alleviate the bullwhip effect. The enterprises have to pay more attention on the information construction. Their limited investment would bring long-term and obvious benefit for corporation from the reduction of the supply chain cost.

4. The tradeoff between logistics cost and customer service level is another important issue could not be neglected, when discuss the bullwhip effect. How to find out a golden balance solution for both sides needs always keep in mind.

5. The simulation is an important and useful method for decision maker to evaluate

different parameters or conditions for optimizing the supply chain, in the study for bullwhip effect.

For the limitation of the resources, there is no detailed investigation for more independent pharmaceutical manufacturers. The company (SBCPC) chose in this paper could not represent the whole industry. Especially for those foreign joint venture pharmaceutical companies, they usually have more advanced information construction and management experience, at least within their own corporation. The performance of those kinds of companies in Chinese medicine market is a very interest subject needs further study.

In addition, because of the limitation of knowledge and experience, the simulation method chose in this paper is only for a two echelons model, although it is easy for comprehension and study. More complex model or simulation would be examined, when facing to study the bullwhip effect in a more complex multiechelon or real situation.

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The following websites gives further information:

State Food and Drug Administration

(www.sda.gov.cn)

China Association of Pharmaceutical Commerce

(www.capc.org.cn)

China Centers for Diseases Control and Prevention

(www.chinacdc.net.cn)

China Pharma Information Net

(www.cpi.gov.cn)