



Deriving industrial logistics hub reference models for manufacturing based economies

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ABSTRACT

Global enterprises require extended logistics operations that integrate channel intermediaries into the network. The method for deriving integrated models for logistics hubs that improve the efficiency of manufacturers' global operations is the focus of this paper. Under government sponsorship, six industrial logistics hubs were implemented by leading manufacturing sectors across Taiwan over a five year period from 2004 until 2008. Each industry sector had unique industry characteristics, business strategies, and logistics models. Therefore, this paper describes how generalized and quick to implement integrated logistics hubs are developed by studying the successful reference models and systems used by six independent industrial sectors. The research results provide a field tested method for deriving integrated logistics hub models in different manufacturing economies with notes that provide sufficient methodological detail for repeating the construction of logistics hubs in other manufacturing economies.

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1. Introduction

The means by which industries strengthen and enhance supply chain efficiency and decrease logistics management costs are critical factors for economic development and serve as reference models for transferring technologies to developing economies. In order to assist industry in the construction of new logistics hubs across industry sectors, the Taiwan Department of Commerce, the Ministry of Economic Affairs, commissioned the Identification and Security Technology Center of the Industrial Technology Research Institute (ITRI) to execute a five year integrated logistics and business hub development project from the years 2004 to 2008. The goal of the project was to assist industry to integrate information flows (via a business hub) and material flows (via a logistics hub) to facilitate global supply chain linkage. The business hub provided information sharing, management and control for raw materials and components procurement, inventory level keeping, transportation tracking, customs clearance services, customer order processing, and other activities at the request of supply chain participants. The logistics hub is operated by Logistics Service Providers (LSPs)

that manage shipment consolidation, warehousing, transportation, packing, collaborative replenishment and tax bonded warehousing. The general operation model for the integrated industrial logistics hub is shown in Fig. 1.

The development project positions manufacturers as the leaders to form the strategic alliances with trading partners (suppliers, customers, carriers, forwarders, and transportation companies) acting as the primary financiers of the integrated hub. The functional goal of the hub is to integrate supply chain resources, provide real-time material supplies, ensure information transparency, improve logistics efficiency, and increase customer service quality. Another goal of the project is to encourage the aligned partners to outsource tasks to domestic LSPs. The LSPs receive detailed requirements from the industry sectors and receive financial incentives to develop professional and globally oriented services. The steps taken for the development project are shown in Fig. 2. With the goal of hub integration as a prerequisite, the manufacturers derived the specifications according to the scope of the project:

- Provide an integrated plan for the materials and components supply chain and product demand chain operations.
- Develop an inbound shipping system for the materials and components purchasing and outbound shipping system for product ordering.
- Provide an order tracking and query system for the materials and components supply chain that satisfies the requirements of global product demand.

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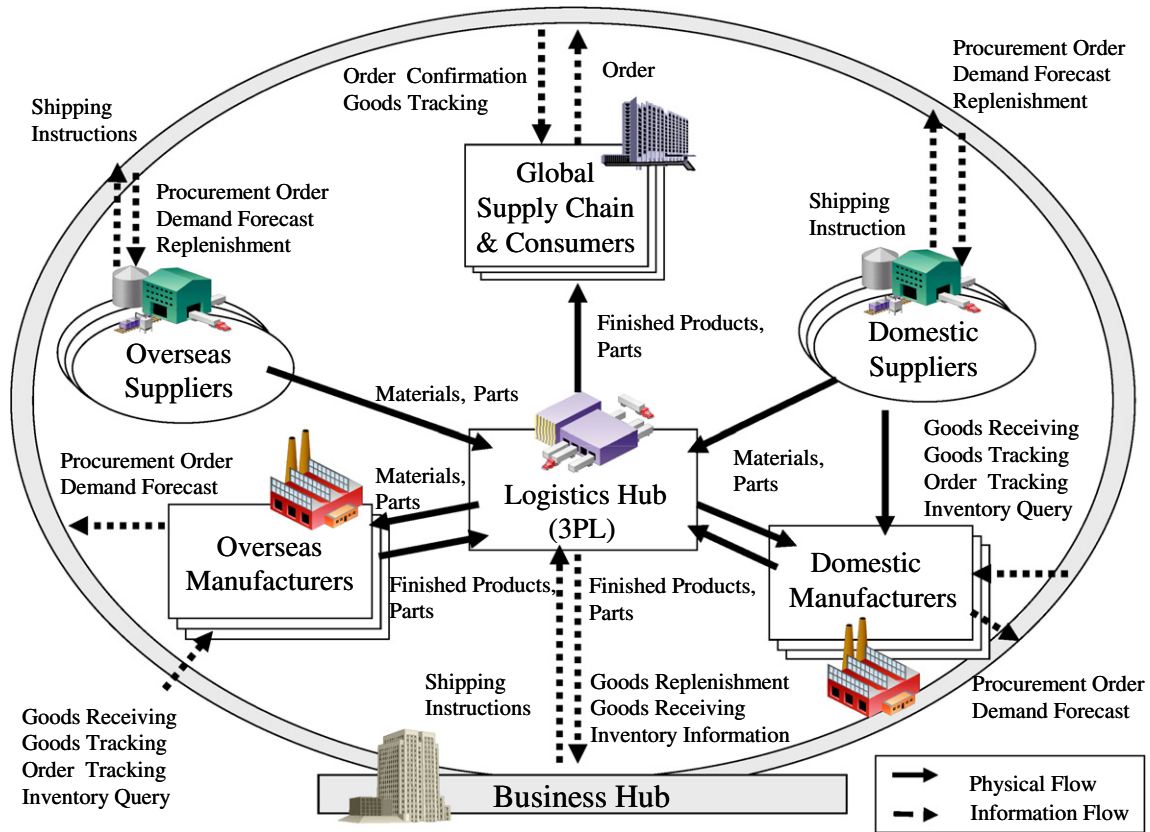


Fig. 1. The integrated business and logistics hub.

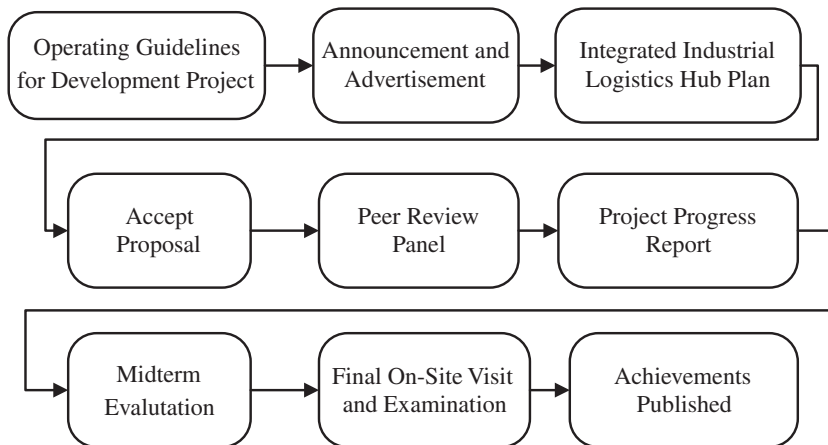


Fig. 2. The steps of implementing a hub development project.

- Develop an inventory and safety stock management system for products, materials, and components.
- Develop a goods tracking and query system for products, materials, and components.
- Develop a collaborative planning, forecasting, and replenishment (CPFR) system.
- Perform a pilot test for the global logistics hub.
- Implement global standard radio frequency identification (RFID) application systems where appropriate and cost effective.

Each development project started on the date the manufacturer passed a peer review. The development project executive agent

(ITRI) was designated by the government to sign contracts with the selected companies and offer consulting services. The manufacturer was responsible for executing the steps of the proposal and was required to pass a midterm evaluation and final review. An on-site visit was scheduled for the final evaluation of the newly developed logistics facilities. The review committee checked the achievements, key performance indicators (KPIs), and the documents and systems listed in the proposal. Further, the review committee asked questions and provided suggestions for future hub development. Each company was required to reply to all committee requests and report all changes and modifications.

This paper describes the implementation of six industries' integrated logistics hubs over a five year period. Some manufacturers

invested in RFID technology (e.g., RFID electronic seals and an Electronic Product Code Network) to enhance operational performance and reduce management costs. Since different industries have their own character, business strategies, and logistics models, the problems and the corresponding solutions of different manufacturers are described in Section 2. Section 3 depicts the case companies' implementation experience and presents the future outlook for other companies and industry sectors. Finally, conclusions are drawn in Section 4.

2. The development of integrated logistics hubs

The integrated logistics hubs were developed for six industrial sectors that linked 986 upstream and downstream supply chain manufacturers, 25 logistics service providers, and 11 information service providers. Approximately US \$9.7 million in combined public and private funding was required to complete the project. The achievements and benefits of the integrated logistics hubs for each industry sectors are provided in Table 1 and are described as follows.

Electronics industry. Long lead times for procurement and high inventory costs were found to complicate the integration of material and information flows. The manufacturers often lack real-time communications between upstream and downstream supply chain

members. In addition, repeated data entry from manual operations and inefficient labor handling decreased logistics efficiency. For these reasons, when the project was proposed and implemented from 2004 to 2005, the following specifications were added. First, the logistics hub was required to support shipment consolidation from multiple suppliers and to stabilize material supply. The logistics service providers were also advised to enhance their logistics efficiency. Second, a business hub was required to integrate logistics information from the aligned members including inventory and safety stock management, order tracking management, goods tracking management, demand forecasting management, and collaborative replenishment management. The logistics model of the electronics industry, shown in Fig. 3, represents a reference model for global logistics operations. The inventory and overseas delivery with respect to finished products are controlled primarily by the logistics hub.

Automotive industry. The logistics operations for finished cars are managed by different brands' dealers at different locations. Each dealer follows its own pre-delivery inspection (PDI) and retrofit operations which resulted in a redundant use of resources. Finished goods were often damaged during the transportation processes and landing times were too long. Dealers required a long order-to-delivery lead time and used the telephone to track the delivery status. Further, the slot spaces and materials in the

Table 1
Comparing achievements and benefits of six manufacturing sectors.

Manufacturer	Achievements	Benefits
Conventional electronics industry	<ol style="list-style-type: none"> 1. Logistics hub implementation: Support shipment consolidation and stable material supply. 2. Business hub implementation: Integrate logistics information and related functions. 	<ol style="list-style-type: none"> 1. Upgrade information systems to share and exchange logistics information 2. Reduce inventory by increasing supply chain inventory visibility 3. Use E-document to replace fax and telephone 4. Shorten supply chain shipping time by integrating order processing operations
Automotive industry	<ol style="list-style-type: none"> 1. Export aftermarket parts hub: Build an RFID-based goods tracking system for export parts 2. Aftermarket parts hub for domestic sales: Integrate the logistics operations of aftermarket parts for different dealers 3. Crate a locally manufactured automobile hub: Centralize the retrofit operations and inspections 4. Create multi-brands automobile import hub: Perform pre-delivery inspection and deliver cars directly to dealers 5. Export automobile hub: Control the automobile export processes 6. Multi-brands automobile production line hub: Merge the multi-brands' production lines into one 7. Knock-down imported parts hub: Set up a tax bonded warehouse within manufacturer's factory 	<ol style="list-style-type: none"> 1. Reduce dealer's order-to-delivery lead time 2. Integrate pre-delivery inspection and retrofit operations at the Taipei Port 3. Outsource logistics operations to professional logistics service providers to decrease operational costs and encourage innovation 4. Provide timely shipment status via an RFID-based goods tracking system. Decrease landing times to reduce the potential risk of damage to automobiles in port 5. Build an automatic material supply and replenishment system to save factory space, manpower, and cost. In addition, the suppliers can directly ship materials and parts to the assembly line
Integrated circuit industry	<ol style="list-style-type: none"> 1. Hong Kong transfer hub implementation: Fulfill logistics service with logistics service providers from Taiwan and Hong Kong 2. Taiwan logistics hub implementation: Establish RFID-based incoming and outgoing shipment operations 3. Overseas logistics hub implementation: Offer vendor managed inventory services for overseas customers 4. Business hub implementation: Develop a supply chain information platform 	<ol style="list-style-type: none"> 1. Outsource logistics operations to decrease the logistics cost (limited space and high rental) and let the manufacturer focus on core competencies 2. Vendor managed inventories enhance service quality and provide an international competitive advantage 3. Enhance supply chain information transparency to balance demand and supply and decrease inventory levels 4. Increase the data exchange efficiency with customers to improve order processing, and shipment processing
Automotive materials supply industry	<ol style="list-style-type: none"> 1. Logistics hub implementation: Apply the joint-inventory and joint-distribution mechanism 2. Business hub implementation: Integrate logistics information between upstream and downstream members 	<ol style="list-style-type: none"> 1. Institutionalize the joint-inventory and joint-distribution mechanism to increase shipment speed and share logistics costs 2. Establish a new third party logistics company to assist supply chain participants as active members of the logistics operations
Automotive aftermarket parts industry	<ol style="list-style-type: none"> 1. International transportation and trade channel construction: Fulfill logistics service with logistics service providers from Taiwan and North America 2. Supply chain management system implementation: Integrate and manage logistics information 3. RFID-based goods tracking system implementation: Monitor the export container throughout the journey to abroad customers 	<ol style="list-style-type: none"> 1. Achieve tighter corporation within suppliers and promote industry upgrade 2. Shorten supply chain response time, deliver goods on-time, and increase customer satisfaction 3. Enhance the container and goods tracking ability and logistics service quality
Semiconductor manufacturing industry	<ol style="list-style-type: none"> 1. Vendor managed inventory logistics hub implementation: Provide better warehouse management for stable material supply 2. Business hub implementation: Build visible information connections between suppliers, manufacturers, and logistics service providers 	<ol style="list-style-type: none"> 1. Logistics service providers take charge of the logistics hub operations and consolidate goods shipments from multiple suppliers 2. Using vendor managed inventories, the lead time is shortened (from warehouse to production line) and inventory levels are reduced

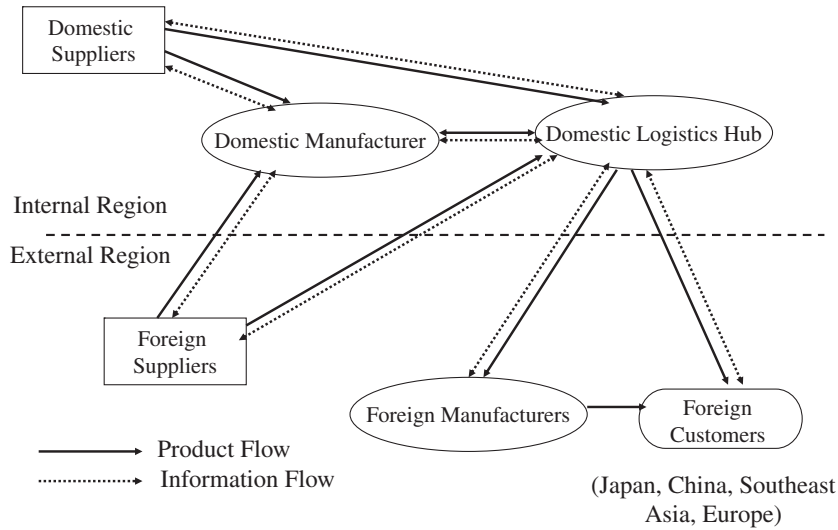


Fig. 3. The reference logistics model for the electronics industry.

warehouse of the car factory were insufficient due to the large number of parts requiring frequent replenishment. Following the analysis, the five year project focused on the creation of hubs for the export of aftermarket parts, the domestic sales of aftermarket parts, the import of automobiles, the export of automobiles and knock-down parts, and the creation a brand name production line. The specifications required building an RFID-based goods tracking system for the export aftermarket parts to increase information transparency and customer satisfaction. For the domestic market, the hub was designed to integrate the logistics operations of aftermarket parts for different dealers and construct an automatic replenishment mechanism. Since the manufacturer wanted to centralize the retrofit operations and inspections, RFID technology was used to control and monitor finished cars. The storage facility was designed so that cars could be imported into a bonded warehouse at the Taipei Port. Upon off-loading from ships, pre-delivery inspection was performed and delivered directly to dealers to reduce the risk of damaging the automobiles. In order to better control automobile export processes, inland transportation, export preparation, and dock loading operations, RFID technology tracking was implemented. The hub recruited local logistics service providers with sufficient skill and capital to adopt the new technology. The manufacturer merged the multi-brand production lines into

a single line for small-quantity demand. The hub utilized an automatic material supply and replenishment system to save factory space, manpower, and cost. For knock-down parts, the manufacturer set up a tax bonded warehouse within the factory. The import parts are stored in the hub and are then assembled into cars before shipping overseas. This approach simplifies the tax refund processes and reduces the customs duties fees. The logistics model of this industry is shown in Fig. 4.

Integrated circuit industry. The logistics operations for the integrated circuit manufacturers were overloaded and provided insufficient automation for emergency orders and order status management. Since most customers wanted a vendor managed inventory service, the recommended approach shortened lead times and transportation distances. Low information transparency and a lack of visibility lead to high inventory levels and long lead times. When the project was implemented, the Hong Kong transfer hub, the Taiwan logistics hub, an overseas logistics hub, and a business hub were simultaneously developed. Fig. 5 depicts the logistics model of this industry. The first step for the manufacturer was to construct an international logistics channel for finished products moving from Taiwan to Hong Kong and to outsource related logistics operations including warehousing, transportation, export operations, custom clearance, and tax bonded processes.

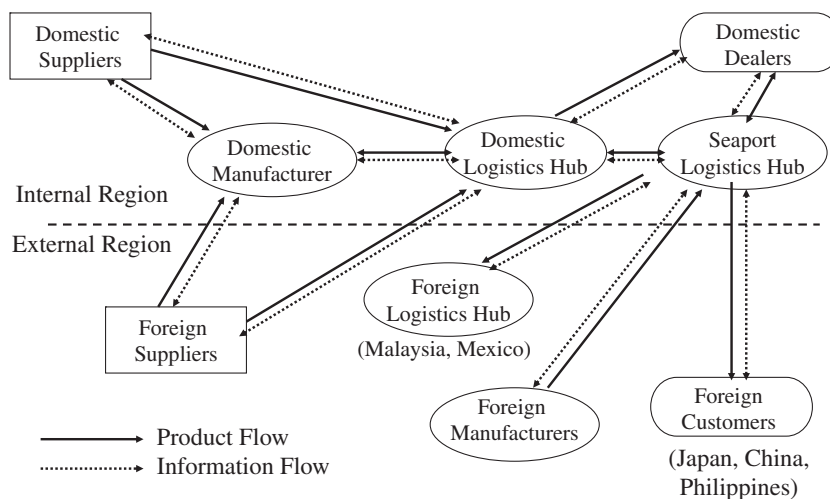


Fig. 4. The reference logistics model for the automotive industry.

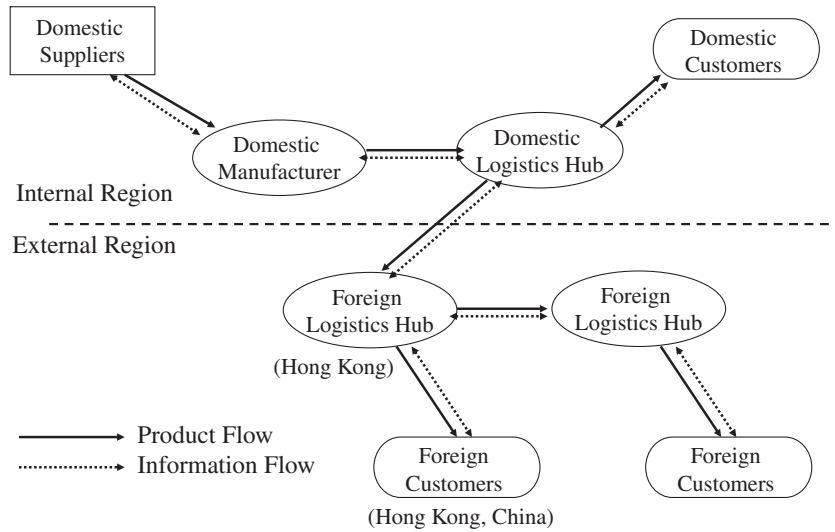


Fig. 5. The reference logistics model for the integrated circuit industry.

The goal of the Taiwan logistics hub was to use RFID to better manage incoming and outgoing shipment operations. The overseas logistics hub implemented vender managed inventory services for overseas customers and the business hub provided a supply chain information platform to manage order processing, shipment processing and tracing, material and parts receiving, inspection, and inventory control.

Automotive materials supply industry. The automotive materials supply industry reported difficulties delivering goods to location on-time. In addition, the distribution costs were high due to wide spread geographic distribution and the over use of phone communications. Unable to provide professional services, the manufacturer had reached a deadlock in development. When the hubs were implemented, several key steps were taken to improve efficiencies. The manufacturer transferred its original transportation fleet, warehouses, operators, and equipment to the hubs operated by a third party logistics company. Fig. 6 illustrates the logistics model of the automotive materials supply industry. The three hubs which are established in the northern, central, and southern regions of Taiwan used a joint-inventory and joint-distribution process to consolidate goods shipments from multiple suppliers to multiple customers. The development target for the business hubs were to implement a supply chain management system to integrate logistics information from upstream and downstream mem-

bers and to include order processing, transportation, goods tracking, and replenishment information.

Automotive aftermarket parts industry. The automotive aftermarket part company was under great pressure to shorten due dates and provide an online shipment status for dealers in North America. The development project rebuilt the supply chain management system and added an RFID-based goods tracking system. In order to improve tracking between distribution and transportation service providers in Taiwan and North America, the design of the RFID network became the key focus of the project. A new supply chain system integrated logistics information with RFID technology to track export containers from the production line, to inland transportation, to the dock terminal, to the overseas container terminal, and finally to the overseas logistics hub as shown in Fig. 7. The model utilizes external distribution resources (a foreign wholesalers' logistics hub) for transporting finished products to North American customers.

Semiconductor manufacturing industry. Raw materials are internationally sourced and supply is frequently uncertain in the semiconductor manufacturing industry. The suppliers use real-time replenishment systems, but low information transparency causes longer lead times and slow reactions to shortages. Thus, the manufacturer experienced difficulty managing raw material inventories. This project focused on creating a vendor managed logistics

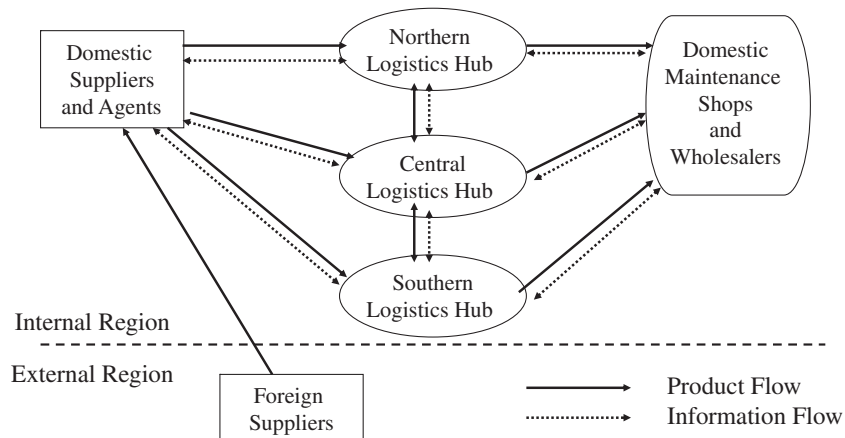


Fig. 6. The reference logistics model of the automotive materials supply industry.

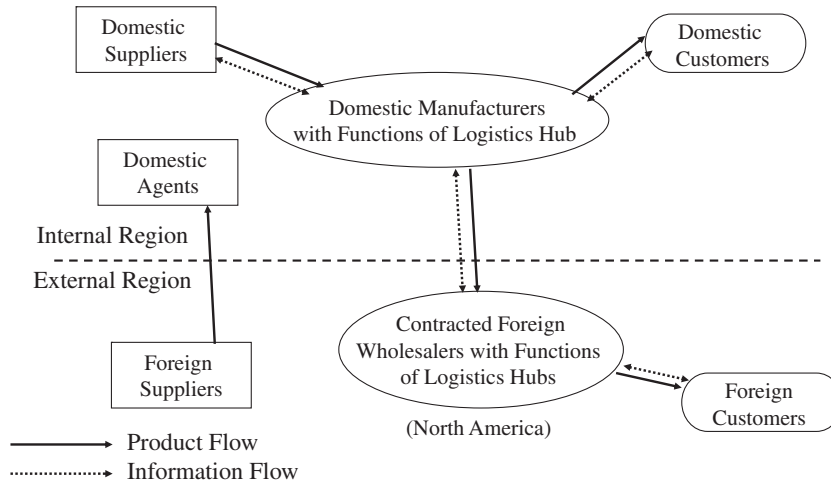


Fig. 7. The reference logistics model of the automotive aftermarket parts industry.

hub and a manufacturer’s business hub. The logistics hub provides warehouse management, real-time delivery, and replenishment for material supplies. The business hub provides information sharing between suppliers, manufacturers, and logistics service providers while integrating procurement, order processing, storage, goods tracking, and the replenishment of materials (Fig. 8).

2.1. Problems and solutions for the industrial sectors

This section describes the deficiencies and problems experienced by the six companies implementing the hubs. The solutions are provided as references for future companies planning to implement logistics hubs. Some of the business models implemented initially failed to demonstrate improved logistics performance between manufacturers, suppliers, and logistics service providers. The manufacturer reviewed the supply chain and provided the recommendations for hub improvement. Some suppliers disputed the new logistics policy during the initial promotion and implementation. Therefore, the manufacturer convened supplier seminars to explain the suppliers’ responsibility and reinforce the direction and goal of the project to achieve success.

Domestic service providers are mostly small and medium sized enterprises with limited capability to operate logistics hubs. The manufacturers interviewed several companies to select candidates willing to create new logistics operation models based on the requirements and capabilities. The project sponsors used key per-

formance indicators to evaluate improvements for all aspects including information transmission. Some of the supply chain members had ERP or MRP systems but others simply used PCs, faxes, and telephones. The manufacturers used two approaches (application-to-application and web-based) to exchange data for different levels of computerization among partners.

During the system requirement development phase, manufacturers experienced difficulty collecting and coordinating different departments’ data and opinions. The manufacturers added a project executive with the authority to control resources, hold monthly meetings, and monitor the progress of each department. There was also difficulty with RFID including low recognition by the tag readers and the high cost of equipment. Therefore, a technology review was conducted to assist the logistics service providers and manufacturers to purchase and implement RFID equipment.

2.2. Logistics outsourcing preference analysis

The outsourcing preferences of manufacturers in the automobile industry were analyzed using clustering techniques. The K-means clustering algorithm was used to group manufacturers based on their preference attributes and thus provide better aligned logistic services. Table 2 lists the seven logistics activities defined for full outsourcing, partial outsourcing, and self-management categories. The data were collected from 98 manufacturers

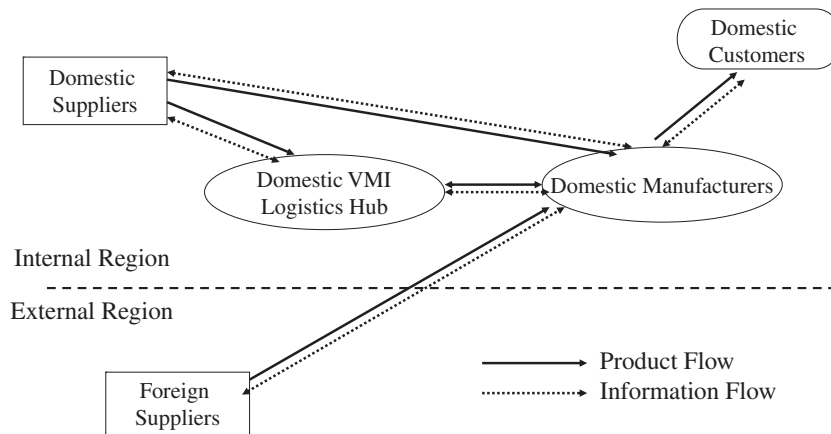


Fig. 8. The reference logistics model for the semiconductor manufacturing industry.

Table 2
The outsourcing status quo of surveyed manufacturers (Trappey et al., 2009)

Logistics activity	Outsourcing percentage		
	Total outsourcing	Partial outsourcing	Self-management
1. Customer order management	6	14	80
2. Inventory and warehouse management	19	41	40
3. Product circulation processing	22	37	41
4. After-sales services	4	8	88
5. Distribution and delivery services	43	47	10
6. Product logistics information	5	17	78
7. Returned and recycling services	3	11	86

that managed to varying degrees their own logistics activities except for distribution and delivery services (Trappey, Trappey, Huang, & Lin, 2009). In particular, customer order management, after-sales services, logistics information analysis, and returns and recycling services, remain under the companies' self-management. The statistical analysis of the surveys showed great potential for developing logistic hubs and outsourcing additional services to LSPs.

The manufacturers' preferences for outsourced logistic services are divided into basic and advanced services. The customer's preferences are shown in Table 3. In terms of basic logistics services, on-time delivery, satisfying the customers' standard operating procedure, maintaining products in good condition, providing a convenient domestic service network, providing flexible distribution capabilities based on quantity, and lowering the processing cycle for orders were the most valued preferences. For advanced logistics services, the establishment of online information systems, the design of customized logistics service based on product characteristics, reasonable pricing, warehouse security and insurance, information security, real-time logistics tracing, and the provision of the deliverers' contact information, were rated as the manufacturers most valued preferences. The survey data support management policies that these services and attributes are critical to successful industrial logistics hub development.

3. Future outlook for integrated logistics hubs

The future outlook provides generalized suggestions for government and industry to develop industrial logistics hubs. The future outlook includes logistics outsourcing services, information and communication technologies, supply chain security, general model and key performance indicators, green environmental protection, and cooperation with free trade zones.

3.1. Logistics outsourcing services

Globalization and competitive pressures have re-emphasized the importance of the LSPs (Choy et al., 2008). Logistics outsourcing is an accepted strategy for modern supply chain management (Sohail & Sohal, 2003) and is critical to link logistics hub with domestic LSPs. Multinational firms are decentralizing their logistic operations in order to focus on core business tasks such as research and development, manufacturing, and marketing (Carbone & Stone, 2005).

In Morgan Stanley's report (Ho & Lim, 2001), LSPs are classified ranging from first party logistics (1PL) to fifth party logistics (5PL). The 1PL (i.e., manufacturer) essentially owns and handles all self-

Table 3
The basic and advanced logistic preference analysis (Trappey et al., 2009).

Result category	Preference attributes of customers	Mean	Standard deviation	
Basic logistics services	3. Accurate on-time delivery	4.53	0.65	
	4. Comply with industrial customers' logistic operating procedures	4.02	0.81	
	5. Satisfy logistics services goals including picking, tallying, packing, sub-packaging, examination, and assembly	3.91	0.75	
	6. Maintain products in a good condition for all the loading and unloading operations	4.41	0.64	
	7. Convenience of domestic service network	4.15	0.69	
	8. Irregular distributing capability based on quantity	4.19	0.70	
	9. Flexible distribution capability based on emergency demand	3.97	0.68	
	10. Processing cycle and efficiency per order	4.10	0.75	
	Advanced logistics services	11. Establish an online information system	4.03	0.74
		12. Design customized logistics services based on products' characteristics	4.08	0.714
13. Reasonable price		4.30	0.68	
14. Provide staff with good service attitude and efficiency		3.73	0.83	
15. Good attitude provided when managing complaints and compensation		3.91	0.80	
16. Set up warehouse and inventory stocking based on intermediaries location		3.99	0.77	
17. Supplier capable of vendor managed inventories		3.92	0.83	
18. Bundle customers' advertisement and promotion with the product		3.48	0.66	
19. Capable of promoting warehouse security and insurance		4.04	0.69	
20. Provide secure and confidential information		4.06	0.67	
21. Provide online real-time tracking		4.22	0.73	
22. Provide deliverers' contact information		4.27	0.62	

logistics functions. The 2PL provides a small number of conventional services such as trucking and warehousing. The 3PL performs a large portion of clients' supply chain logistics activities. The 4PL provides integrated logistic services for the logistics outsourcing requirements and the 5PL focuses on providing e-logistics solutions for the entire supply chain. According to the survey by Industrial Economics & Knowledge Center (IEK), Taiwan's LSPs are mainly 1PL (28.7%) and 2PL (58.2%). Consisting mostly of small and medium sized enterprises (SMEs), these companies only provide basic logistics support and services to their customers. Few LSPs provide services for customers' primary supply chain and logistics activities. The 3PLs, 4PLs, and 5PLs contribute 9.8%, 1.9%, and 1.4%, respectively to the supply chain. Taiwan's LSPs are mostly providing basic storage and transportation services for their customers.

Since the majority of manufacturers seldom outsourced their logistics services, they found it difficult to select qualified 3PLs during the project implementation. Manufacturers needed a means to evaluate the LSPs' service quality, logistics network, and information technology. Some manufacturers have their own logistics department and found logistics outsourcing a contradiction to their traditional management practices whereas others found converting their logistics departments into an independent 3PL company as an attractive investment strategy.

The abilities and services of Taiwan's LSPs are insufficient when compared to foreign large-sized competitors. The leading foreign

LSPs such as DHL, UPS, and FedEx have used mergers, acquisition, and alliances to gain competitive advantage. This research suggests that the industrial logistics hub can be developed by second and third tier LSPs. Other than extending the scope and depth of their physical logistic services, domestic LSPs should enhance their information technology capability and adopt horizontal and vertical integration via strategic alliances among business partners. Horizontal integration between the same business groups can increase the economy of scale. The vertical integration between business groups within the long-term improve information transparency and supply chain visibility.

3.2. Information and communication technologies

While relying more on logistic outsourcing services, enterprises simultaneously increase the collaboration with their supply chain partners. Besides establishing virtual enterprise, they also integrate their information management. According to *Aberdeen Group's (2006)* global supply chain benchmark report, most companies state that supply chain process visibility is their top concern. Three-quarters of the firms lack enterprise-wide automation for global supply chain processes. Among the top 10 information and communications technology enhancements planned and implemented included “expanding the number of trading partners by providing status information,” “incorporating additional status events,” and “adding warning alerts”. In addition, over half of the survey respondents indicated that they wanted to add RFID and mobile technologies into their supply chain.

The information flow of industrial logistics hub is divided into two parts including physical goods' real-time status information, and supply chain information sharing and transmission. In order to track logistics status, enterprises collect information across the supply chain. The barcode is widely used but has limited capacity for storing information and the print quality directly affects its readability. Furthermore, barcodes require time to identify large number of objects since each item must be manually scanned (*Sahin, Dallery, & Gershwin, 2002*). The RFID is expected to revolutionize the supply chain by offering timely and unique tracking capability for products (*Lekakos, 2007*). *Gao et al. (2004)* have outlined the advantages of replacing RFID with traditional bar codes. The benefits of RFID include better tracking of product logistics (*Lee & Park, 2008*), improved efficiency and accuracy in warehouse management (*Poon et al., 2009*), reduced counterfeits, and better control of stealing (*Lu, Bateman, & Cheng, 2006*).

Although RFID offers a number of significant advantages and has found applications in many industrial sectors, there are still few firms implementing RFID. Since the cost of RFID software and equipment has restricted many popular RFID applications, domestic industry sectors and LSPs are at the early stage of adoption. The implementation of RFID often results from customer mandates and collaboration. Before implementing the RFID systems, firms must identify their needs and justify the costs of using return-on-investment (ROI) to evaluate the long-term viability. Each company must evaluate product options and the impact of different functions on their business process. Firms should also follow the evolution of RFID standards closely. Since international standards evolve over time, firms must be aware of the latest trends and innovations in order to develop a sustainable global RFID strategy. Often many advanced technologies such as mobile technology, wireless, global positioning satellite (GPS), and knowledge-based reasoning technology have recently been applied to manufacturing, and logistics services (*Chow, Choy, Lee, & Chan, 2005*; *Giaglis, Minis, Tatarakis, & Zeimpekis, 2004*; *Prater, Frazier, & Reyes, 2005*). *Kim, Yang, and Kim (2008)* report that firms can achieve a distinct competitive advantage through innovative information technology (i.e., RFID and mobile technologies), which en-

ables the creation of e-logistics services. *Chow, Choy, Lee, and Lau (2006)* designed an intelligent system that incorporates RFID technology, case-based reasoning (CBR) technique, and route optimizing programming model to assist logistics service providers in warehouse resource planning and execution.

Besides collecting the physical goods' information, enterprises are exploring ways to improve the efficiency of sharing and transmitting supply chain information. For supply chain activities, different companies use different system architectures, data formats, and system functions (*Ho, Trappey, & Trappey, 2004*). Building an effective XML-based data exchange mechanism and constructing a logistics information system to manage the logistics and supply chain operations is critical for reducing the time required to process and transmit accurate real-time data (*White, Daniel, & Mohdzain, 2005*). Enterprises should examine the level of satisfaction and the actual needs for effective use of logistics and supply chain management information systems (*Ketikidisa, Kohc, Dimitriadisa, Gunasekarand, & Kehajovae, 2008*). There is a deep divide between actual systems and original expectations for business hub systems. Most systems were developed by application service providers (ASP) for central manufacturers without considering the needs of smaller users (i.e., transporters, suppliers, brokers, and carriers). Thus, the company needs to communicate and reach a common consensus with all system users to gain the maximum benefits for the business hub.

3.3. Supply chain security

The issues of supply chain security and fast customs clearance are creating new ideas and practices such as customs-trade partnerships against terrorism (C-TPAT), container security initiatives (CSI), and freight security requirements (FSR). Among these security initiatives, the security and facilitation framework proposed by World Customs Organization (WCO) has become a widely utilized standard. WCO SAFE is a voluntary compliance program, which aims to enhance the certainty and predictability of high-risk consignments, provide detection, and secure the seamless movement of goods throughout the global supply chain. The SAFE framework consists of four core elements. First, it harmonizes the advance electronic cargo information requirements on inbound, outbound and transit shipments based on WCO data models. Second, each country that joins the SAFE framework must commit to ongoing risk management to access security threats. Third, the framework requires that at the reasonable request of the receiving nation, the exporting nation's customs administration will perform the inspection of outbound high-risk containers by non-intrusive detection instruments such as large-scale X-ray inspection machines and radiation detectors. Fourth, it defines the concrete benefits received by businesses that commit to the compliance program.

In addition to the four core elements, the framework is supported by two pillars. The first pillar is the customs-to-customs network arrangement which transfers the responsibility and authority of import custom agents to export custom agents. The customs administrators also apply unique consignment reference numbers that may be used by agents at any point during the customs process. The second pillar addresses the customs-to-business partnership. This partnership uses the authorized economic operator concept to enhance cooperation between customs administrations and private enterprises. The WCO SAFE participants who voluntarily meet the highest level of security receive benefits such as speedier clearance for low risk consignments, fewer customs inspections, and reduced times for border crossing. The framework pillars involve a set of subordinate standards and detailed explanations for field reference (*WCO, 2007*).

3.4. General models and key performance indicators

When developing integrated logistics hubs, the improvement or innovation of business models for supply chains and their logistic operations are essential. Researchers have depicted general models for the precision machine tool industry (Trappey, Trappey, Lin, Liu, & Lee, 2006), the optoelectronics industry (Trappey, Trappey, Lee, Hsu, & Lee, 2006) and automobile industry (Trappey, Trappey, Liu, Lee, & Hung, 2008). Further, quantitative analysis and decision models are critical for successful logistic operations. For instances, Taylor, Meinert, Killian, and Whicker (1999) and Tjokroamidjojo, Kutunoglu, and Taylor (2006) developed an advanced planning and dispatching method for the pickup and delivery of truckloads. Cheung, Shi, Powell, and Simao (2008) and Leung, Wu, and Lai (2006) proposed quantitative decision models for region-specific cross-boarder logistic problems related to fleet management, drayage, and shipping operations management between China and Hong Kong.

Applying distinct and appropriate key performance indicators (KPI) are also critical for developing logistics hubs. The KPI must reveal the performance of each supply chain participant. Each company should establish the KPIs according to the project scope and industry characteristics when building the industrial logistics hub. Fawcett and Cooper (1998) and Keebler and Durtsche (2001) derive the logistics and supply chain KPIs including inventory turnover, order fill rate, on-time delivery, transportation cost (inbound and outbound), customer complaints, inventory levels, inventory accuracy, order cycle time, cash to cash cycle time, supply chain response time, perfect order fulfillment, and order processing response time.

This paper recommends that companies use the supply chain operation reference (SCOR) model to represent business activities and processes. The SCOR model was developed by the Supply Chain Council (SCC) in 1996. Although SCOR is not a standard, the process reference models integrate well-known concepts of business process reengineering (BPR), benchmarking, and best practices analysis into a cross-functional framework that supports supply chain description, measurement, and analysis. The SCOR model Version 9.0 (SCC, 2008) has been applied to many practical cases including TFT-LCD manufacturing industry (Lin, Chen, Tsai, Lai, & Huang, 2005).

3.5. Green environmental protection

Corporate social responsibility (CSR) has become one of important strategies for global enterprises. Growing environmental concerns have resulted in the advancement of green supply chain management concepts and practices (Murphy & Poist, 2000). The objective of the green logistics is the improvement in logistics operations, such as transportation, storage, packing, loading, and circulation process, without environmental pollution and excess resource consumption. Green logistics is divided into green forward logistics (e.g., green supply logistics, green production logistics, green market logistics), and green reverse logistics. Green transportation and storage applies green transportation strategies, plans logistics network and distribution route effectively, and uses green vehicles (e.g. vehicles that burn fuel such as natural gas, alcohol and gasoline). Green packing and circulation adopt packing that fulfills the 4R request requirement that includes reduction, reuse, reclaim, and recycling). Finally, green reverse logistic constructs responsible collection and recycling of end-of-life cycle products to reduce pollution and maximize reuse.

3.6. Cooperation with free trade zones

From a logistics perspective, free trade (logistics) zone provides a comprehensive range of logistics services including consolida-

tion, packing, simple or in-depth processing, land, sea, air transportation, storage, and customs clearance in order to achieve the efficient distribution of commodities. Many firms plan to invest in international logistics zones (Lu & Yang, 2007). Therefore, some economic regions (e.g., Singapore, Hong Kong, Korea, and Japan) have constructed or have established international logistics zones to expand the capacity of their existing infrastructure for economic development and global competitiveness.

Taiwan has also followed the trend by developing five international logistics zones combining with free trade incentives that are called Free Trade Zones (FTZ). These centers are located at the Keelung seaport, the Taipei seaport, the Taoyuan international airport, the Taichung seaport, and the Kaohsiung seaport. FTZs in Taiwan benefit companies by providing value-added production facilities, relaxing hiring constraints, and providing savings on shipping tax and duty (Taiwan FTZ, 2010). Further since these within zones are considered outside the normal customs territory, products manufactured in the FTZs can be transported freely and flexibly without import inspection, customs clearance or escorted shipment. Companies operating in FTZs can also streamline procedures for granting entry and issuing landing visas for business personnel. Finally, FTZs Permit setup of financial holding companies for foreign investment and allow offshore banking units (OBUs) to handle foreign currency transactions.

4. Conclusion

Market globalization is increasing the adoption of new business models for product manufacturing and logistic operations. Under these circumstances, the management of supply chains becomes more complicated and necessitates the use of new logistic models to ensure competitive advantage. The aim of this research is to assist industry to construct integrated business and logistics hub reference models which offer a cooperative logistics operations environment. The main functions of the industrial logistics hubs are to support information sharing, improve delivery services, and to better manage warehouse management, and customs clearance services. This paper describes the architecture of the logistics hubs and reviews the problems and challenges which can occur during implementation. Finally, in order to better serve the global supply chain, the research highlights the future trends in logistics outsourcing services, logistic communications technologies, supply chain security, LSP key performance indicators, green environmental protection, and the development of free trade zones.

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