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VMI for Electronic Manufacturing Services (EMS):
A Case Study of Celestica (Suzhou) Technology Co., Ltd

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Abstract

In the past decade, the electronic business environment has changed dramatically. Electronic Manufacturing Services (EMS) today face a trouble that a shorter consignment time is requiring by customer meanwhile some material has a long lead-time or purchasing cycle. In order to march demand and keep service level, Manufacturing Services (EMS) has to set high level inventory and safety stock as well as raw supplier. Hence increase total inventory cost of the supply chain, and some shipment will delay because long material purchasing time. Even more, stock been eliminated is still a potential financial problem will threaten Manufacturing Services (EMS).order to deal with the challenge.

In this thesis, a case company is studied. After introduce relevant theory, the paper demonstrates the benefit of VMI, compare VMI and combined VMI both for supply chain and 3PL company, propose as 3PL-VMI molded for the upstream. As research goes further, JIT delivery and Fast feed mechanism is suggest. Hence, a new supply chain with 3PL-VMI in the upstream to ensure the replenishment and short the lead-time, a Fast Feedback in the downstream to fast feedback information and order from end customer to achieve a high level service meanwhile reduce the whole supply chain inventory holding cost as well as stock cash cost threaten.

Key Words

EMS, VMI, 3PL, Safety Stock, JIT

Content

1 Introduction

It is obvious that the electronic products has fast consume character, the competitive of market is becoming more and more serious, demand uncertainty has a big influence on Electronic Manufacturing Services (EMS), inventory pressure emerge on every aspects of the supply chain, how to make a replenishment policy to meet the demand uncertainty has become the chiefly problem. This paper will introduce VMI management, integrating with Celestica (Suzhou) Technology Co., Ltd and one 3PL company, with a case study, learn its existing supply chain inventory management, discuss every roles and function in the supply chain, find its limitation, try to build a new VMI management model, minify the inventory cost to meet the challenge.

Chapter 2 collects date and figure to illustrate the current challenge of EMS industry. With deeply observe Celestica's financial detail, it is urgency for Celestica to have something change in the supply chain to deal with the trouble.

Chapter 3 overviews terms which will be used in the paper, most of them is just brief overview except uncertainty and VMI theories.

Chapter 4 deep analysis three decision models, one is 3PL manage combined-VMI inventory, second is uncertainty analyzing based on demand and lead-time follow random distribution, third is VMI benefit analyzing.

Chapter 5 is a case study, first states the current supply chain of Celestica (Suzhou), point its limitation and problem, find source for these problem, then propose a 3PL-VMI combined Pull mode. Following is some key points for VMI implementation and risk analysis.

Chapter 6 is conclusion and further research discuss.

2 Description of the Problem

2.1 Introduction of EMS Industry

Electronic manufacturing services (EMS) are companies that design, assemble, produce, and test electronic components and assemblies for original equipment manufacturers (OEMs). Typically, OEMs retain ownership of product designs and brand names. Some electronic manufacturing services are contract electronic manufacturers (CEMs) that specialize in rapid prototyping or product testing. Others offer small, medium, or large production runs. Electronic assemblies can be built from vendor-owned, customer-supplied, or consignment materials. Design services

provide conceptual product development advice and mechanical, electrical, and software design assistance. Testing services perform in-circuit, functional, environmental, agency compliance, and analytical laboratory testing.

2.2 The Current Financial State in EMS Industry

OEMs will continue to outsource to electronics manufacturers and original design manufacturers which will drive the electronics out sourcing market to nearly $300 billion in 2008.

Electronics outsourcing skyrockets

($ billions, worldwide)
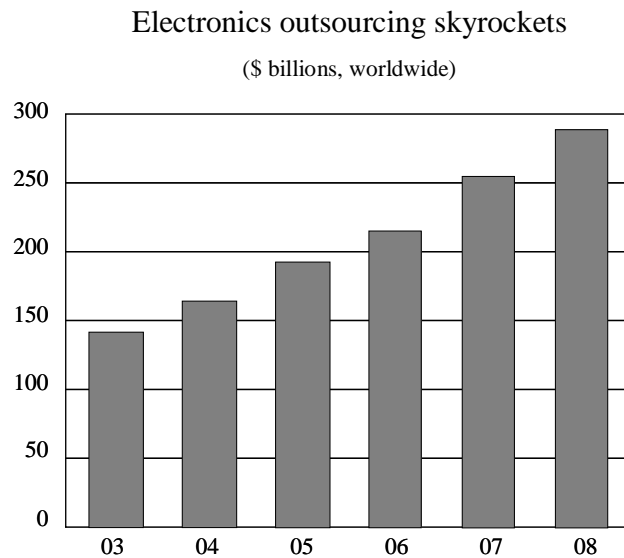
FIGURE 2.1   Electronics Outsourcing Skyrockets in the past few years

Source: Technology Forecasters

Due to sale driving increasing, in 2007 the biggest 20 Electronic Manufacturing companies continue to enlarge their share of the world market. But iSuppli thinks this simply fact cover up some complex reality affect competitive trend of this industry.

2.3 The Current Financial Problem in Celestica

ISuppli company's primal rank of Electronic Manufacturing Services (EMS) indicates in 2007 the biggest 10 Electronic Manufacturing Services supplier have increased sale to 192.%, 10 biggest original equipment manufacturers (OEMs) supplier have increased sale to 31%. In the aggregate, these 20 biggest Electronic Manufacturing companies whole sale reached 209 billion dollar.

TABLE 2.1 Changing Sale of 10 Biggest EMS Companies for The Past Two Years

EMS suppliers	2006	2007	Changing rate	Turn over changing rate
Foxconn	$39,253	$54,706	39.4%	$15,453
Flexctronics	$28,876	$33,346	15.5%	$4,470
Jabil Circuit	$11,087	$12,432	12.1%	$1,345
Sanmina-SCI	$10,872	$10,138	-6.8%	-$734
Celestica	$8,811	$8,069	-8.4%	-$742
Elcoteq	$5,139	$5,740	11.7%	$601
Benchmark	$2,907	$2,915	0.3%	$8
Venture	$1,971	$2,617	32.8%	$648
Universal Scientific	$1,676	$2,046	22.1%	$370
Plexus	$1,513	$1,624	7.3%	$111
Total	$112,105	$133,633	19.2%	$21,529
Total without Foxconn	$72,852	$78,927	8.3%	$6,076

This rank is interesting, the biggest 10 Electronic manufacturing services (EMS) companies are rise sale to 19.2% in 2007, but 71% increasing amplitude comes from Flexconn company. If disregard the contribution of Flexconn, the total mount of rest 9 Electronic manufacturing services companies is only 8.3%.

2.4 Existing Problem and Challenges of Celestica

Celestica company' sale is decrease 6.8%; its share of the market was a little decrease. On the other hand, this company has shrink line, enhance customer optional flow. Hence, Celestica profit is rising in early 2008. In the passing 180 days, it has increased its profit to 1.3%. At the meantime, Celestica has declared to further reduce employees and fellow subsidiary.

To meet the challenge, reducing cost has always been the critical factor in electronics manufacturing service industry. Indeed, lowering costs is why OEM outsources to electronics manufacturing services (EMS) providers and the reason why major EMS providers have moved high-volume manufacturing to china.

However there is more than just cheap labor cost, optimizing the cost of supply chain is the prime solution to improve the competitive edge.

"I don't want to increase cost for suppliers. I want to develop a strategy that reduces cost across the supply chain- not just for Celestica-because if I do increase their costs, it drives their costs up and I'm going to get it back in price." Says Boucher, chief supply chain and procurement officer, Celestica (Jim Carbone 2005).

3 Literature review

3.1 Overview of Supply Chain Management

Supply chain management is one of the most essential aspects of conducting business (Swaminathan 2000).

With a trend of technology development fast, market globalization and customer demand variety, enterprise competitive edge changed internal and external, opportunity and challenge force enterprise to consider supply chain management. From a material flow perspective, every member of a supply chain can through sharing sale forecasting, demand, producing capacity via a information communicating mechanism to cooperate to achieve a more rational management of material flow and financial flow, to avoid Bull-whip affect which will bring supply chain inefficient, multi-inventory, stock-out and overstock, decrease service level and delayed neither in produce line and goods transportation.

The term supply chain management (SCM) has risen to prominence over the past twenty years. For instance, at the 1995 Annual Conference of the Council of Logistics Management, 13.5% of the concurrent session titles contained the words "supply chain", just two years later, the number of sessions containing the term rose to 22.4%. (John William James Soonhong Nancy Carlo Zach 2001).

There are variety definitions due to different perspective. Many people outside of the direct member (in research and industry) do not realize this because an ordinary consumer often experiences only its effects (Swaminathan 2000).

For example, a definition due to Simchi-Levi et al(1999, p.1) that focus only the flow of goods.

Supply chain management is a set of approaches utilized to efficiently integrate suppliers manufactures, warehouse, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements.

A shorter SCM definition is proposed by some scholars in Rai university.

Supply Chain management is the integration of procurement, logistics, planning,

forecasting and transportation.

With a comprehensive overview of former literatures and supply chain management in the past twenty years, John, William, James, Soonhong Nancy, Carlo and Zach (2001) proposed a more general definition of supply chain management.

A supply chain is defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer.

With a depth consideration of this definition in practice, this definition well describes supply from to aspects. One is principal parts of the supply chain which compose of at least three entities, supplier, manufacturer, customer from the downstream to the upstream, relationship and communicating between these entities that is material, service, finance, information flow.
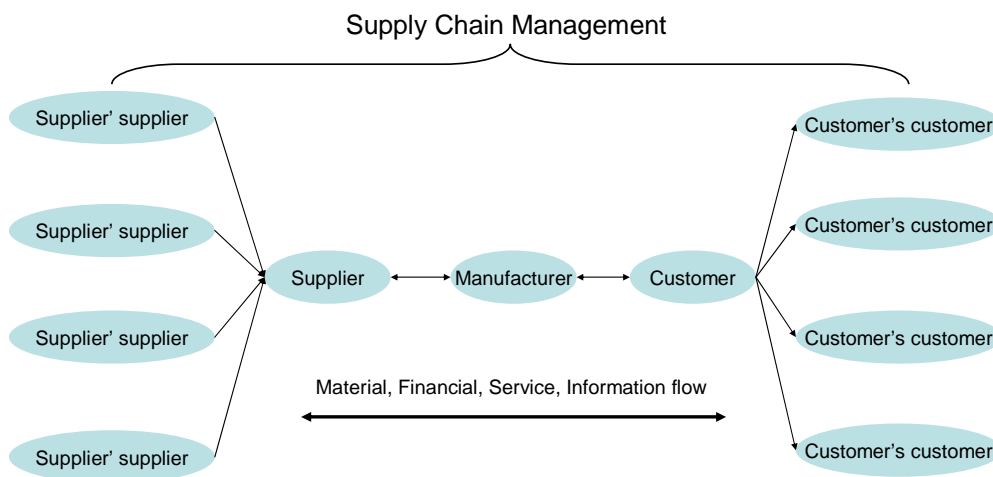
FIGURE 3.1   Description of Supply Chain Management

3.2 Uncertainty in Supply Chain Management

3.2.1 Brief Overview of Uncertainty

Uncertainty means *during a time horizon, characters and state of each participator can not efficiently, currently observe, forecast and measure real demand. The severity competition of market existing much uncertainty. During cooperation of enterprise in supply, there are many internal elements and outer element generates uncertainty factors.*

Cooperation between enterprises in the supply chain will generate various uncertainty elements because of information asymmetry, information misunderstanding, market uncertainty, politics, economy, law change etc., To

increase the competitive edge of whole supply chain, it needs to adopt mode to conquer uncertainty during supply chain operation, such as improve information sharing, optimize contract, establish supervise mechanism and control construction, especially supervise during each step of supply chain operation, and adopt various ways to motivate companies in order to make operation more efficient. Many practices have proved that, whether enhance control and reduce of the uncertainty of supply chain, are the critical factor to gain excepted benefit.

3.2.2 Safety Stock Introduction

Because of the widespread existence of uncertainty of supply chain management, communities in supply chain may not totally trust each other relate to production or material replenishment in time. Customers or manufacturers turn to set a safety stock be under the apprehension that supplier can not shipment or delivery delayed disregard the reason cause then to be. Same, suppliers in order to march the variety demand from manufacturer or customer, they turn to set safety stock based on forecasting of cycle demand, indeed, the demand from customer can not be forecasted accurate because there are these various factor from the end market affect the demand quality, supplier have to rely on forecasting and preplan produce and sale policy. Here is the reason of multi inventory in supply chain, because of demand uncertainty and forecasting inaccurate, stock-out situation and accurate situation is widely existence in supply chain. On the other hand, enterprises have to set a high level safety level to meet large order from downstream.

3.2.3 Risk of Stock Cost

With a consideration of supply chain management perspective, set up a safety stock to meet these uncertainties is unavoidable. Under the state of uncertainty existing, in order to keep service level, enterprises have to keep safety stock, high level of service level must result high level of inventory level, which mean high level of risk take from the warehouse, and these risks mainly emerge in two points.

♦ Capital which has been invested in the inventory can not be moved for other business programs or invest in other property, enterprise may has to borrow additional investment fund to maintain the inventory operation and continuous investment. This reason will enlarge the capital burden of the enterprise.
♦ Stock of inventory is probably steal or overdue, result in overstock, and if overstock do not been deal with a timely inventory management policy, it surely will enlarge the acreage of warehouse as well as the operation flow, capital stunk in the inventory.

High level of inventory and safety stock is obviously a risk to an enterprise in such a competitive environment. Inventory cost is a core competitive edge for a successful enterprise with consideration of its impact on production price. If an enterprise can

reduce several percent of inventory cost, it will be a greet profit to itself. In traditional goods sale flow, from raw material supply to end customer, there are multi inventory and safety stock, to implement supply chain inventory management, such as VMI, it can decrease the influence of uncertainty of supply chain thus to decrease the risk of high inventory, eliminate overstock as well as risk share to lowest the inventory cost while keep a competitive service level.

3.2.3 How Safety Stock Work

How much is reasonable level of safety stock? Figure (3) is a safety stock sketch. If demand is uncertain and it obeys statistical normal distribution, its order process and safety stock during a lead time cycle is showed below.
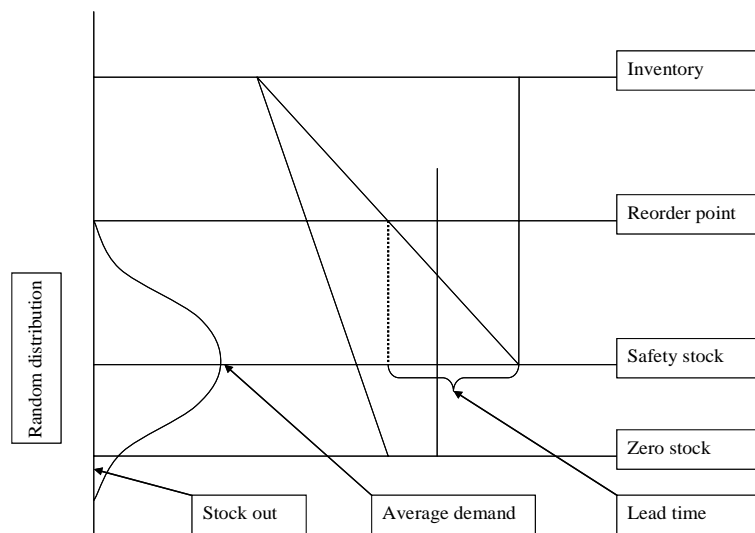
FIGURE 3.2   How Safety Stock Work Under Uncertain Demand

3.3 Brief Overview of Bullwhip

Definition of bullwhip

The bullwhip effect is the consequence of individual agents in the supply chain acting in their own best interests (Silver, E.A., Pyke, D.F. and Peterson, R. 1998).

Whip-effect is that when each part of the supply chain decides manufacturing and supply policy only base on neighborhood enterprise, demand information from the downstream will extremely enlarge along with the supply chain; inventory of upstream enterprise will extremely increase. A game named Bear Game was very popular from 1960s until now because many scholar interested in this phenomena, 1994-1997, American supply chain management experts HauL Lee and V Padmanabhan collect various data to investigate this pheromone, and sum up this

into four reasons, demand forecast adjust, order scale policy, price regulate, disadvantage leverage.

To mitigate bullwhip effects, several changes must be made. Incentive must be put in place to reduce demand forecast errors, reduce excessive order sizes in a allocation situations, and encourage in formation sharing and system alignment. As these initiatives become policy, everyone, especially the consumer, will benefit from reduced costs and improved supply chain efficiency (Steven Nahmias 2002).

3.4 Brief Overview of 3PL

Third Party Logistics "3PL" emerged in the early 1990s when logistic service provider start offering consolidate services and an increasing number of customers, for a variety of reasons, entered in to longer business contracts with the logistics service providers (Madhu R and Richard T, 2004) The services offered by 3PL providers consume a significant portion of overall logistics and supply chain budgets (C. John, Gary R.A and Gene R.T, 2001). After a full overview and comparison, TOMPKING company gives a comprehensive definition of 3PL.

Third party logistics is utilizing an outside firm to perform some or all of the supply chain functions that an organization requires.

This can involve any aspect of logistics and is more than simply outsourcing warehousing or transportation. As a rule, a service provider integrates more than one link within the overall supply chain, but the service can be as narrow or broad as needed. In essence, 3PL providers sell three commodities: labor, space, and time (TOMPKING).

3.5 Brief Overview of VMI

VMI strategy keeps rising in the last decades, the important of VMI has been widely recognized, the relationship between retailer and suppler are different compare with traditional models. The term of "Vendor-Managed Inventory" (VMI) was emerged in the USA in the early 1990s with major projects implemented by Wal-Mart, K-Mart and Home Depot. VMI is a supply chain practice where the supplier is responsible for maintaining the clients inventory levels (Peter Kahn (2007). Rapidly, manufacturers began to treat it as an effective way of regaining control of their supply chain and reducing the power base of the large retailer. VMI or continuous replenishment has proven to be highly successful in reducing costs in the grocery and retail industry.
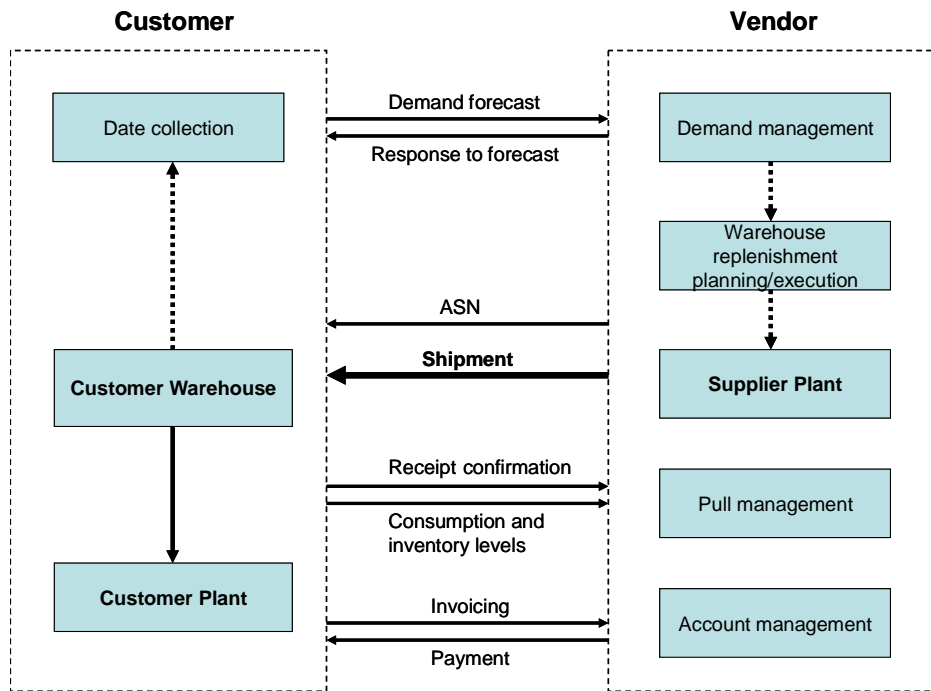
FIGURE 3.3   Typical VMI Process   (Christopher Roberts 2004)

VMI theory break traditional inventory management model that divide supply chain into various roles, it use system and integration to manage inventory. The supplier has access to client's stock levels and it generates the stock replenishment orders based on agreed inventory levels, fill rates and transaction costs. Orders are usually send automatically by the stock monitoring software, but they can be overridden by both supplier and the client (Peter Kahn 2007). Vendor management inventory (VMI) is a mode for supply chain collaboration gaining ground in multiple industries around the world (Astrid Vigtil 2007). In many theories, VMI are also called "consignment inventory", namely customer doesn't take ownership of a product until a point very near the tail end of the supply chain. In the meantime, all the coordination and financial obligation for the product is handled by a vendor or collection of vendors (Brett Harper 2006).

Vendor Managed Inventory is a concept where the vendors or suppliers are responsible to manage the organization's inventory system given the organization's internal data (inventory level, sales data, etc.) (Abdelmaguid Tamer, et al. 2001).

As existence of bullwhip, Enterprise keep its business secrete and self-closed policy in order to protect itself from competitors, cooperation between enterprises is often some trades in a short time, furthermore there are many man-made obstructions of information communication between enterprises. Such, enterprise cannot but built high safety stock, in the next place, VMI can maximize reduce whip-effect.

3.6 Brief Overview of JIT

JIT is to remove all waste from the manufacturing environment, so that the right quantity of products are produced in the highest quality, at exactly, at exactly the right time (not late or early), with zero inventory, zero lead time, and no queues (Steven Nahmias 2002).

Compare JIT with VMI with respect to dimensions of safety stock level and feedback speed.
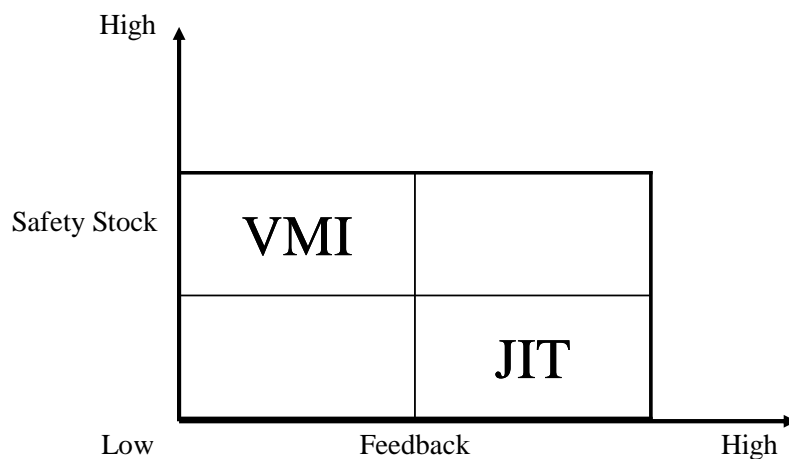
FIGURE 3.4   Safety Stock and Feedback Speed Compare between VMI and JIT

3.7 Definition of Materials Requirements Planning (MRP)

Materials requirements planning (MRP) is a set of procedures for converting forecast demand for a manufactured product into a requirements schedule for the components, subassemblies, and raw materials comprising that product (Steven Nahmias 2002).

Manufacturing resource planning (MRP Ⅱ) attempts to deal with some of the problems of implementing MRP by integrating the financial, accounting, and marketing functions into the production-planning function (Steven Nahmias 2002).

3.8 Definition of Electronic Date Interchange (EDI)

Electronic Date Interchange (EDI) is one of the enabling technologies for streamlining supply chain operations. EDI refers to the electronic transmission of standard business documents in a predetermined format from one company's business computer to its trading partners' computer (Cannon 1993).

Astrid V (2007) proposed three questions *RQ*1, *RQ*2, *RQ*3 to explain what type of advance exchange date would be valuable to the supplier for successful replenishment planning in VMI.

Types of information exchanged include sales information, forecasting, inventory levels and purchase order (Abdelmaguid Tamer, et al. 2001). These data are transmitted upstream to the vendor's supply chain and used to make decisions that affect manufacturing, shipping, and inventory processes (Andres A, Heather N, Matthew A.W 2004).

The major benefits of EDI include reduction of transaction costs, increased data accuracy, shorter process cycle times, improved inventory management, and improved customer services (Yuliang Yao 2002).

4 Research methodology

4.1 Propose A Combined VMI Mode for 3PL

4.1.1 Challenge for 3PL

It's clear that third-party logistics will continue to be a growth industry in Asia for some time to come, and that China's manufacturing boom will be the prime mover be-hind that growth (Richard Knee, 2002).

Brett Harper (2006) consider today companies looking for 3PL are just as likely to value factors such as experience, knowledge and relationship in the market, company intend to only rely on fix 3PL. They choose 3PL as a true prater, not just another vendor.

3PL users want their 3PL service providers to take on more meaningful, strategic roles. They even see a need for more of a "lead logistics manager" type of involvement (C. John, Gary R.A and Gene R.T, 2001).

4.1.2 Suggest A New Role for 3PL

Consideration of the two challenges above for 3PL industry, 3PL company need to provide more new advanced service to march customer's requirement. Associate with reality and VMI strategy, the paper propose a new Combine-VMI model for 3PL company. This model will also be discussed in the end of VMI implementation in Celestica (Suzhou).
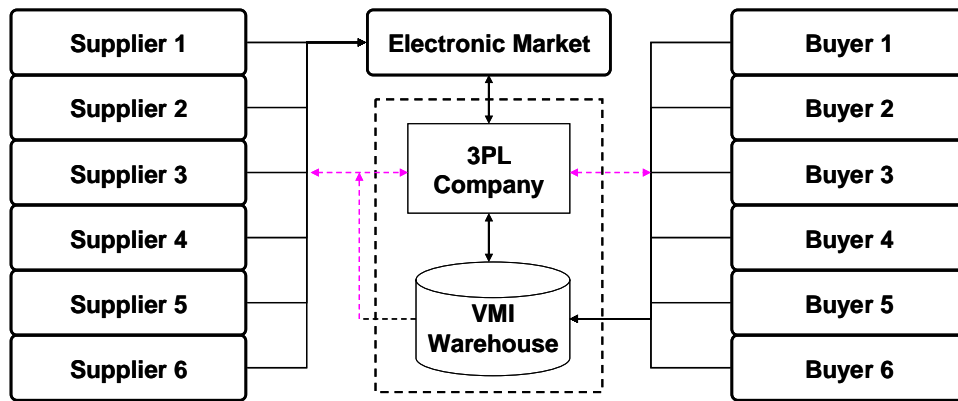
FIGURE 4.1 New Combine-VMI Model for 3PL Company

Figure 4.1 shows a new combined-VMI, compare with traditional VMI mode, this new model combines many customers' VMI inventory. Generally suppliers take title of goods, 3PL company only monitor VMI inventory including warehouse operation, VMI delivering, VMI good balancing.

4.1.3 Consideration of The Electronic Market

Take 3PL company DELTA (Suzhou) for example, near the company there is a larger electronic market being built recently. When it is completed, it is much easier for the 3PL to implement Combine-VMI for upstream suppliers and downstream buyers. A centre warehouse especially for VMI projects form customers' can be located near the electronic market.

4.1.4 Freight Decrease

For instance, 3PL Company DELTA first receive order information from buyer and producing capacity information from supplier, associate with 3PL company transportation capacity, form a optimal VMI replenishment policy, when to delivery and how much to delivery. Based on its advance of transportation, set an optimal routing for corresponding shipment and achieve a lower freight for each customer.

4.1.5 Service Level Increase

Associate with Electronic Market and combined many VMI projects from different suppliers and customers; it is efficient to reduce the urgency and large requirement from the rapid change electronic market in certain time for some customer. Because 3PL have the full information from both Electronic Market and other VMI safety stock detail from different suppliers, it is quite possible that 3PL act as an agency to satisfy urgency and large order by balancing the VMI stock or just purchase goods in the Electronic Market.

4.2 Uncertainty Factors Analyzing

4.2.1 Overview of Economic Order Quantity (EOQ)

The economic order quantity (EOQ) is the simplest and most fundamental of all inventory models. It describes the important trade-off between constant order costs and holding costs, and is the basis for analysis of more complex systems (Steven Nahmias 2002).

Following is a calculation for optimal Q in EOQ model.

$$TC_W = \frac{1}{2}Qvr + \frac{d}{Q}A \tag{4.1}$$

$$\frac{dTC}{dQ} = \frac{1}{2}vr - \frac{d}{Q^2}A \implies Q_W = \sqrt{\frac{2Ad}{vr}} \tag{4.2}$$

$$TC_W = \frac{1}{2}\sqrt{2Advr} + \frac{1}{2}\sqrt{2Advra} = \sqrt{2Advr} \tag{4.3}$$

Where, equation (4.2) Q_w denotes the best size of order quantity, and Q_w will lead to a minimum total inventory cost TC_W at equation (4.3).

4.2.2 Source of Uncertainty Factors in Supply Chain

Large-scale manufacturing system is becoming more complex day by day, especially in its material flows. Different suppliers use different ways to delivery materials and components to product line, after complicated produce process, manufacturers delivery various components and final productions to customers. Material goes through transportation, manufacturing, transportation, remanufacturing, finally assembled to productions, ship to customers. Transportation also has lots options, such as flight, ship, truck, train, etc, they might be mixed sometimes. As complicated as the material flow, there are many factor can generate the uncertainty.

1. Supplier uncertainty, namely the production system of the supplier may have malfunction or the transportation of goods may delayed, result in lead-time uncertainty and uncertainty with meeting order.

2. Manufacturer uncertainty, namely system reliability, plan execution limitation of manufacturer may result in manufacture time uncertainty.

3. Customer uncertainty, namely demand from customer is not fixation, forecasting

always has inaccuracy result in demand uncertainty.

4.2.3 Uncertainty Outcome

Uncertainty of supply chain is mainly behaved as demand uncertainty and lead-time uncertainty. The former relates to sale ratio fluctuation during a lead-time cycle, while the latter relates to various changes of lead-time. These two uncertainty outcomes will affect inventory management policy directly.

1. Demand uncertainty, demand are hard to predict because there are many uncertain factors in the market which will impact the requirement for certain good.
2. Lead-time uncertainty, lead-time from supplier to customer is a key factor to timely replenishment and assure the manufacturing, but as there are various manner of shipment and many man made factor impact the lead-time as well, such as truck broken, weather reason, etc,.

4.2.4 Uncertainty Demand and Lead-time Analyzing

Demand forecasting is used to forecast order quality in a lead-time. In many situation, as state above customer requirement is variety, can only be estimate by forecasting, but demand forecasting have certain error, the demand and order during a lead-time in practice can not forecast accurately. In order to avoid stock out situation, safety stock must be set up in inventory. Kun XIE and Kai LIU (2003) propose a model to analysis the uncertainty subject to demand and lead-time uncertainty.

First assume lead-time here is constant and order quality is already know, the expression is

$$SS = k\alpha\sqrt{L} \tag{4.4}$$

Where

$L-$ Lead-time

$\sigma-$ Standard deviation of demand

$k-$ Safety factor, related to service level

From expression (1) could indicate that demand standard deviation is linearity pro rata with safety stock, demand standard deviation σ is larger, demand variety is larger, under a condition of keeping same service level, safety stock required is larger, average inventory level is larger, risk of inventory is larger. Hence, demand

uncertainty is the prime factor affect inventory cost.

Lead-time is the time from order placed until order is received. In general, it is very difficult to incorporate the variability of lead-time into the calculation of optimal inventory policies (Steven Nahmias 2002). For instance, during electronic component transportation in a manner of truck, there might be snow, raining, or other weather reason to delay the shipment.

Lead-time uncertainty not mean existing inventory policy can not take responsibility of continual replenishment, it is necessary to set safety stock to guarantee to meet the stock out situation during a lead-time. If lead-time is longer, the safety stock should be larger which bring more cost increasing and capital fund risk.

Classical inventory theory illustrates that the levels of inventory and uncertainty in demand and lead-time are related (Silver & Peterson, 1985).

$$SS = k\sqrt{L_{\alpha}\sigma_R^2 + R^2\sigma_l^2} \tag{4.6}$$

Where

L_{σ} Average lead-time

σ Standard deviation of lead-time

R Average demand per lead-time

σ_R Standard deviation of demand per lead-time

k Safety factor

To explain uncertainty impact inventory, here a simple case is studied. A assumed order quality is constant $Q=100$, service level is 97%, from the index table the corresponding $k=1.88$, with general consideration, 3 possible assumption can be stated:

1. Demand is uncertain, lead-time is know and constant, standard deviation of demand $\sigma=2.54$, lead-time is constant $L=1$.
2. Demand is know, while lead-time is uncertain, demand $R=5$, standard deviation $\sigma_R=2$.
3. Demand and lead-time are both uncertain, $\sigma_R=2.54$, $\sigma=2$, $L=1$, $R=5$.

Due to expression 1 and 2, uncertain factors affect inventory level and safety stock can be compared as following table.

TABLE 4.1 Compare uncertain factors of demand and lead-time

Assumption	Order quality	Safety stock	Average inventory
R, L are constant	100	0	50
Assumption 1: R is uncertain	100	$1.88\,\sigma\sqrt{L}$	$50+1.88\,\sigma\sqrt{L}$
$\sigma=2.54$, $L=1$	100	5	55
Assumption 2: L is uncertain	100	$1.88R\sigma_l$	$50+1.88R\sigma_l$
$R=5$, $\sigma_l=2$	100	19	69
Assumption 3: R, L are uncertain	100	$1.88\sqrt{L_\alpha\sigma_R^2+R^2\sigma_l^2}$	$50+1.88\sqrt{L_\alpha\sigma_R^2+R^2\sigma_l^2}$
$\sigma_R=2.54$, $\sigma=2$, $L=1$, $R=5$	100	26	76

Where table 2 indicates that under a condition of service level is 97%.

If demand and lead-time are constant, there is no need to set safety stock, average inventory is 50, but is an ideal assumption.

The first assumption, lead-time is constant while demand is uncertain, safety stock is 5, and average inventory is 55. The second assumption, demand is know and constant while lead-time is uncertain. The third assumption, demand and lead-time are unpredicted, safety stock is 26, and average inventory is 76. Hence, with a precondition of demand and lead-time uncertainty, to meet a requirement of keeping a concern service, safety stock will play a critical role in inventory management.

In traditional inventory management system, safety stock is associated with service level, with relevant investigate, increase service level meantime decrease inventory level as well as safety stock level can not achieve at the same time. In order to increase service level, safety stock must increase. But to much safety stock is also a problem, as stated above, it will result in a high level of inventory, increase capital cost burden for an enterprise. So in order to reduce such risk, primly deal with reducing demand and lead-time uncertainty, to meet a certain service level for the customers, reduce safety stock, many scholars propose several models to achieve this goal, such as VMI, Inventory risk sharing, JIT, CPFR.

4.3 Benefit Analyzing of VMI

4.3.1 Reasons that VMI is Popular

Vendor-managed inventory (VMI) program have begun to proliferate over the past several years. Companies have used them as a potential solution to both the

inventory problems that have plagued the electronics industry and as a method of improving financial performance (Christopher Roberts 2004).

As early as in 1980s, P&G and Wal-Mart began to implement VMI, the buyer, Wal-Mart give the inventory management responsibility to supplier P&G, suppliers substitute distributor (wholesaler and retailer) decide inventory level and replenishment policy. On the first side, it achieve terminal sale pull supply chain via information sharing, enable supplier make replenishment plan more efficient with assistant of downstream, on the other side is consignment sale operation, under a contract agreement supplier own inventory until buyer sale products out. But it was not recognized and attracted attention by academia. Along with product-cycle reducing, uncertainty demand increasing and demand of serves level increasing, the conflicts between inventory and serves level is becoming more and more prominence. At the same time, along with information development, information sharing ability improving, information sharing cost is decreasing; advantage of VMI emerges and has been emphasized day by day.

There are five reasons VMI is popular recently.

- One, it can help the retailer reduce its inventory holding cost and increase inventory turn ratio rely on vender efficient management.
- Second, give the retailer more good opportunity to purchase vender's products.
- Third, vendor has a uniform forecasting, replenishment policy given information especially when there are uncertain demand and uncertain lead time.
- Four, reduce the bullwhip effect and give a sooth demand curve.
- Five, increase the competitive edge of the whole supply chain, every aspects of supply chain will gain more benefit and more competitive.

4.3.2 P&G VMI Successful Case Introduction

Take VMI project implementation of P&G and one retailer to explain processes and benefit of VMI.

The retailer has 10 stores and 1 distribution centre in Hong Kong, before VMI implemented, everything is manual acting.

The VMI technology takes KARS software + EDI of P&G.

Before project implemented, P&G has 115 categories of production units; centre warehouse inventory level is 8 weeks; inventory level for store is 7 weeks; stock out percentage is 5%. P&G relevant employees decided to implement VMI technology to deal with efficient replenishment problem of P&G productions after detailed analyzed high level inventory and stock out rate. This project was launched at March 2003, P&G and retailer invested information technology, logistic shipment, purchasing department to establish multi-function team. During implementation in

the next couple months, reorganize flow of order and delivery, indentify standard flow, new clearly role, task and responsibility, install VMI system, establish electronic data exchange platform.

This system started running at July, 2000. After 3 months, operations index improved obviously, economy benefit was prominent. Retail's total sale (P&G) increased 40%; P&G production units 141 (increased 26%); centre warehouse inventory 4 weeks (decreased 50%); store inventory 5.8 weeks (decreased 17%); stock out rate 3% (decreased 40%). Moreover, retailer's supply chain management had transferred to a more scientific and rational mode, every aspect of retailer worked efficient in this new system, extremely saved work force and increased the efficiency, decreased operation cost.

4.3.3 How VMI Keep Cost Down?

Since VMI well know as an efficient strategy for supply chain management, how is it work to reduce inventory cost? Yuliang YAO (2001) proposed a mathematical method to demonstrate VMI can reduce both vendor and customer's logistic cost under some assumptions.

TABLE 4.2   Notation Introduction

Parameter	Definition of Parameter
d	Annual demand
Q	Order quantity of supplier
q	Order quantity of customer
A	Order cost of supplier
a	Order cost of customer
L	Lead-time from supplier's supplier to supplier
l	Lead-time form supplier to customer
R	Carrying charge per unit during time horizon(supplier)
r	Carrying charge per unit during time horizon(customer)
k	Ratio of vendor' lead-time to customer's lead-time
TC	Total cost

Initially, consider of a normal vendor-retailer relationship, e.g. the inventory level has reorder point both for vendor and customer; they place order when inventory level reach the reorder point. They have their own inventory holding cost and order cost. Without VMI system, the total logistic cost follows traditional Economy Order Quantity (EOQ) function. The corresponding equation is given and the total cost as well.

$$TC_W = \sqrt{2Advr} \qquad (4.7)$$

$$TC_{withoutVMI} = \sqrt{2AdR} + \sqrt{2Adr} = \sqrt{2Ad}(\sqrt{R} + \sqrt{r}) \tag{4.8}$$

Assumption: the replenishment lead-time equals the inventory cycle time.

Now consider the case where the manufacture and the retailer have agreed to implement VMI. With a full overview of the demand information from retailer, vendor monitor retailer's inventory and decide the replenishment plan, which mean the order cost of retailer follow to zero. For computational convenience, takes upper case and obtains a new expression for total cost.

$$TC_{withVMI} = \frac{d}{Q}A + \frac{1}{2}QR + 0 + \frac{1}{2}qr = \frac{dA}{kq} + \frac{1}{2}q(kR + r) \tag{4.9}$$

Since lead-time equals the inventory cycle time, hence, the average inventory level is proportional to the replenishment cycle time. From a compare of relevant equation.

$$\begin{cases} \dfrac{d}{Q} = \dfrac{1}{T} = \dfrac{1}{L} \\ \dfrac{d}{q} = \dfrac{1}{t} = \dfrac{1}{l} \end{cases} \Rightarrow k = \frac{L}{l} = \frac{Q}{q} \tag{4.10}$$

Take the derivative of q for this equation; we obtain the optimal order quantity q for retailer.

$$q = \sqrt{\frac{2Ad}{k(kR + r)}} \tag{4.11}$$

$$TC_{withVMI} = \sqrt{2Ad} \cdot \sqrt{\frac{(kR + r)}{k}} \tag{4.12}$$

To examine the cost saving comparing with without VMI situation, Yuliang Yao set a parameter V to indicate the cost saving percentage.

$$V = \frac{TC_{withoutVMI} - TC_{withVMI}}{TC_{withoutVMI}} = \frac{\sqrt{R} + \sqrt{r} - \sqrt{\dfrac{kR + r}{k}}}{\sqrt{R} + \sqrt{r}} = \frac{\sqrt{a} + 1 - \sqrt{\dfrac{ka + 1}{k}}}{\sqrt{a} + 1} \tag{4.13}$$

Note a of equation (4.13) is the ratio of inventory holding cost of the vendor's to the retailer's.

$$\frac{\partial V}{\partial k} = \frac{1}{1+\sqrt{a}} \cdot \frac{1}{2k^2} \cdot \sqrt{\frac{k}{1+ak}} > 0 \qquad (4.14)$$

If $V \geq 0$, we obtain $k \geq \dfrac{1}{1+\sqrt{2a}}$ $(\forall a)$ from equation (4.15).

$$k = \frac{L}{l} \geq \frac{1}{1+\sqrt{2a}} \Rightarrow L = kl \geq (\frac{1}{1+\sqrt{2a}})l \qquad (4.15)$$

So if $L \geq (\dfrac{1}{1+\sqrt{2a}})l$, $V \geq 0$. It indicates if the lead-time of vendor is equal or larger than $(\dfrac{1}{1+\sqrt{2a}})l$ time of the lead-time of retailer's, it is positive effect to implement VMI.

Inventory holding cost for vendor with VMI is expression $C_{vendor} = \dfrac{1}{2}QR$, since $\dfrac{Q}{q} = \dfrac{L}{l}$ and $k = \dfrac{L}{l}$, so obtain. Since $q = \sqrt{\dfrac{2Ad}{k(kR+r)}}$, substitute Q and q in expression $C_{inv} = \dfrac{1}{2}QR$, obtain $C_{vendor} = \dfrac{1}{2}\sqrt{2Ad} \cdot \sqrt{\dfrac{R^2 k}{kR+r}}$. Substitute $q = \sqrt{\dfrac{2Ad}{k(kR+r)}}$ in expression $C_{customer} = \dfrac{1}{2}qr$, obtain $\dfrac{1}{2}\sqrt{2Ad} \cdot \dfrac{r}{\sqrt{k(kR+r)}}$.

With all the results get above, we can obtain table 4.3 to show the benefit of implementation of VMI.

TABLE 4.3   Benefit Comparison Without and With VMI

Inventory holding cost	Vendor	Retailer
Without VMI	$\dfrac{1}{2}\sqrt{2Ad} \cdot \sqrt{R}$	$\dfrac{1}{2}\sqrt{2Ad} \cdot \sqrt{r}$
With VMI	$\dfrac{1}{2}\sqrt{2Ad} \cdot \sqrt{\dfrac{R^2 k}{kR+r}}$	$\dfrac{1}{2}\sqrt{2Ad} \cdot \dfrac{r}{\sqrt{k(kR+r)}}$

4.3.4 VMI Benefit Computation Model Case Study

Case study, for instance, $d = 1000$, $A = 400$ Yuan, $L = 8$ days, $l = 5$ days, $R = 20$ Yuan/unit, $r = 40$ Yuan/unit.

From the known parameters, we obtain $k = \dfrac{L}{l} = 1.6$, $a = \dfrac{R}{r} = \dfrac{20}{40} = 0.5$,

$$\begin{cases} L = 8 \ day \\ l = \dfrac{1}{1 + \sqrt{2 \cdot \dfrac{20}{40}}} = 2.5 \ day \end{cases} \Rightarrow L > (\dfrac{1}{1 + \sqrt{2a}})l \Rightarrow k > \dfrac{1}{1 + \sqrt{2a}} \Rightarrow V > 0 \qquad (4.16)$$

From equation $(4.16) \, L \geq (\dfrac{1}{1 + \sqrt{2a}})l$, hence $V > 0$, so VMI will have a positive effect on this vendor-customer supply chain inventory control, substitute parameter in equation above and easily obtain a inventory holding cost detail as filled in the table below.

TABLE 4.4   Benefit Comparison With and Without VMI for This Case

Inventory holding cost	Vendor	Retailer
Without VMI	2000 Yuan	2828.4 Yuan
With VMI	1647.6 Yuan	2059.4 Yuan

Table 4.4 indicates without VMI, the inventory holding cost is 2000 Yuan and 2828.4 Yuan, while is reduced a lot with VMI, as the result 1647.6 Yuan and 2059.4 Yuan. Note here assume lead-time for vendor and customer equal to their replenishment cycle, that is the precondition.

It is obviously when lead-time of vendor's and customer's satisfy certain results of proportional to inventory holding cost of each partner, VMI implementation will reduce inventory cost efficiently.

5 Case study

5.1 Case Company Introduction

Celestica (Suzhou) Technology Co., Ltd is a wholly owned subsidiary of Celestica Inc, a Toronto-based company.

Celestica's Suzhou facility was established in December 2000 with an initial investment of US$120 million. It started with less than 100 employees in a small factory inside the Xinqu Industrial Square, Suzhou Industrial Park. As the business gained greater momentum, Celestica increased its presence by expanding the facility to a new site in August 2003. Built up with an additional investment of US$20 million, this new facility is located at No. 448, Suhong Middle Road, Suzhou Industrial Park. Today, Celestica's Suzhou facility employs more than 1,600 employees.

5.2 Existing Supply Chain Investigate
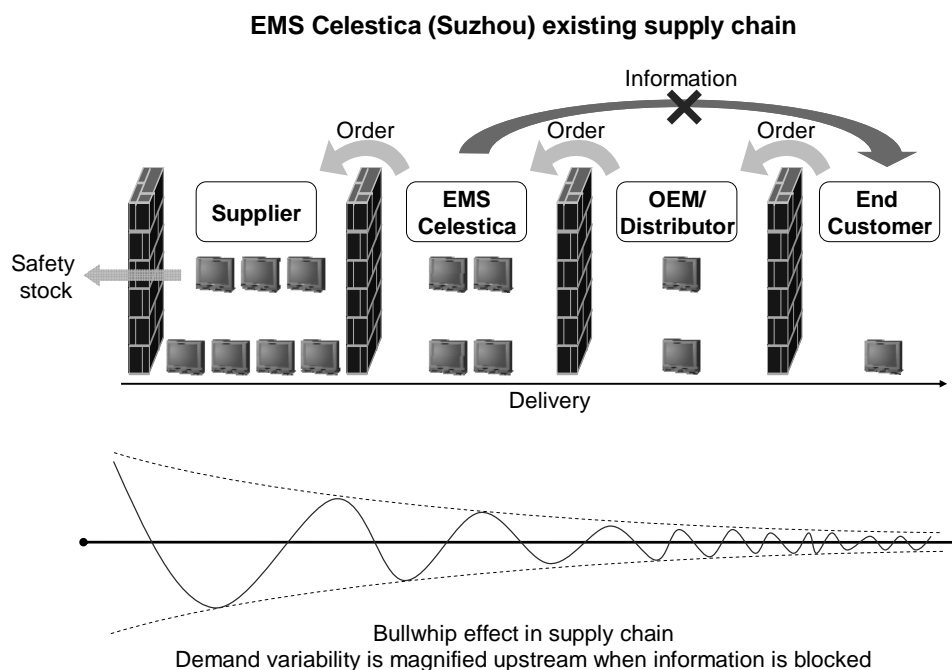
FIGURE 5.1   Existing Problem in Supply Chain of Celestica (Suzhou)

Figure 5.1 describes the current supply chain problem, as a traditional EMS enterprise Celestica (Suzhou) mainly is purchasing electronic component and supply downstream OEM/Distributor with electronic products. In this supply chain, demand was received upstream one by one by order only, the cooperation between each member is very limitation which described as red wall in the figure, the wall generally represent factors block information sharing and communicating. Because of information asymmetry, members of the supply chain can only get the date through order, and in order to march variety demand, they have to keep high safety stock to keep service level. The worst problem which is not very visible is the requirement of consignment form the customer is very short, as in such a competitive market, it is unavoidable, but for EMS industry, the lead-time of some material is very long and unique that Celestica (Suzhou) had to build high level safety stock to march these specially and unpredicted order to maintain customers

and keep service level. It lead to a crag-fast situation, one aspect is to set high level safety stock, by this it march the unpredicted large order, large quantity of safety stock will hold a lot money, and as market are changing rapidly, safety stock have the possibility to be eliminated which is really a big financial pressure for company; one the other aspect, if reduce the safety stock, it will weaken the ability to market variety demand and lead to less competitive advantage, more worse, loose sale and customer.

5.3 Reason Research

Most raw material requirement of Celestica (Suzhou) are electronic component, material categories are variety and complex, material manufacturing cycle is long, some of these material is unique and can not be substituted. Material suppliers mainly are international distributor and original manufactory. The main problems emerged in inventory management of Celestica (Suzhou) can be described in following points.

1. Since raw material category is variety, Celestica (Suzhou) has a lot supplier, it is hard to understand and coordinated with them all, and rise relationship with them as well. Moreover, many of them are domestic enterprises which are very careful to protect their own benefit.
2. Celestica (Suzhou)'s manufacturing plan is easily impacted by market demand change, traditional inventory management can not deal with such quickly change market, produce line paused and financial turnover problem are the outcome of stock out or over stock.
3. Material needed of Celestica (Suzhou) is mainly Integrate Circuit (IC). The manufacturing cycle of IC generally is 2-16 weeks, but mightily competitive market environment do not accept Celestica (Suzhou) has such a long purchasing cycle, otherwise their production will be eliminated before sale, can not satisfy certain order will also loose sale and customer.
4. Some electronic component of raw material in Celestica (Suzhou) has special function, they are only applied in some narrow aspects, and always has unique original supplier. The special character lead original suppliers not willing to stock up early, for the sake of continual replenishment and manufacturing, company has to set sufficient safety stock to march some large order quantity.
5. Electronic component has a constant production lifecycle time, just as food, if exceed the lifecycle time, the material will be deterioration failure. It is always a financial threaten for Celestica (Suzhou) if large inventory is deterioration in the further.
6. Forecasting and apply safety calculation mathematic methodology is a general way to set safety stock level and decide replenishment plan. But in practice, the safety stock strategy is not so successful because the data form downstream customer is only based on order, that is, can not really predict the further demand for relevant item, the error for forecasting is unsatisfied.

5.4 Condition before VMI Launch

To meet challenge Celestica (Suzhou) must take new inventory management strategy, low cost and keep service level, increase competitive edge finally.

In practice, because of special character of EMS industry, the expected VMI strategy is defined as following.

Supplier owns the warehouse in or near EMS manufactory, supplier monitor the inventory level and safety stock level. Based on order data given by EMS manufactory, supplier forecasting future demand and decide replenishment plan for relevant electronic component. The transfer of title of stock is take place when EMS company pick up stock from VMI warehouse, before that time the title of stock is belong to the supplier.

Some arguments are needed to know:

➢ It is obvious that successful VMI is based on the closer and deeper partnership between vendor and retailer (Abdelmaguid Tamer, et al., 2001)
➢ For a VMI program to succeed, there are must be adaptation, flexibility and streamlining in both the organizations (Victoria A. Micheau 2005).
➢ For VMI to work effectively trading networks require a very high degree of collaboration between customers and their supplier (Brian Marsden 2007).

So, before implementation of VMI in this EMS supply chain, there is several points for Celestica (Suzhou).

1. Convince internal management and employees of new methods of doing business
2. Fast Feedback and Know How technology must be well recognized by the employees.
3. Convince external members; compose supplier and downstream customers to trust each other, based on contract and belief support system of VMI.
4. Sigh efficient VMI contract, through proposal, requirement and law to pressure supplier and customer to give relevant data for better supply chain cooperation.
5. Introduce into EDI system for a data investigating, analyzing and communicating as well. EDI system is critical to implement VMI, in the EDI system, information compose of data, flow, MPR, information tracing, market trends. EDI enable supplier, EMS, OEM, distributor and end customer to achieve information sharing, order, delivery, inventory level and safety level inquiring.
6. Logistic department choose optimal methodology to decide VMI replenishment plan. E.g. 3PL-VMI forecasting and operational methodology substitute traditional VMI.

5.5 VMI Model Proposal

To solve this problem, start with information flow control, logistic management and change role of supplier, reduce time interaction, detail proposal is based in two aspects.

3PL-VMI Model based on EDI for EMS upstream supply chain
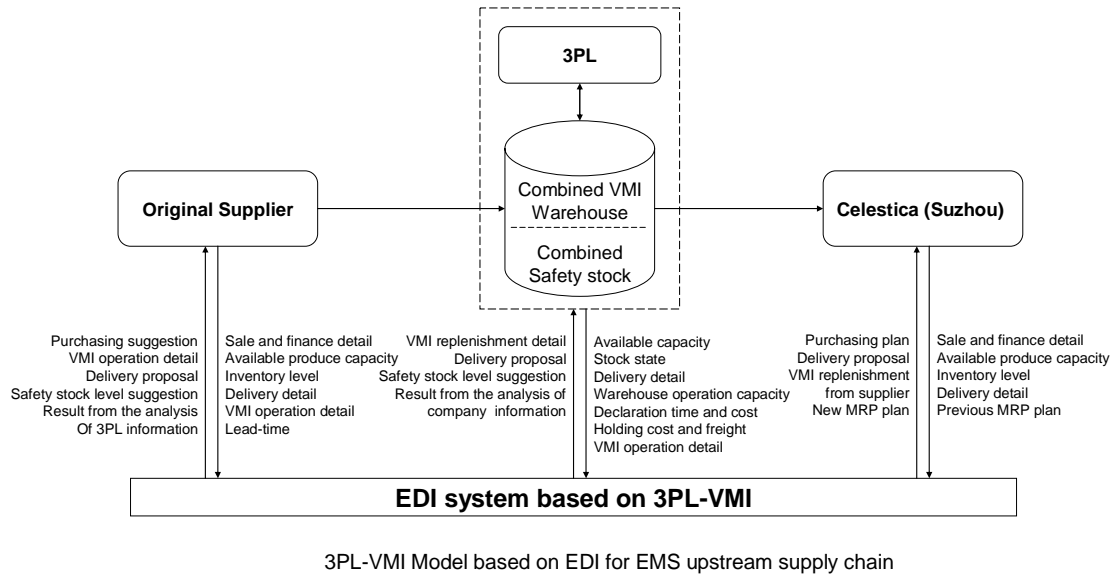
FIGURE 5.2   3PL-VMI Mode for EMS Upstream Supply Chain

On one side is to cooperate with supplier to decrease the lead-time, take advantage of their expertise of raw material manufacturing and powerfully supply chain net work; VMI is mainly implemented upstream, downstream JIT technology to find demand, meantime activate VMI replenishment from supplier by shorten the lead-time for fast feedback downstream. Based on the case study in the end, traditional separately VMI management is not recommend, but a new VMI strategy, with 3PL involved, is proposed aiming at lead-time reducing while maximal reduce the safety level.

| Purchasing plan
Replenishment
Delivery proposal
New MRP plan
VMI replenishment
from supplier | Sale and finance detail
Available produce capacity
Inventory level
Delivery detail
Previous MRP plan | Purchasing suggestion
JIT Replenishment plan
Result from the analysis
of customer and market | Require MRP information
Produce capacity information
On-hand stock state
Company's customer file
Order information from customer | Market trend analysis
Customer tracing
Product structure
Demand searching
Result from customer file |

EDI system of Know How and Fast Feedback mechanism

"Pull" Model base on EDI for EMS downstream supply chain

Figure 5.3 "Pull" Model for EMS Downstream Supply Chain

On the other side, indeed, as a perspective view of demand oriented, first consider the downstream. Extend the order cycle time, note it is not mean to extend purchasing cycle time of OEM/Distributor, but extend order arriving time by early receive information from customer and form order as soon as possible. More detail for downstream supply chain integration, it is more likely a pull system. Customers from downstream not only give order to Celestica (Suzhou), but also give their customer's file information. Which means, most EMS company only receive order form downstream, that lead to information asymmetry, because what these EMS have are just the orders or forecasting from OME/Distributor, not the information really comes from end customer, the real information of end customer is comprehensive and useful which should be use and analysis completely.
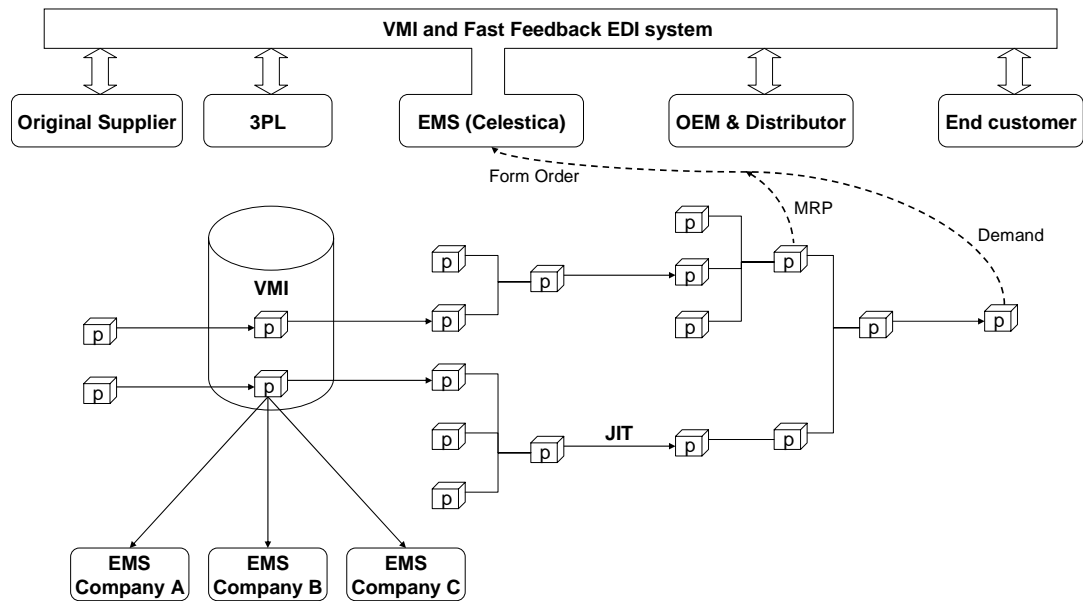
3PL-VMI combined Pull model in EMS supply chain management

FIGURE 5.4   Final Structure of 3PL-VMI Pull Model Description

Figure 5.4 is a combine model for whole EMS supply chain. It indicates that the EDI system links each partner together, information communicating and analyzing is fished on the EDI system. Result from information from end customer and supplier supply chain ability, EMS Celestica form order as early as possible. Which successfully achieve pull order from downstream and short lead-time upstream to regain control of the supply chain and reduce the inventory costs.

5.6 Implementation of VMI

Generally describe, it is a 3PL-VMI combine Pull supply chain model, a little complicate, but have the comprehensive advantages.

Install of EDI system based on 3PL-VMI and establish Fast feedback mechanism

1. Sign VMI contract with partners of the supply chain, convince contract support of VMI system. Especially, got to fully analysis how to make contract with 3PL company which is new and popular recently.
2. By apply of EDI platform for the supply chain; Celestica (Suzhou) should able to collect the real end customer's information. Require information from different partners of EMS supply chain, relevant date compose of production MRP, delivery capacity, stock level, purchasing plan etc,.
3. Fast Feedback and Know How technology must be learned and applied for downstream supply chain, that is, analysis date at the first time before customer placed a order to OEM/Distributor, Celestica (Suzhou) must able to form a

internal order to finish a potential manufacturing as soon as possible, as it can get downstream MRP plan detail and know its supplier' manufacturing cycle and lead-time. After purchasing suggestion under a precondition of contract with downstream companies, if requirement JIT replenishment permission, delivery the right products with the right quantity at the right place at the right time. Because of JIT delivery, inventory of Celestica (Suzhou) can maximal reduced. This point explains how the JIT delivery involved in Fast feedback mechanism and how Fast Feedback intend to achieve a goal aiming at improve service level and reduce inventory.

4. When potential internal order is formed, immediately start manufacturing plan meanwhile inform supplier start to make corresponding material VMI support plan. The key factor to achieve Fast Feedback JIT replenishment need efficient material support, 3PL-VMI in the upstream will efficient assist supplier to achieve the goal by reducing the lead time and balance a safety stock via combined safety sock for serial companies, for instance, various demand from EMS company A, EMS company B, EMS company C will self balance lead to a lower level safety stock. This step lower the stock capital investment and decrease lead-time, the factors change will lead to a significant meaning to guarantee whole VMI strategy running better.

5. 3PL-VMI is suggested to implement on the left side, 3PL company management the VMI warehouse for supplier and combined the delivery due to freight reducing. The title of stock is change once the company gives a pick up requirement to 3PL company. Supplier is obviously reducing the safety stock because this mode can balance deferent demand from different VMI contract EMS company. With a know of MPR plan downstream, the potential demand can be formed as internal order as soon as possible, and JIT will take the rest delivering task. As conclusion, downstream can extend the order arriving time and the upstream can reduce lead-time and stock capital risk.

5.7 Benefit of VMI

The benefit of implement VMI in Celestica (Suzhou) supply chain.

1. Material consignment timely and complete ratio is guaranteed. Celestica (Suzhou) can arrange material to produce line in any time based on manufacturing plan, which ensure the produce and improve service level.
2. Reduce inventory turnover time, reduce inventory capital. VMI can obviously reduce inventory turnover time because title of stock is transferred only when factory pick up these stock from VMI warehouse in 3PL company.
3. Due to VMI and Fast Feedback strategy thought, internal organization will be proved. Requirement of VMI and Fast Feedback drive employee to a consideration of customer orient and supply chain inventory control mind, this is really help with further company strategy decision make.
4. Data from all the members of the supply chain, and it must enhance its analyzing

and forecasting ability, comprehensive information will enable the company observe market trends clearly and give a more accurate forecasting and replenishment, with additional benefit of observation of the market trends, it is good for further development decision making.

5. The project will satisfy some urgency order and large production requirement in random time. Since all the members of EMS supply chain has a wholly cooperation and attend to build a long time and steady strategy relationship, if there is some urgency production requirement, EMS supply communities will willing to first satisfy the requirement of its collaborator, guarantee manufacturing or sale for each other.

6. Financial benefit; VMI reduce cost of order, 3PL involved reduce freight, reduce lead-time and warehouse operation cost, combined VMI safety stock save capital cost.

7. Based on combined VMI and Pull strategy, the model enable supplier and customers act a more significant part in supply chain, not outside, to march the uncertain demand and rapidly change market and regain a leading position in competitive market.

5.8 Risk of VMI

Compare with traditional supply chain management, VMI in EMS industry has many advantages; however, many negative factors still existing impact VMI in reality practice, which can not be despised.

1. Overstock risk, VMI has extremely decrease the risk emerge in manufacture overstock by supplier monitor customer's inventory and set the safety stock. Since VMI contract compose relevant agreed overstock risk sharing mechanism if overstock is happen or stock is eliminated, supplier will burden the most overstock risk which probably feedback in production price. Though a new 3PL-VMI model is proposed, the risk is still existing as a threaten.

2. Risk of material price. The title of stock transfer at the time when material pick-up by 3PL and delivery to manufacturer' factory. Since the price of electronic material in the warehouse is easily impacted by market trend change. It must emerge price risk for EMS manufacture.

3. EDI system risk. One disadvantage of traditional VMI solutions was that the technological investment was so high that it restricted access to only the largest supplier – who could afford the time and money involved in seeking the benefit (Brian Marsden 2007). The selection and function establishment of EDI will be a long time of continual process for EMS company, the investment of both employees and capital are big pressure for company organization and economy.

4. Cross culture challenge, to well cooperate with partners of EMS supply, especially for Celestica (Suzhou), as an entry foreign company, how to coordinate with domestic material supplier and end customer that mainly have different culture, the relationship with internal employee and external partners is

really a risk, if company want to well perform in the VMI implementation.

5.9 VMI Case Analyzing

Celestica (Suzhou) want to implement VMI with one supplier upstream intend to reduce stock cost and lead-time. Original plan is traditional VMI cooperate with supplier. Since same material sale to different EMS companies, Celestica (Suzhou) intend to persuade supplier to implement combined VMI strategy associated with 3PL company by convince supplier with the total stock saving and inventory cost saving from 3PL-VMI with VMI.

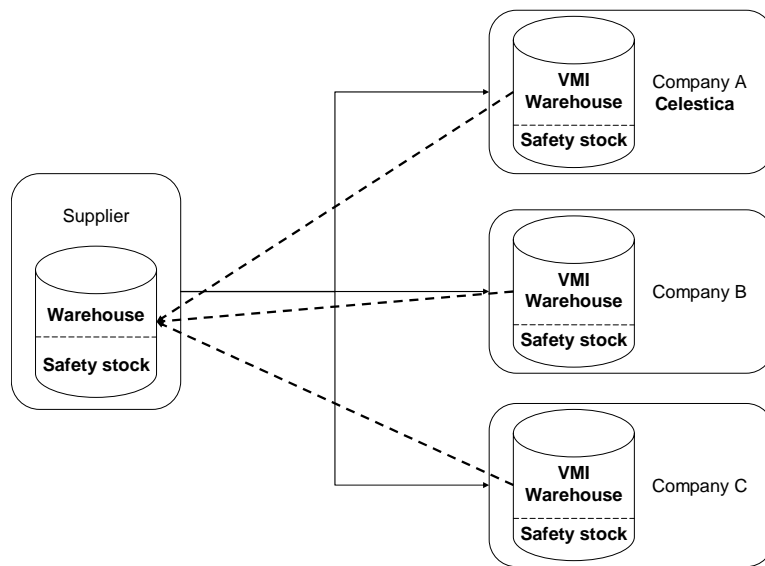***FIGURE 5.5***   Combine Separately VMI Inventory to Centre VMI Warehouse

The implementation of the "traditional" VMI – i.e. limited to supplier-customer dyads – leads to wasting significant opportunities that could instead be exploited by managing the supply network as a whole rather than as a series of dyads (Pamela Danese 2005).

Generally, first introduce relevant notations for EOQ model in the table following.

TABLE 5.1 Notations Introduction for Case Computation

Parameter	Definition of Parameter
d	Total demand in a replenishment cycle
Q	Order quantity
A	Order cost
F	Transportation cost
L	Lead-time from supply to customer
l	New lead-time give by 3PL company
σ	Standard deviation of the errors of demand forecast during lead-time
v	Unit value
r	Carrying charge percentage during time horizon, note time here is one month.
S	Reorder point
SS	Safety stock
SS_i	Capital of safety stock
k	Safety factor, related to service level
B_2	Fractional charge per unit short
TC	Total cost
$P_u(k)$	The complementary cumulative distribution
$G_u(k)$	A special function of the unit normal variable. The fill rate is equal to $1 - G_u(k)$

$$TC = C_{order} + C_{delivery} + C_{inventory} + C_{stockout} \tag{5.1}$$

$$C_{order} = \frac{d}{Q} A \tag{5.2}$$

$$C_{delivery} = Fd \tag{5.3}$$

$$C_{inventory} = \frac{1}{2} Qvr + k\sigma vr \tag{5.4}$$

$$C_{stockout} = \frac{d}{Q} B_2 v\sigma G_u(k) \tag{5.5}$$

$$P_u(k) = \frac{Qr}{dB_2} \tag{5.6}$$

$$SS = k\sigma \tag{5.7}$$

$$C_{SS} = vk\sigma \tag{5.8}$$

Decision rule for a specified Fractional Charge (B_2) per unit short can be found in Silver, E.A., Pyke, D.F. and Peterson, R. (1998). Here, we do not prove the function again and the decision rule.

First introduce EOQ model with normal lead time demand and per unit shortage cost.

The total expected cycle cost is TC

$$TC = \frac{d}{Q}A + Fd + \frac{1}{2}Qvr + k\sigma vr + \frac{d}{Q}B_2 v\sigma G_u(k) \tag{5.9}$$

$$\begin{aligned}\frac{dTC}{dQ} &= -\frac{d}{Q^2}A + 0 + \frac{1}{2}vr + 0 - \frac{d}{Q^2}Bv\sigma G_u(k) \\ &= \frac{1}{2}vr - \frac{d}{Q^2}[A + Bv\sigma G_u(k)]\end{aligned} \tag{5.10}$$

Since equation (4.2) $Q = \sqrt{\dfrac{2Ad}{vr}}$ he optimum order quantity Q^* can be calculated by

set $\dfrac{dTC}{dQ} = 0$

$$Q^* = \sqrt{\frac{2Ad}{vr}}\sqrt{1 + \frac{B_2}{A}v\sigma G_u(k)} = Q_W\sqrt{1 + \frac{B_2}{A}v\sigma G_u(k)} \tag{5.11}$$

Consideration of short charge B_2 factor in B items, with respect to ABC classification demonstration by Silver (1998), introduce iterative process steps to achieve a optimal Q and k following.

Step1, Calculate $Q(EOQ) = \sqrt{\dfrac{2Ad}{vr}}$, and calculate corresponding $P_u(k) = \dfrac{Qr}{dB_2}$.

Step2, Search value k from the unit normal distribution table, find corresponding

$G_u(k)$, then calculate Q by $Q = Q_W \sqrt{1 + \dfrac{B_2}{A} v\sigma G_u(k)}$. Round Q to the nearest integer, rename as Q^*.

Step3, If Q^* is equal to the former Q^*, stop, otherwise, go step2.

From these three steps, well could figure out a optimal Q^* and k as well, substitute k in $SS = k\sigma$ lead to a safety stock level, then the reorder point is easy to obtain reorder point $s = \hat{x} + SS$, and a safety stock capital $C_{SS} = vk\sigma$.

A brief overview of ABC classification

Managers must first establish how critical the item under consideration is to the firm. With recall to previous chapter in their book, Silver, E.A., Pyke, D.F. and Peterson, R. (1998) give a brief definition of ABC classification.

A items make up roughly 20 percent of the total number of items, but represent 80 percent of the dollar sales volume; B items comprise roughly 30 percent of the items, but represent 15 percent of the dollar volume; C items comprise roughly 50 percent of the items, and represent only 5 percent of the dollar volume.

Consider of a representational case study, a B item has a specified Fractional Charge (B_2) per unit short will be chosen and will be analyzed to lead a viewpoint to prove the adoption of 3PL combined VMI model is more competitive and implement VMI separately.

Item T9704KN is a B item produced by one EMS supplier, this raw material is not customized for company Celestica, but also for two other similar EMS companies. Here, for computation and expression convenience, denote the three EMS enterprise as company A, company B, company C.

After collection data of this item T9704KN and overview and extract of these files, relevant value of parameter is given following. Noted demand per month of this item follows normal distribution, d and σ is calculated by a historical date of three month requirement.

TABLE 5.2 Demand d (month) and σ of item T9704KN

Parameter	Company A	Company B	Company C	Combination of ABC
d	1130	1860	440	3430
σ	35.2	46.8	20.6	77.3

Other value of parameters, v=1836, A=300 Yuan, F=1.8 Yuan, r=0.01, B_2=0.06, L=3

days, replenishment cycle is one month.

Following table 5.3 and total cost for each member under different situation is calculated based on iterative process steps which has been given above.

TABLE 5.3   Iteration Processes for Finding Q and k of Item at Company A

Q	$P_u(k)$	k	$G_u(k)$	$Q_W \sqrt{1+\dfrac{B_2}{A}v\sigma G_u(k)}$
192	0.00283	2.77	0.00087	202
202	0.00298	2.75	0.00089	203
203	0.00299	2.75	0.00089	203
203				

$$TC_A = \frac{d}{Q}A + Fd + \frac{1}{2}Qvr + k\sigma vr + \frac{d}{Q}B_2 v\sigma G_u(k)$$
$$= 1699.9 + 2034 + 1863.5 + 1777.2 + 192.1 \qquad (5.12)$$
$$= 7536.8 \quad yuan$$

$$C_{SS-A} = vk\sigma$$
$$= 178092 \quad yuan \qquad (5.13)$$

The results denote both total cost and safety stock capital for item T9704KN in company A. Total cost is 7536.8 Yuan and safety stock capital is 178092 Yuan. Note the total cost TC_A is an optimal total cost per month.

Do the same iterative processes computation and get results for the rest.

TABLE 5.4   Iteration Processes for Finding Q and k of Item at Company B

Q	$P_u(k)$	k	$G_u(k)$	$Q_W \sqrt{1+\dfrac{B_2}{A}v\sigma G_u(k)}$
247	0.00221	2.85	0.00064	260
260	0.00233	2.83	0.00069	261
261	0.00234	2.83	0.00069	261
261				

$$TC_B = \frac{d}{Q}A + Fd + \frac{1}{2}Qvr + k\sigma vr + \frac{d}{Q}B_2 v\sigma G_u(k)$$
$$= 2137.9 + 3348 + 2395.9 + 2431.7 + 253.5 \qquad (5.14)$$
$$= 10567.1 \quad yuan$$

$$C_{SS-B} = vk\sigma$$
$$= 244188 \quad yuan$$
(5.15)

Total cost for item T9704KN in company B is 10567.1 Yuan and the safety stock capital is 244188 Yuan.

Do the same iterative processes computation and get results for the rest.

TABLE 5.5   Iteration Processes for Finding Q and k at Company C

Q	$P_u(k)$	k	$G_u(k)$	$Q_W\sqrt{1+\dfrac{B_2}{A}v\sigma G_u(k)}$
120	0.00455	2.61	0.00142	126
126	0.00477	2.59	0.00151	127
127	0.00481	2.59	0.00151	127
127				

$$TC_C = \frac{d}{Q}A + Fd + \frac{1}{2}Qvr + k\sigma vr + \frac{d}{Q}B_2v\sigma G_u(k)$$
$$= 1039.4 + 792 + 1165.9 + 979.6 + 118.7$$
(5.16)
$$= 4095.5 \quad yuan$$

$$C_{SS-C} = vk\sigma$$
$$= 99144 \quad yuan$$
(5.17)

Total cost for item T9704KN in company C is 4095.5 Yuan and the safety stock capital is 99144 Yuan.

So far, the separately total cost for currently VMI strategy are all calculated, results in a total VMI cost for item T9704KN for this EMS supplier.

Then consider the situation of Combined-VMI strategy for the supply chain management.

Assumption, every demand during a replenishment cycle occurs at the same time, which means, the three companies A, B, C share a same replenishment schedule, and all the rest parameters are not changed, especially the lead-time.

Calculation based on this assumption.

TABLE 5.6 Iteration Processes for Finding Q and k in Combined-VMI Model

Q	$P_u(k)$	k	$G_u(k)$	$Q_W\sqrt{1+\dfrac{B_2}{A}v\sigma G_u(k)}$
335	0.00163	2.94	0.00047	335
357	0.00174	2.92	0.00051	357
358	0.00174	2.92	0.00051	358
358				

$$TC_{CVMI} = \frac{d}{Q}A + Fd + \frac{1}{2}Qvr + k\sigma vr + \frac{d}{Q}B_2v\sigma G_u(k)$$
$$= 2874.3 + 6174 + 3286.44 + 4144.1 + 416.1 \qquad (5.18)$$
$$= 16895 \quad yuan$$

$$C_{SS-CVMI} = vk\sigma$$
$$= 414936 \quad yuan \qquad\qquad (5.19)$$

Under a strategy of Combined-VMI strategy, total cost for item T9704KN in supplier is 16895 Yuan and the safety stock capital is 414936 Yuan.

Now consider the situation of 3PL-VMI strategy for the supply chain management.

Assumption, every demand during a replenishment cycle occurs at the same time, which means, three companies A, B, C share a same replenishment schedule. As a model cooperated with 3PL company, most 3PL company have good location for delivery and they do have significant power and advantage to lower the lead time and freight as well. Especially like DELTA located in Suzhou industry area, take DELTA Logistic company as a example the lead time is much shorter, as item T9704KN it will only take 2 days lead-time which needed 3 days previously from supplier itself, moreover, as a additional advantage of DELTA Logistic company, DELTA intend to give a cheaper freight of 1.5 Yuan, due to their mass truck and combined delivering. But in order to investigate the essential advantage of 3PL-VMI strategy, demonstrate the change of lead-time as a prominent factor of saving total VMI cost and capital. The impact of freight value change will be calculated in the last and analysis.

For all the rest parameters are not changed.

Calculation based on this assumption.

$$\sigma_{NEW\ TIME} = \sigma\sqrt{\frac{NEW\ TIME}{L}} \qquad\qquad (5.17)$$

Lead-time is $L=3$ days, New Lead-time is $l=2$ days, so

$$\sigma_{NEW\ TIME} = \sigma\sqrt{\frac{l}{L}}$$

$$= 63.1\ units$$

(5.18)

Where, $\sigma_{NEW\ TIME}$ is the new σ in a new lead-time when 3PL is involved in VMI strategy.

TABLE 5.7 Iteration Processes for Finding Q and k in 3PL-VMI Model

Q	$P_u(k)$	k	$G_u(k)$	$Q_W\sqrt{1+\frac{B_2}{A}v\sigma G_u(k)}$
335	0.00163	2.95	0.00045	352
352	0.00171	2.93	0.00049	354
354	0.00172	2.93	0.00049	354
354				

$$TC_{3PL-VMI} = \frac{d}{Q}A + Fd + \frac{1}{2}Qvr + k\sigma vr + \frac{d}{Q}B_2v\sigma G_u(k)$$

$$= 2906.8 + 6174 + 3249.7 + 3394.5 + 330$$

(5.19)

$$= 16055\ yuan$$

$$C_{SS-3PL} = vk\sigma$$

$$= 339660\ yuan$$

(5.20)

Under a strategy of 3PL-VMI strategy, total cost for item T9704KN of supplier is 16055 Yuan and the safety stock capital is 339660 Yuan.

Now, nest step follows the assumption given in the 3PL-VMI part, consider of freight change situation, denote as 3PL(*f*)-VMI, here 3PL company will offer a lower freight *f*=1.5 Yuan.

Calculation of freight change situation.

$$TC_{3PL(f)-VMI} = \frac{d}{Q}A + f_{3PL}d + \frac{1}{2}Qvr + k\sigma vr + \frac{d}{Q}B_2v\sigma G_u(k)$$

$$= 2906.8 + 5145 + 3249.7 + 3394.5 + 330$$

(5.20)

$$= 15026\ yuan$$

$$C_{SS-3PL} = vk\sigma$$
$$= 339660 \quad yuan \tag{5.21}$$

Where, note under a strategy of 3PL(f)-VMI strategy, nothing is changed expect the total freight cost. Total cost for item T9704KN of supplier is 15026 Yuan and the safety stock capital is 339660 Yuan.

More comprehensive data are collected and compared following.

TABLE 5.8   Total Cost and Safety Stock Capital under Different VMI Models

	VMI cost (Yuan)	Freight (Yuan)	Lead-time (Day)	Safety stock (Unit)	Safety stock capital (Yuan)
Company A	7536.8	1.8	3	97	178092
Company B	10567.1	1.8	3	133	244188
Company C	4095.5	1.8	3	54	99144
Separately-VMI	22199	1.8	3	284	521424
Combined-VMI	16895	1.8	3	226	414936
3PL-VMI	16055	1.8	**2**	185	339660
3PL(f)-VMI	15026	**1.5**	**2**	185	339660

As well as other two tables separately compare with their VMI costs saving and safety stock capital saving.

TABLE 5.9   Comparison of VMI Cost Saving with Each Strategy

VMI Cost saving	Separately-VMI	Combined-VMI	3PL-VMI	3PL(f)-VMI
Separately-VMI				
Combined-VMI	5304			
3PL-VMI	6144	840		
3PL(f)-VMI	7173	1869	1029	

TABLE 5.9   Comparison of Safety Stock Capital saving with Each Strategy

Safety Stock Capital saving	Separately-VMI	Combined-VMI	3PL-VMI	3PL(f)-VMI
Separately-VMI				
Combined-VMI	106488			
3PL-VMI	181764	75276		
3PL(f)-VMI	181764	75276	0	

From table 5.8 and table 5.9, it indicates traditional Separately-VMI strategy have the largest total cost as well as safety stock capital, no doubt it is the most unsuitable strategy for supplier. As the Combined-VMI and 3PL-VMI, total cost and safety stock both decrease comparing with Separately-VMI model. With depth illustration from table 5.9, it is obviously 3PL-have a more power advantage in participate in VMI management even though with disregard to cheaper freight.

According to above discussion, 3PL(f)-VMI is the most optimal strategy for EMS supplier, total inventory cost goes down, order cost goes down, lead-time goes down which is critical issue for service level, freight goes down, safety stock volume goes down. So far, for this item T9704KN, if apply 3PL(f)-VMI, best Q is solved to be 354 units, total VMI inventory cost is equal to 15026 Yuan, VMI safety capital is equal to 339660 Yuan. So the total cost to implement new 3PL(f)-VMI strategy for EMS supplier with its customer is

$$15026 + 354686 = 339660 \text{ Yuan}$$

Sum up, based on case study and results comparing and discussion, 3PL involved in EMS supply chain VMI management will have a positive significant meaning, it is essentially appearing by lead-time decreasing. Because reducing the lead-time from upstream of EMS supply chain is a critical issue with respect to fast-feedback in the downstream supply chain. Even though EMS could achieve fast-feedback goal and find potential business opportunity in the market or end customers, without lead-time reducing, they still can not have what they want in time, they can not launch producing plan efficiently, they can not produce and support their customer with enough production or service. Due to long lead-time, suppliers who implement VMI strategy with EMS enterprise will have to keep larger safety stock to meet to uncertainty demand, prepare for unpredictable larger order to keep high service level and maintain customers as well as market. Short lead-time will lower the safety stock directly. 3PL also provide a Combined-VMI function, combination of demand and delivery has tow significant, one is low the safety stock, because one larger demand from one customer mighty be balanced by another's smaller demand, in what way it lower the safety stock level, combination of delivery achieve a lower freight. 3PL enable EMS enterprise to achieve fast-feedback and sharing benefit from low total capital save from supplier of EMS who implement VMI.

6 Conclusion

In the paper, traditional VMI mode has been deeply introduce so as uncertainty demand express on the supply chain. Especially present the reality finance state of electronic manufactory industry and inventory as well as supply chain uncertainty challenge meet in the practice of Celestica.

As deeply investigate, this paper present existing VMI process in Celestica in China,

deal with its default and limitation, integrating with a new electronic market very nearby a lot 3PL, with a new trying mode of 3PL, this paper give a new supply chain VMI management 3VMI mode to decrease no only Celestica inventory cost but also decrease whole cost of the supply chain inventory cost, efficiently deal with the uncertainty elements, increase competitive edge for whole supply chain. But more research, such as electronic market which has no finished in the reality, some constriction elements like policy and location are not discussed now, these problem will be discussed if there is relevant news.

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