Managing uncertainty in logistics service supply chain

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Abstract: Many third party logistics (3PL) providers in South China are small and medium-sized companies and lack of systematic mean on handling information. Uncertainties are created in the business processes due to insufficient information for decision-making. In this study, a logistics information system called Integrated Logistics Information Management System (ILIMS) is proposed. It aims to manage the information flow efficiently between the involved parties in the logistics supply chain through integrating business processes and increasing information transparency to reduce uncertainty. In addition, it provides an effective channel for the 3PL providers to communicate with different contracted suppliers as well as customers through wireless Internet applications. A case study of applying ILIMS in a local 3PL company is discussed. By using this generic system, supply chain uncertainty that associates with the logistics processes can be reduced and leads to a significant performance improvement in the overall order fulfilment process.

Keywords: logistics information system; supply chain uncertainty; third party logistics providers.

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1 Introduction

It is well recognised that companies increasingly see themselves as part of a supply chain to compete against other supply chains, than a single firm competing against other individual firms (Christopher, 1998). Uncertainty not only affects the decision-making capability of a firm, but also undermines the competitive advantage of its supply chain. Third party logistics (3PL) provider, as an external provider who manages, coordinates and delivers logistics activities on behalf of a shipper (Hertz and Alfredsson, 2003), forms a logistics service delivery supply chain by integrating its customers and suppliers. Shore and Venkatachalam (2003) believe that an effectively designed and integrated supply chain is essentially a source of competitive advantage. Huan (1995) also emphasised that firms maintaining closer relationships and effective communications with the trading partners is essential to provide customers with satisfactory service. Information, as the lifeblood of today’s communication and technology, is the key enabler of an effectively designed supply chain, supporting the daily business operation of 3PL providers and their trading partners in a collaborative manner. Any barrier that is imposed against the free flow of information in the supply chain will create uncertainty in doing business, which results in dissatisfaction and loss of competitiveness.

According to Africk and Calkins (1994), there are two types of 3PL providers: asset based and non-asset based. Asset based 3PL providers own the logistics hub, warehouse, transport team and logistics service management system that provide ‘one–stop shop’ logistics service to their customers. However, the non-asset based 3PL providers, which are essentially small and medium-sized companies, subcontract part of their operations to key supply chain partners including land transport, warehouse owner and freight forwarder to provide the logistics service. Efficient and effective communication with other trading partners is the key success factor of these small and medium 3PL providers. In order to maintain competitiveness, they need to adopt new methods for sharing information with their partners to minimise uncertainties. The Integrated Logistics Information Management System (ILIMS) is designed for the non-asset based 3PLs to suit these needs. ILIMS is a web-based common platform to enable different parties in the supply chain to share logistics information with greater speed and accuracy as well as integrating the logistics processes in the logistics supply chain.

This paper establishes a generic model of a logistics information system that aims to reduce the supply chain uncertainty through streamlining the logistics process and utilising wireless technology to facilitate information flow in the supply chain. In addition, it provides performance reports with Online Analytical Processing (OLAP) to improve decision making. OLAP is a category of software analytical tool that provides features of multidimensional conceptual view and intuitive data manipulation on database data.

The organisation of the paper is as follows: Section 2 presents the related studies for the research. Section 3 presents the ILIMS system architecture and its information-sharing model. Section 4 presents a case study with reference to the system architecture and model provided in Section 3. The results of the case study are discussed in Section 5. Section 6 presents the conclusion and future development.

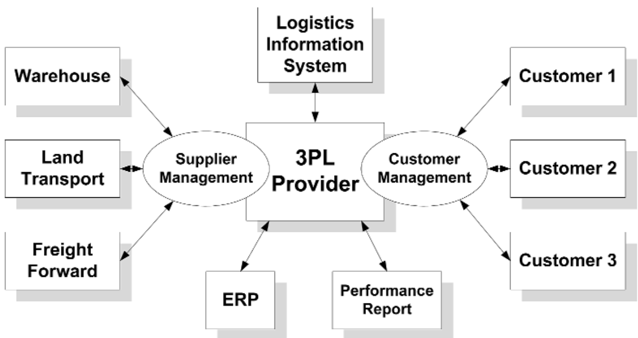
2 Related studies

In recent years, in a stringent competitive environment, many companies have tried to shift their resources such as manpower, cost and technology into their core processes. The non-core processes like stock keeping and logistics have been sub-contracted. Lieb and Miller (2002) believe that, in general, 3PL providers have global expertise with professional knowledge and skills as well as equipment in a logistics scenario. Many companies, therefore, outsource different levels of logistics services to them. As a result, 3PL in the form of joint efforts between manufacturers, distributors and services providers has appeared such that rapid product transportation and customer-orientated logistics activities can be offered for competitive advantage (Yeung and Chang, 2002). The joint effort of 3PL with business partners forms a logistics service delivery supply chain that involves collaboration in business operation and decision making. As shown in Figure 1, the 3PL provider is essentially in a strategic position on the logistics service supply chain through acting as a supply chain activities coordinator on logistics service delivery.

Besides, it is also an information hub controlling the flow and sharing of logistics information with other trading parties in the supply chain.

According to Grossman (2004), collaboration implies the ability to electronically share information about business activities and interact on a nearly real time basis across the supply chain. This requires the breaking down of traditional organisational boundaries and provides information visibility into the supply chain. Lack of correct, accurate and up-to-date information would create uncertainty in the supply chain such as the inability to make timely decisions or failure to perform accurate forecasting (Vorst and Beulens, 2002).

Figure 1 Strategic position of 3PL providers on the supply chain



2.1 Supply chain uncertainty and value chain management

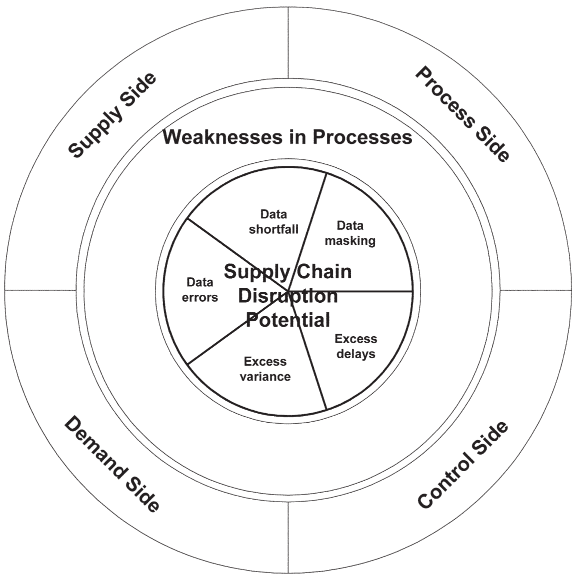
Many organisations attempt to reduce uncertainty in their operations by improving the capability of obtaining, filtering and analysing the appropriate information to facilitate decision making within the firm or share with other participants in the supply chain to maximise mutual business benefits. Supply chain uncertainty refers to the situation of failure to perform decision making in supply chain activities. One of the central causes of such failure is lack of information (Vorst and Beulens, 2002). This is one key issue that is known to impact on the performance of a supply chain (Wilding, 1998). In fact, the lower the uncertainty the less slack the firm has to build in its internal design and thereby lower the operation costs. Hence, there is significant incentive to reduce uncertainty.

Uncertainty in a firm can be caused internally by the business processes or externally by the suppliers or buyers. Towill et al. (2000) has mentioned four types of uncertainty sources that might cause disruption to a supply chain. They are:

- supply side uncertainty
- demand side uncertainty
- process side uncertainty
- control side uncertainty.

Besides, a problem analysis model was proposed for identifying process weaknesses and disruption potentials of product delivery process (PDP) against the four sources of uncertainty in a supply chain. The model is shown in Figure 2 in details, which can be used as the ground for analysis and application in case studies.

Figure 2 Uncertainty analysis for product delivery process in a supply chain



Al-Mudimigh et al. (2004) suggested that reducing the uncertainty of a supply chain with better value chain management has become a way of improving supply chain performance. This can be achieved by improving the business processes of the related value chain activities of a firm. Information Technology plays a vital role in improving value chain management such as reducing inventory level and speeding up business processes, which result in greater customer satisfaction and competitive advantage.

Porter (1985) introduced the concept of value chain. It is a tool to disaggregate a firm into its strategically relevant activities for value creation. By analysing the activities of a value chain, Rayport and Sviokla (1995) believe that it is able to redesign the internal and external processes of a firm to improve the competitive advantage. Thus, supply chain uncertainties that arise in various value chain activities can be reduced by redesigning the operation processes of 3PL to improve information sharing with suppliers and customers.

2.2 Traditional operations of non-asset based 3PL providers

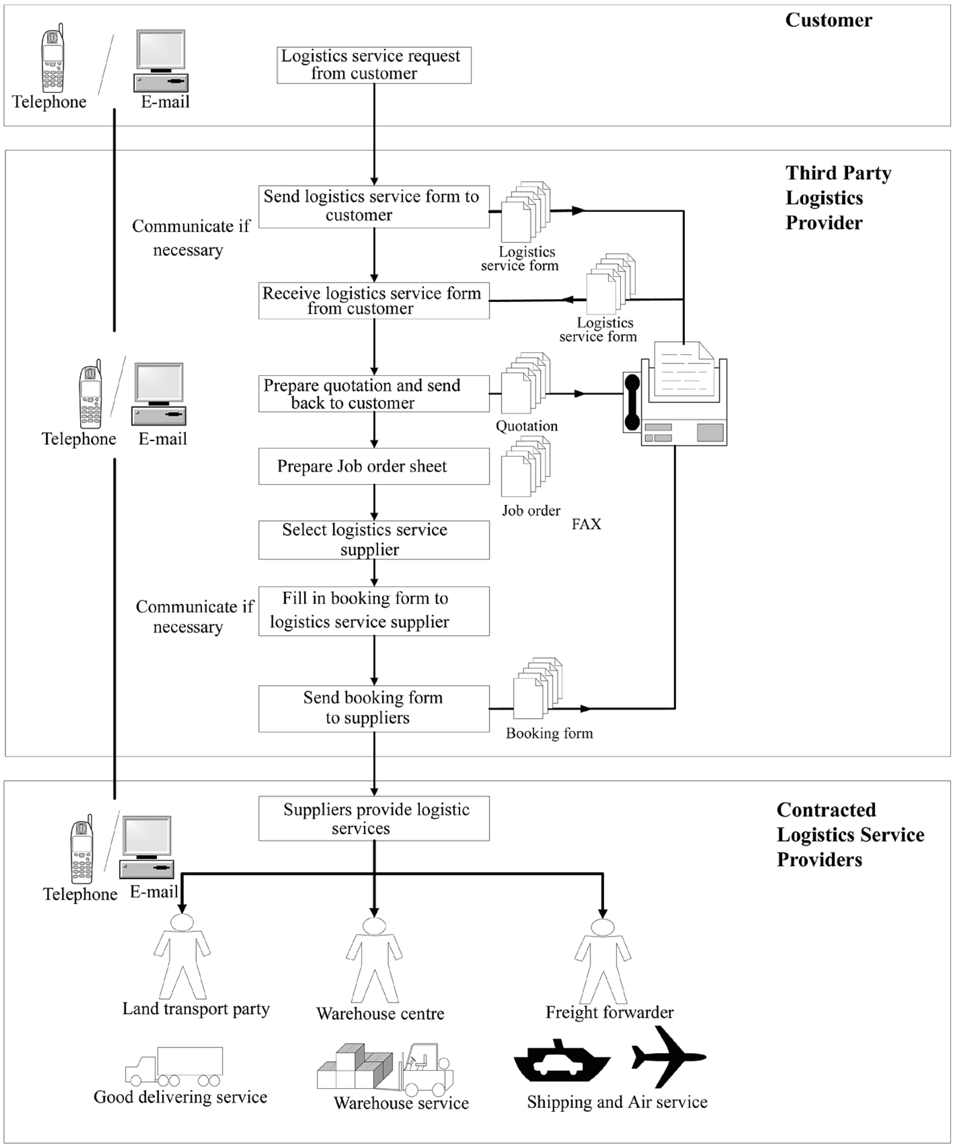
A 3PL provider acts as the middleman in the supply chain network to deliver essential information from the factory all the way up to the right destination for the right party at the right time. If the firm is operated without any logistics information system, a small-scale 3PL provider has to use manual tools such as paper documents to transfer information to different supply chain parties through fax machines or hand delivery by courier. Thus, manual data sorting, reentering, auditing and faxing are overheads but essential steps in processing paper documents. It relies on for 3PL providers not to make any mistake, as any error can cause service failure and loss of profits to the company.

In general, non-asset based 3PL providers use telephone or e-mail as their major communication method for connecting with suppliers and other supply chain parties to provide services like collecting logistics service requests from customers or sending notice of late goods delivery due to traffic congestion, cargo misconnection, etc. Owing to the different operating environment of each party, a 3PL provider needs to call several parties, repeating the same information for the same case. This is, therefore, an expensive, time-consuming and potentially unreliable method.

Figure 3 shows the generic order fulfilment process of non-asset based 3PL providers in the following order:

- receive an order by fax from customer
- assign a job number for the order
- verify with the factory, by phone, the actual quantity available to ship
- place a booking with the contracted parties by fax for required logistics service
- prepare the necessary loading documents such as cargo receipts
- inform the trucker by phone where to pick up and deliver and the deadline
- issue an invoice with the agreed price to the customer for the service rendered
- send out the bill of lading or any related shipping documents to the customer and the requested parties by mail.

Figure 3 Generic order fulfilment process of non-asset based 3PL provider



It is noticed that during the order fulfilment process, it is important to provide responsive customer service while keeping a close relationship with customers and suppliers. The more effective and robustly the operation process can be linked, the deeper integration with customers and partners can be achieved and the greater the value can be delivered. Currently, core competencies of 3PL providers include:

- providing booking services for air and sea freight forwarding services
- arranging cross-border trucking
- preparing tailor-made documentation.

It is observed that there are weaknesses in the existing operation methods adopted by non-asset based 3PL providers. It would cause disruption to the supply chain due to various uncertainties and the drawbacks are summarised in Table 1.

Table 1 Drawbacks of existing methods adopted by non-asset based 3PL

Business activities	*Process weaknesses*	*Potential supply chain disruption*
Demand side		
Service selection	No catalogue for viewing services offered	Delay for searching desired service
Price negotiation	Quotations only kept for successful deals	Incomplete track record for future analysis
Order placement	Sent by fax and confirmed by phone	Human error and delay
Supply side		
Order tracking	Manual based operations	Human error, delay and poor info-sharing
Supplier management	Order by fax with status update by phone	Human error and delay
Billing	Invoice generated by accounting software	No single view on customer record
Process side		
Order processing	Paper based and manual operations	Human error and delay
Document transfer	By fax, by hand delivery or by post	Human error, delay and poor info-sharing
Control side		
Performance management	No pre-defined metrics and formal review	No continuous improvement
Customer complaints	Do not take record	No continuous improvement

In brief, the existing operation involves a lot of manual procedures, is inefficient, unreliable and insecure. It could result in loss, duplication, incorrect distribution or unauthorised disclosure of business information. It therefore reflects the needs of a logistics information system to address the issues in the corresponding business functions.

2.3 Logistics information system

The logistics information system (LIS), in general, is an integrated system linking information from order processing, inventory control, production planning, warehousing and accounting. LIS offers 3PL with better value chain management through operations processes, automation, decision support ranging from strategic to operational and facilitating business transactions. It allows 3PL to retrieve, store and transform data into useful information for the right people at the right time. LIS is essentially a key enabler of the satisfactory delivery of logistics services by increasing information accessibility and reducing uncertainties for 3PL in the daily operations process. The value-added activities in the logistics process should therefore be integrated to the system for maximising business value. A thorough understanding of how 3PL companies differ, and how the business processes structured in a particular type of company is important to properly develop the design and architecture of LIS.

According to Rutner et al. (2003), LIS has been a major area of study in the logistics and operations areas for more than 25 years. A major stream of research focuses on the adoption of LIS and its impact on an organisation (Gustin et al., 1994, 1995; Rutner et al., 2001, 2003). A number of additional studies present the framework of LIS for integrating with external systems through using various IT applications (Huan, 1995; Kang and Kwon, 1997). Most of the previous studies present the benefits of LIS to organisations by transforming business processes or facilitating information flow. However, the previous works do not examine the integration of LIS into the internal operations of a company in the context of control of information sharing and uncertainty management, particularly for 3PL providers. The previous research helped to identify a number of goals for this research. Firstly, the key-enabling technologies of LIS for enhancing the capability of communication and information sharing should be identified for this study. Secondly, the operation model of 3PL providers that connects LIS to the business processes of the firms should be established.

2.4 Enabling technologies of logistics information system

The influence of information technology on logistics is to help reduce the cost of obtaining information and allow logistics service providers to offer value added services such as tracking and tracing shipments (Lewis, 2001; Lynagh et al., 2001). In order to reduce uncertainty for small and medium sized 3PL providers due to poor information sharing, technologies such as multi-tier client-server method, wireless internet application and online analytical processing are reviewed to formulate the design of LIS.

2.4.1 Multi-tier client-server method

The challenge of business computing comes along with a set of new requirements, and new technology. Access to information systems is no longer limited to local networks. Customers and suppliers using mobile clients or a simple web browser must be able to use business function via the internet. Client/Server computing method (Edwards, 1999; Lewandowski, 1998; Steiert, 1998) meets this new challenge. It usually comprises two or more tiers of application, which is designed for handling large numbers of clients and is suitable for high volume access on the internet. The model includes a presentation tier that interfaces with the clients, an application tier and a database tier that reside on the back-end server. According to Edwards (1999) and Lewandowski (1998), the application tier sits between the presentation tier and database tier, and is seldom implemented as a monolithic programme. Instead, it is implemented as a collection of components that are used in a variety of client-initiated business transactions. Two commonly used component technologies are Object Management Group (OMG)'s CORBA and Microsoft's DCOM/COM. The concept of component based multi-tier client/server method is suitable for LIS by connecting 3PLs to the supply chain parties in a dynamic and distributed business environment.

2.4.2 Wireless internet connectivity

Internet-connected mobile devices are valuable tools in present business operations, as they allow users to access and transfer information in real-time. The mobile application service has enabled the business to operate more efficiently. It is one of the key components to reduce uncertainties in decision making. A wireless communication system that integrates with conventional information systems provides real-time information access, reducing service costs and increasing operation efficiency through providing timely and quality information necessary to maintain inventory control and field operations status such as tracking vehicles location or order status (Gebresenbet and Ljungberg, 2001; Rishel et al., 2003; Yao and Carlson, 1999). Since the truck fleet handles the physical delivery and provides valuable information on inventory control and order management, uncertainties caused by lack of information can be reduced by integrating wireless technologies into LIS. Mobile devices can access LIS by using General Packet Radio Service (GPRS). GPRS is the 2.5 G implementation of internet packet switching protocol on European GSM networks for connecting mobile devices to the internet. The service is available at most GSM wireless network operators.

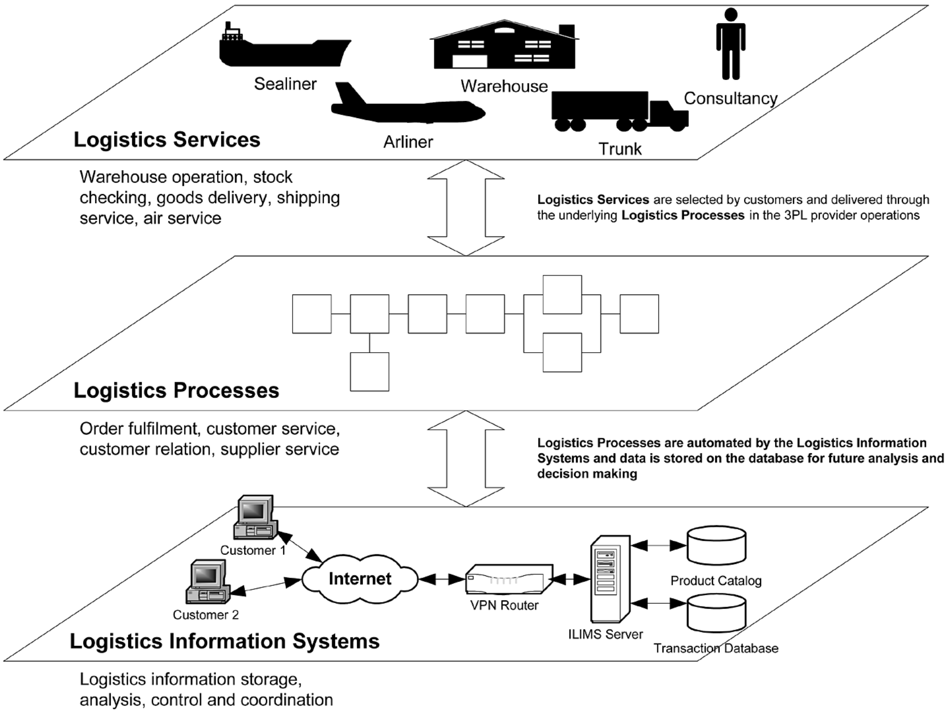
2.4.3 Online analytical processing

Codd et al. (1993) suggested that the conventional relational database used for transaction processing had reached its maximum capability with regard to the dimensionality of the views of the data available to the user. Therefore, Online Analytical Processing (OLAP) was developed to assist decision makers in freely manipulating the business data across many simultaneous dimensions. In order to assist 3PL reduce supply chain uncertainties through better analysis the acquired business data, OLAP is deployed in LIS.

3 Integrated Logistics Information Management System

An Integrated Logistics Information Management System (ILIMS) is an LIS that integrates all the involved logistics processes together so that appropriate logistics services can be provided in real time. It is a web-based common platform that allows different parties to transmit, capture, share and collect the required information over the internet. A generic operation model of ILIMS is shown in Figure 4 in order to realise the design goals. It consists of three layers, namely, logistics service, logistic process and logistics information system.

Figure 4 ILIMS model for non-asset based 3PL provider



- The logistics service is the physical activity on the supply chain, including warehouse operations, inventory management, distribution, reverse logistics, transportation and freight forwarding services.
- The logistics process is the collection of activities facilitating the materials and information flow in the supply chain. It supports the delivery of the required logistics services through connecting the business with its customers and suppliers. Logistics processes generally include order fulfilment, customer and supplier management, procurement and demand management.
- The logistics information system is a common platform for manipulating and sharing logistics information among companies in the logistics supply chain from customers and logistics service providers to business partners. It underpins the upper tiers of the model through automating the logistics processes, providing decision support from strategic to operational, and facilitating business transactions. Hence, an effectively designed LIS allows 3PL to retrieve, store and transform data into useful information for the right people at the right time. LIS is essentially a key enabler in the delivery of logistics services. When designing LIS, it is essential to integrate the activities in the logistics process seamlessly with the corresponding logistics services. Consequently, the performance of 3PL providers and all the involved parties in the supply chain can be improved and uncertainties can be reduced.

3.1 System architecture of ILIMS

Figure 5 shows the system architecture of ILIMS, which is divided into four main tiers.

- Tier 1 – The presentation tier: is the user interface (UI) of the system that allows users to access the business functions through HTML compatible web-browsers on traditional PCs, Personal Digital Assistants (PDA), handheld computers or smart phones.

- Tier 2 – The application tier: contains the business logics for delivering the logistics services. It interconnects with e-mail services for generating notifications to customers that carry information like invoices or shipping documents.

- Tier 3 – The database tier: is the central data storage required by the business logics for further manipulation. It interfaces with the Enterprise Resources Planning (ERP) system for updating accounting records and on-line analytical and processing (OLAP) applications for producing performance reports based on historical data (Lau et al., 2003).

- Tier 4 – The security tier: supports the Virtual Private Network (VPN) connecting trusted parties in the supply chain network for sharing business intelligence. Security Socket Layer (SSL) protocol is deployed for connecting business parties to provide a minimum level of security control on the system level over the public internet.

ILIMS employs a distributed computing design embracing the Distributed Component Object Model (DCOM) technology due to the fact that Windows customer base is widely adopted and a relatively lower cost of investment is required in implementing the system. The function of each tier is discussed below.

3.1.1 The presentation tier

This tier allows different parties including mobile clients such as PDA and Smart Phone to access business information through the internet in accordance with the access right granted by the 3PL providers. It is the user interface of ILIMS accessing to various business functions. This tier provides inputs to the application tier and manages the display of outputs. The operation is shown in Figure 6. The server-side is the website that contains a number of web pages for providing various functions to different groups of users. The web pages are constructed by using Hypertext Markup Language (HTML). HTML is designed for representing information and for navigation between information entities. It interprets users' requests to perform an operation on the data. Since HTML is not used for automated information processing, other technologies such as ASP (Active Server Pages), and JAVA Script were included to make the static pages more dynamic.

ASP is a server-side scripting environment, which is used to create dynamic and interactive web pages. When the web-server receives a request for an ASP file, it processes server-side script code contained in the file, builds the web pages and sends them to the browser.

Figure 5 System architecture of ILIMS

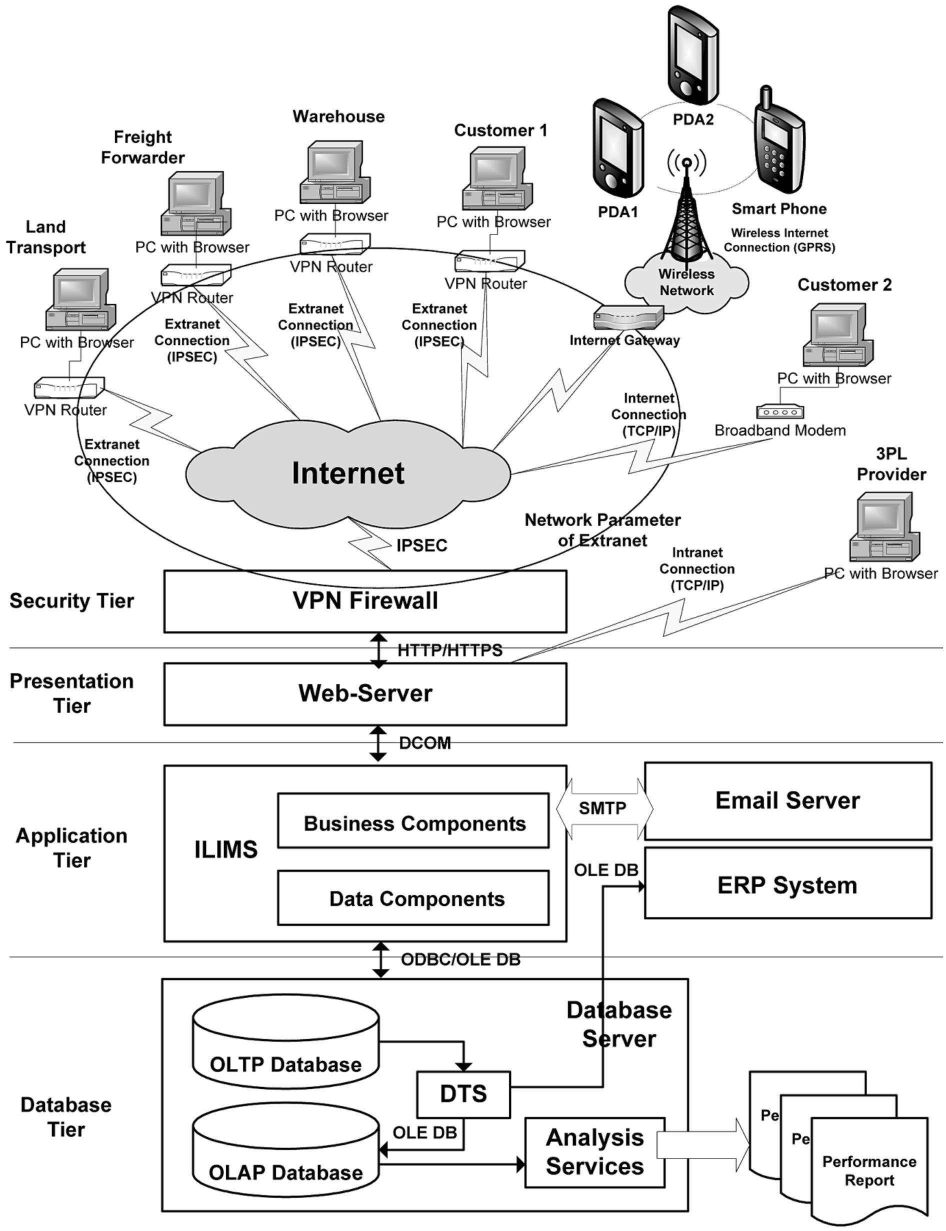
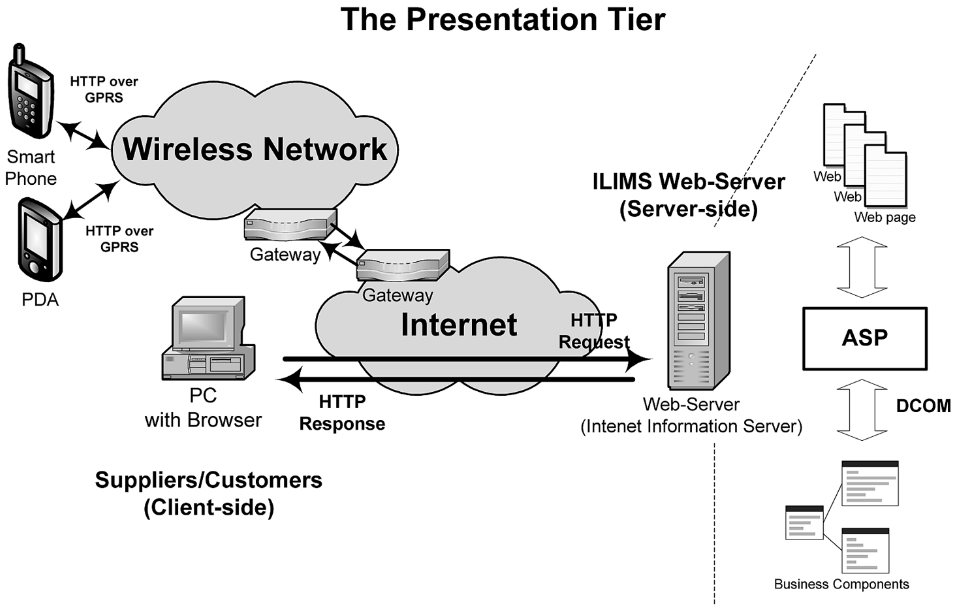


Figure 6 The operation model of presentation tier



3.1.2 The application tier

The application tier is the business logic of ILIMS, which provides functional applications accessed through the internet. It contains an ILIMS application server, providing a basic operating environment for logistics business functions supported by the business and data components. The business functions are implemented as Component Object Model (COM) components. They are accessed through DCOM calls initiated by ASP on the presentation tier when the web-server receives requests from the browser. Specific sequences of UI access procedures are defined and implemented on the web pages for executing the related business functions selected over the browser.

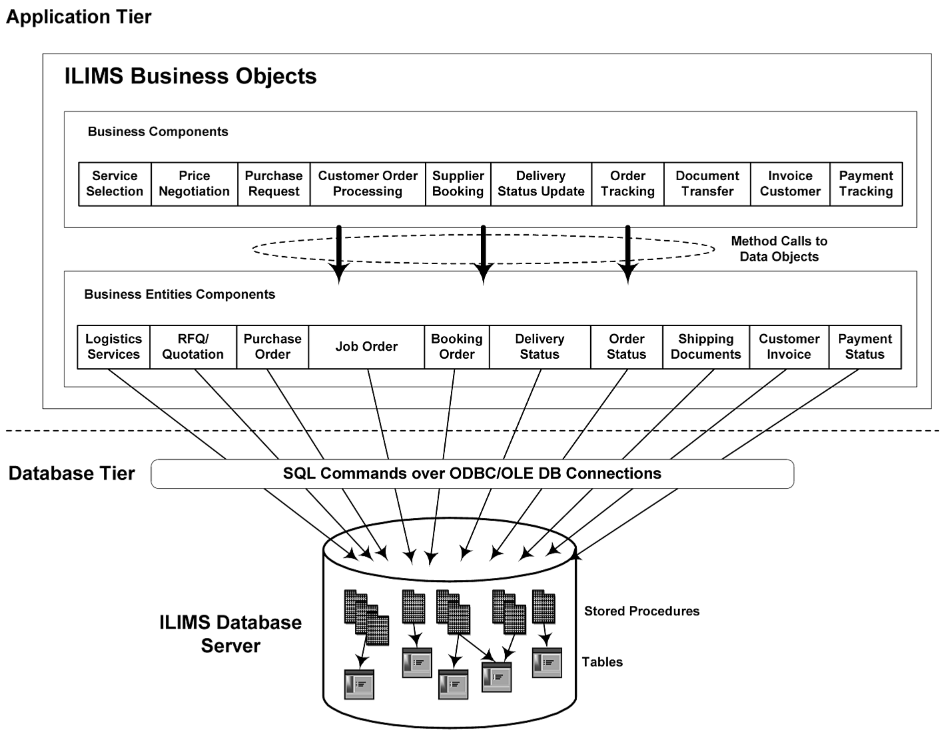
The ILIMS interconnects with the e-mail server communicating through Simple Mail Transfer Protocol (SMTP) for generating e-mails to customers, where business information, such as invoices or shipping documents, is carried. The ERP server, though not part of ILIMS, interconnects with the ILIMS database. Transaction data are synchronised with the ERP server through the inherit Data Transformation Services (DTS). DTS is a tool of the SQL database server that includes a Transform Data Function for data mapping in the selected format.

3.1.3 The database tier

The database tier is a database server storing different kinds of business data such as information of customer, supplier, business transactions and order status. Figure 7 depicts the data operations between the application tier and database tier. The business entity components defining the specific data characteristics are invoked by the business components when executing the business processes. They also expose methods of retrieving, inserting, deleting and updating the corresponding information to the database server through Structure Query Language (SQL). The SQL queries and associated data operations are implemented as stored procedures. A stored procedure is a set of SQL statements usually stored in the server that helps to enhance the performance and maintainability of data operations.

Moreover, data can be exported to other relational database management systems (RDBMS) or OLAP database system by mapping selected data columns to a set of transformations. The transformed data are then sent to the desired destination through DTS.

Figure 7 Data access between the application and database tier



3.1.4 The security tier

Web application programmes such as ASP files that run on web servers are potentially insecure due to the fact that they are easily attacked through compromising program codes or scripts. Hence, a security system must be established such that unauthorised internet users could not execute programmes or read files on the server. It is necessary to define security objectives for addressing the corresponding security concerns. Three security objectives are defined on the system.

- confidentiality – information that is transmitted on the Internet is protected against unintended or unauthorised access
- authentication – the identity of a user who wishes to access the system has to be verified
- authorisation – users are able to access specified information or resources from the system based on their identity.

Table 2 shows the technologies and associated system components deployed on ILIMS for meeting the designed security objectives.

Table 2 Security technologies and associated system components

Security objectives	*Security technologies*	*System components*
Confidentiality	Network Level: IP Security Protocol (IPSEC) provide data encryption for tightly connected suppliers and customers	Network Level: Firewall that supports IPSEC for building Virtual Private Network (VPN)
	System Level: Security Socket Layer (SSL) Protocol for all connected suppliers and customers	System Level: web server that supports SSL Protocol (Internet Information Server)
Authentication	Network Level: IP Security Protocol (IPSEC) provide network authentication for tightly connected suppliers and customers	Network Level: Firewall that supports IPSEC for building Virtual Private Network (VPN)
	System Level: Security Socket Layer (SSL) Protocol for all connected suppliers and customers	System Level: web server that supports SSL Protocol (Internet Information Server)
Authorisation	Application Level: Role placed on business components through programming COM objects	Application Level: Windows server's users or user groups are assigned to appropriate COM roles
	Database Level: SQL Logon resource rights	Database Level: access privileges on SQL Database Server (e.g. select, insert, delete and update)

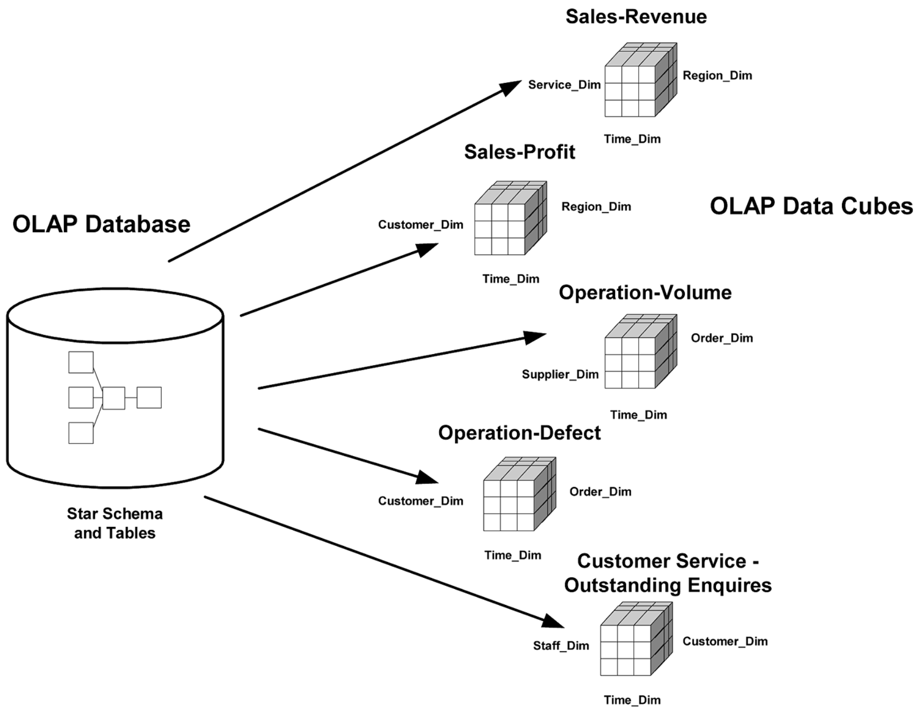
3.2 Multi-dimentional view of performance data

In the database tier, the relational database server provides information to create the OLAP database for producing performance measurement reports to support decision making. This is done through extracting relevant data columns from the database tables through DTS. They are then transformed into a data structure called star schema to facilitate multi-dimensional data retrieval and analysis on OLAP. Uncertainties can be reduced through evaluating possibilities and trends in different aspects of business areas with OLAP.

In ILIMS, the OLAP cubes are designed to provide multi-dimensional views of performance data through the analysis services available on the OLAP server. As shown in Figure 8, five OLAP cubes are constructed to provide the desired performance measurement reports in ILIMS.

The dimensions defined for each business area categorise the measurements of the cube. Each measure is analysed through the analysis tools provided by the OLAP applications. The tools perform roll-up and drill-down operations to provide performance reports of different details for evaluating the business performance of 3PL companies. This reduces the uncertainties caused by a lack of information and knowledge.

Figure 8 OLAP data cubes for analysing performance



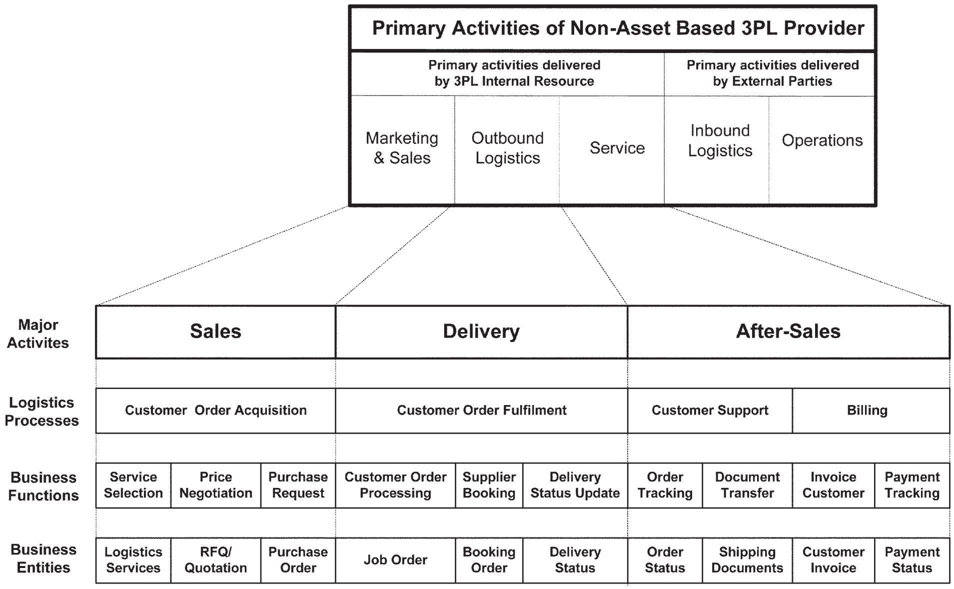
4 Case study

ILIMS was applied with the intention of reducing supply chain uncertainties by improving the information sharing capability of First United Logistics Solutions Limited (FULS). The wireless devices that integrate with ILIMS was provided by CSL Cosmos Solutions Limited, an e-mobile workforce and an e-logistics mobile data solutions provider in Hong Kong. FULS, established in 2000 as the affiliated company of the Apex Group, is one of the many non-asset based 3PL providers in Hong Kong. The targeted customers of FULS are primarily overseas companies, which demand 3PL integrated logistics service in China. Most existing customers are Taiwanese computer manufacturers, and each of them has their particular supply chain requirement patterns. Almost all their manufacturing plants are located in mainland China, with their headquarters in Taipei responsible for decision making and their Hong Kong offices acting as the coordinating and transshipment point of export. FULS has around 30 core customers and more than 100 frequent customers who have manufacturing operations on the mainland and headquarters in Hong Kong. On the other hand, it has over ten core logistics service suppliers and over 30 potential suppliers for delivering the required physical logistics operations.

The major business activities conducted at FULS are shown in Figure 9. The primary activities are divided into five generic categories, namely, marketing and sales, outbound logistics, operations, inbound logistics and operations. The inbound logistics, outbound logistics and operations activities are delivered through the resources of external logistics suppliers. The coordination of these suppliers is part of the outbound logistics activities. The remaining activities, i.e. marketing and sales and operations form the core business activities of non-asset based 3PL companies. Figure 9 shows the four major underlying logistics processes. They are:

- customer order acquisition
- customer order fulfilment
- customer support
- billing.

Figure 9 Third party logistics (3PL) activities by FULS



The processes are the four pillars supporting the primary activities. They are automated by ILIMS to eliminate manual procedures, establish a common platform for conducting business transactions, and provide a single view on various business functions and data.

Like most of the non-asset based 3PL providers, FULS sub-contracts the physical operations to its core logistics service suppliers. However, the operations are manual-based which is inefficient, costly and unreliable. This does not only undermine the business performance and potential growth, but also create various uncertainties in the supply chain operations. Table 3 summarises the uncertainties that may cause supply chain disruptions. The uncertainties are potential bearers of achieving effective decision making and efficient operations in daily business.

Table 3 Sources of uncertainty and weaknesses in FULS

Sources of uncertainty	*Weaknesses in value chain activities*
Supply side	Short notification of changes to supplier requirements Excessive supplier delivery lead time
Demand side	No customer stock visibility Excessive customer delivery lead time
Process side	No measures of process performance No linkages between value chain activities
Control side	Poor operations audit Poor control on incorrect and untimely information

4.1 System implementation and integration

In order to facilitate and control the information flow between various business parties, FULS implemented ILIMS in 2003. Through deploying ILIMS, the value chain activities of FULS are optimised. Table 4 shows the detail implementation of ILIMS in various business activities at FULS.

The presentation tier is implemented as the web pages written by HTML and ASP. It provides the entry points for users to access the business logics, input information and read the corresponding outcomes. The user interfaces of ILIMS that are customised for three groups of users, that is, FULS staff members, customers and suppliers. It is primarily designed by accessing through traditional PCs connected to the internet. On the other hand, the users of mobile terminals are the contracted logistics service providers working at remote locations such as trucks or warehouses. The users can connect to the ILIMS database through PDAs to perform functions such as status update or order retrieval. Figure 10 shows the user interfaces of ILIMS on the PDA.

In the application tier, the logistics processes including customer order acquisition, customer order fulfilment, billing and customer support, are automated by ILIMS. Table 5 shows the details of process automation and the electronic documents supported by the business components in ILIMS.

The database tier is a central information repository for storing business data generated in the transactions. Business components on the application tier attend to client requests by triggering data operations such as the retrieval, insertion and deletion of data. As a result, transactions are updated. The COM components issue SQL commands to the database tier for accomplishing corresponding data operations. The results are eventually sent back to the presentation tier where the client can get the information. Besides, the data of selected performance metrics is transformed by DTS and stored in the form of OLAP cubes. Figure 11 shows the performance report of the Sales-Revenue in 2003 with the drill-down sales figures. The roll-up and drill-down features of OLAP are applied to any dimension of measurements, generating a performance report summary in real time.

Finally, through the security tier, FULS and its core customers and suppliers are integrated by means of VPN, which provides additional controls on authentication and confidentiality.

Table 4 Implementation of ILIMS on various value chain activities in FULS

Business activities	*Presentation tier*	*Application tier*	*Database tier*	*Security tier*
Sales support				
Service selection	Web pages of service information	Select and extract information	Maintain tables of service information	Provide the following security mechanisms to business activities: ● Network layer: connect all core customers and suppliers with VPN over the internet, and connect all non-core customers and suppliers with standard HTTP protocol over the internet. ● System layer: use SSL protocol for all connected suppliers and customers ● Application layer: roles verification when business components (COM objects) are called ● Database layer: enable access level privileges for data operations
Price negotiation	E-documents for quotation and RFQ	Auto create quotations for std services and documents routing	Maintain tables of transaction records	
Order placement	E-documents for PO and PO confirmation	Auto confirm purchase request and document routing	Maintain tables of transaction records	
Service delivery				
Order processing	Web pages of status update for customers	Select suitable suppliers according to price quoted	Maintain tables of transaction records	
Supplier booking	Web pages of status update for FULS	Prepare booking orders to suppliers and job orders as internal records	Maintain tables of transaction records	
Status update	Web pages for suppliers to input update information	Update both FULS and customers with the new status	Maintain tables recordsof status	
After-Sales				
Order tracking	Web pages for customers to track order status	Extract order status information	Read order status records	
Document transfer	Web pages for customers and suppliers to request shipping documents	Route selected shipping documents to requested parties	Maintain records of shipping documents for each order	
Billing	Web pages to present bills for customers	Prepare and route bill to customer after completing the order	Maintain records of customer invoice for each order	
Controlling				
Performance management	OLAP tool to present performance reports	Generate reports according to pre-defined metrics	Maintain a database of OLAP data cubes	
Customer compliant	Web pages for FULS to log complaints	Send alert to FULS for un-resolved issues	Maintain customer compliant records	

Figure 10 View of order status on PDA through the presentation tier

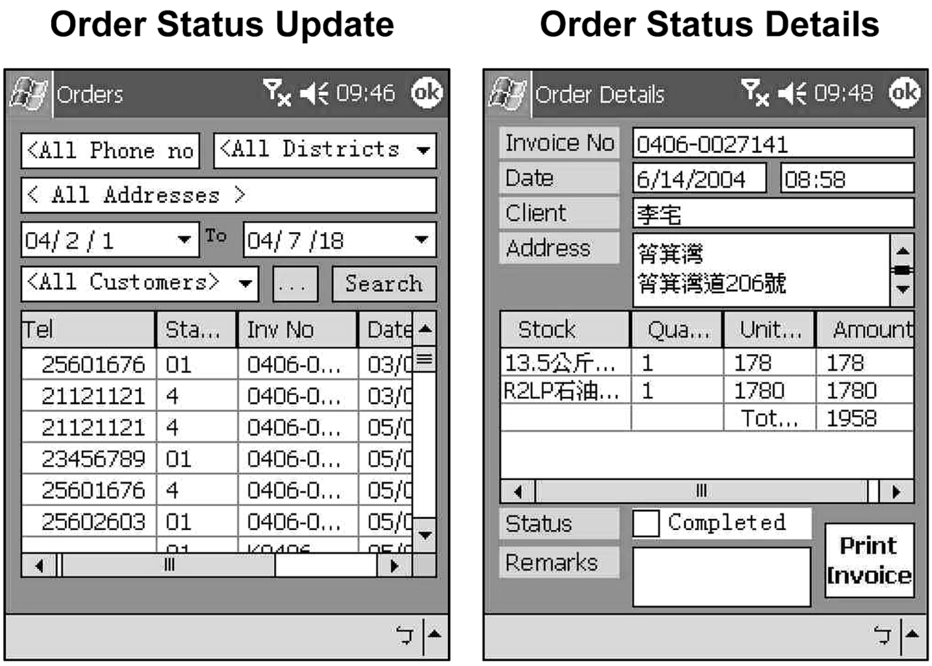
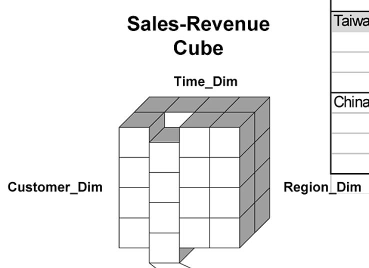


Table 5 Business functions and documents supported by ILIMS

Logistics process	*Business component*	*Business document / information*	*Document flows*
Functions and documents supported by ILIMS			
Customer order acquisition	Service selection	Detailed service information	To customer
	Price negotiation	Quotation (Q)	To customer
		Request for quotation (RFQ)	From customer
	Purchase request	Purchase order (PO)	From customer
Customer order fulfilment	Customer Order Processing	Job Order (JO)	From FULS
	Supplier booking	Booking order (BO)	To suppliers
	Delivery status update	Delivery status information	To FULS
Customer support	Order tracking	Order status information	To customer
	Document transfer	Shipping documents	To customer and supplier
Billing	Invoice customer	Customer Invoice	To customer
	Payment tracking	Payment status information	To customer and FULS
Functions and documents not supported by ILIMS			
Customer order fulfilment	Custom declaration	Custom declaration documents	Special requirements incur additional cost

Figure 11 Performance report on sales-revenue by region with application of drill-down



Sales-Revenue Pivot Tables for Performance Reporting

Region	Sales Revenue ($ millions)				
	Customers	Time (2003)			
		Q1	Q2	Q3	Q4
Taiwan	Electronics	$1.23	$1.20	$0.89	$1.50
	Toys	$3.60	$2.27	$2.60	$3.80
	Clothing	$3.22	$4.80	$3.51	$2.85
	Miscellaneous	$0.72	$0.65	$1.21	$1.62
China	Electronics	$0.27	$0.23	$0.19	$0.32
	Toys	$2.20	$2.03	$1.80	$2.14
	Clothing	$1.78	$1.92	$1.65	$1.60
	Miscellaneous	$0.25	$0.22	$0.30	$0.35
	Total	$13.27	$13.32	$12.15	$14.18

Drill-down

Region	Sales Revenue ($ millions)				
	Customers	Time (2003)			
		Q1	Q2	Q3	Q4
Taiwan	Electronics				
	Chun Kee Manfacturing	$0.22	$0.23	$0.17	$0.30
	Man Woo Holding	$0.30	$0.27	$0.07	$0.38
	Denway International	$0.71	$0.70	$0.65	$0.82
	Toys	$3.60	$2.27	$2.60	$3.80
	Clothing	$3.22	$4.80	$3.51	$2.85
	Miscellaneous	$0.72	$0.65	$1.21	$1.62
China	Electronics	$0.27	$0.23	$0.19	$0.32
	Toys	$2.20	$2.03	$1.80	$2.14
	Clothing	$1.78	$1.92	$1.65	$1.60
	Miscellaneous	$0.25	$0.22	$0.30	$0.35
	Total	$13.27	$13.32	$12.15	$14.18

5 Results and discussions

Before using ILIMS, the business processes in FULS were manual-based. The capability of information sharing and performance management was low, as the transaction data and logistics documents were not captured on computers. Various uncertainties appeared in daily business such that the staff in FULS are not able to make a timely decision and be responsive to customer enquiries due to lack of information.

With ILIMS, the problems are addressed and values are added to FULS. This is beneficial not only to FULS, but also to its customers and suppliers. The presentation tier of ILIMS provides FULS staff and other business parties with a single view of business information in a user-friendly approach. The manual procedures in the business activities are automated by ILIMS through the business components of the application tier. Moreover, all the logistics documents are now prepared through ILIMS. Business data generated in the transactions are stored electronically in the database of ILIMS, which can be shared with other business parties of the logistics service supply chain simultaneously, so that the efficiency and decision-making capability of FULS are improved. As a result, users can obtain timely business information not only on the PCs connected to the internet, but also on the mobile devices with wireless internet connectivity. Through using the security technologies, user identities are reliably authenticated before users entering the system and information is shared only with authorised users. This helps FULS in trust building with customers and suppliers, which is particularly important in providing confidence on using the system. Table 6 summarises improvements in total cost savings after the implementation of ILIMS.

Table 6 Average cost saving after the implementation of ILIMS

Items	*Cost saved/year (Hong Kong dollar)*	*Amount decreased (%)*
1 Printing and stationery	15,000	75
2 Telephone and fax	97,840	80
3 Man-time on sharing information	81,600	85
4 Postage fee	20,000	50
Total saving/percentage (average):	166,840	77

With OLAP analytical tools, performance reports that incorporate the performance metrics and dimensions are provided. Hence, FULS is able to perform multidimensional analysis on historical data to evaluate the performance on the aspect of sales, operations and customer services. Moreover, the ILIMS also helps FULS to identify the most valuable customers, under-performed suppliers, and peak season of particular customers' supply chain as well as customer satisfaction. Possessing such information, FULS is able to target the most valuable customers. Hence, the right services are provided in particular during high seasons. This helps improve the performance of the following two business areas, which are

- revenue generation by increasing the volume of business
- customer satisfaction.

As a result, the revenue was increased by 10% at Hong Kong dollar 5.3 million in 2003. The customer retention rate is 100% as there was zero customer loss, due to the fact that FULS was able to offer attractive prices and better customer services.

6 Conclusion and future development

In this study, an Integrated Logistics Information System (ILIMS) is designed by adopting multi-tier client-server architecture, wireless internet technologies and OLAP applications to provide logistics process automation, enhancement of information sharing and improvement of decision making. ILIMS is implemented in FULS and in the companies of its customers and suppliers. The proposed system systematically integrates FULS, the suppliers and customers on its supply chain by enabling free flow of information in a secure and reliable manner so that the system can be used to trace and update order status, review performance and service quality. As a result, uncertainty that caused by lack of information is reduced. The analysis shows that the adoption of ILIMS has resulted in a significant improvement on cost saving, revenue generation and customer satisfaction.

Further work on this growing field of ILIMS is recommended. Two areas are worth exploring. They are

- the system model for functions that are outsourced to external parties
- the predictive data analysis.

As non-asset based 3PL providers tend to in-source the function for providing more value-added services such as Vendor Managed Inventory (VMI), one of the outsourced functions that should be researched on is warehouse management. Moreover, since the performance reporting function is descriptive based on historical data. Developing a predictive model is recommended to provide knowledge functions and the output can be shared among supply chain parties to improve their overall competitiveness.

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