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## Survey analysis of supply chain adjustment for Taiwanese information technology firms

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Owing to the globalization of industry, the explosion in customer services and product life-cycle compression, most manufacturers have been adjusting the processes and activities of their supply chains to remain competitive and optimize total profit. The aim here was to explore the issues surrounding the changes in manufacturing supply chains and the consequential impact on freight transport demand. A questionnaire to survey Taiwanese information technology (IT) firms was designed and conducted to chart in detail the changes in supply chains of manufacturers, the trends in the international division of labour, and the strategic adjustment of manufacturing and logistics strategies. Surveys and interviews led to the conclusions that (1) vertical integration and international division of labour are very conspicuous among Taiwanese IT firms, (2) there are different strategies of supply chain adjustment at various stages of the product life-cycle, (3) with the transformation of the supply chain, manufacturers require faster transport services, i.e. the demand for air transport may increase and the demand for sea transport may decrease, and (4) once the firms decide on foreign investment, the availability of international transport services becomes one of the considerations for factory offshore relocation. However, transport cost is not a major consideration for firms' supply chain adjustments.

### 1. Introduction

Over the past decade, the trends in the rapidly changing world economy have been forcing firms to reshape the processes and activities of their supply chains to enhance competitiveness (Christopher 1998). Manufacturers are increasingly establishing new factories overseas to survive in a fiercely competitive global environment. Individual firms are not only changing the origin/destination (O-D) of transport demand and modal choice, but also they are influencing overall international freight flows (Feng and Chia 2000). Under this world-wide specialization of production, transport between continents and between countries increases at a faster rate than world economic growth.

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As for the supply chain, previous studies focused on the movement of goods from raw material procurement to product distribution during the manufacturing process. This includes producing sequences, placing orders, inventory management, transport, warehousing and customer services. Some studies include the entire commercial process from upstream suppliers and downstream customers in the domain of the supply chain, integrating into the discussion of supply chains, product, service and information, production and logistics. Wyland *et al.* (2000) suggested a conceptual structure for supply chain management to integrate manufacturing, retailing and logistics. Cooper *et al.* (1997), Zinn and Bowersox (1998) and van Hoek and van Dierdonck (2000) proposed the concept of postponement for supply chain operations. Furthermore, Pagh and Cooper (1998) identified four generic supply chain postponement/speculation (P/S) strategies by combining manufacturing and logistics' postponement and speculation. In addition, Ganeshan *et al.* (1999) provided a taxonomy of supply chain management research, which reviewed the studies on the conceptual perspective, evolution, categories and researched methodologies of supply chain management. Generally speaking, the concept of supply chain and logistics has been discussed for over 50 years (Ganeshan *et al.* 1999). However, many of the studies focused on the analysis of business processes within individual firms. Some studies describe the changes of freight flows and the modal choice of firms in relation to changes on the supply chain.

Regarding the influence that product development has on the supply chain, most research has categorized product life-cycle (PLC) into a series of stages: introduction, growth, maturity and decline (Dicken 1992, Birou *et al.* 1998, Wyland *et al.* 2000). PLC was adopted to expound on the evolution of international production. Birou *et al.* (1998) indicated that PLC can reflect important characteristics of a product. Thus, the life-cycle can be taken as an adequate tool to determine strategies for logistics, operation and purchasing. Higashi and Okawa (1994) also showed that the form of corporate alliance used may also depend on what stage of the PLC is involved. In addition, Pagh and Cooper (1998) took PLC as one of factors that could explain different adjustment strategies on the supply chain.

In freight transport studies, Qrtuzar (1990), Langevin (1996), Crainic and Laporte (1997), Feng and Chia (2000) and Garrido *et al.* (2000) all provided reviews on the solution approaches in freight transport. Most of the studies indicated that current freight transport researches tend to emphasize the role and importance that freight transport plays in the overall manufacturing/distribution processes. However, some of these previous analyses of freight transport have suffered from a variety of shortcomings. First, most of these studies imply that product manufacturing is done at the factories in a concentrated area. Under the trend of globalized production, firms manufacture their products at diversified multiple sites. Logistics' operations of the supply chain will determine the direction of freight transport flow. Therefore, the previous freight transport studies were difficult when reflecting on the current supply chain operating realities and the demands that firms currently place on freight transport services to meet their needs. Second, earlier studies were based on limited data and might not have captured all the effects of firms' globalized production. Third, part of these previous studies underestimated the transport demand incurred by the internationalization of production activity, since they did not take into account the

dynamics of the interaction between a firm's freight demand and adjustments in the supply chain's operations.

Nevertheless, some researchers have investigated the links between supply chain restructuring and freight transport in recent years (McKinnon and Woodburn 1996, Morash and Clinton 1997, Cooper *et al.* 1998, Lehmusvaara 1998, Voordijk *et al.* 1999). Morash and Clinton (1997) indicated that transport can play a key integrative role in supply chain structures. In a globalized environment, transport's contribution to the international supply chain structure takes on a new and increased importance. Transport capabilities such as reliability, time compression and just-in-time (JIT) delivery must be integrated with their enabling supply chain structures. McKinnon and Woodburn (1996) conducted a survey of changing freight transport requirements of 88 manufacturers. They also found that changes in the frequency and scheduling of freight deliveries in response to tightening customer service requirements and JIT management appear to have become a more prevalent cause of freight traffic growth than the physical restructuring of logistics systems. Manufacturers anticipate that their freight demand will increase in line with sales and be largely unaffected by road transport cost increases at the levels currently proposed.

Some researchers have used location theory and world system theory to explain industrial spatial distribution. Healey and Ilbery (1990) indicated that world system theories explained the evolution of a world economy in terms of the international character of the capitalist system. The global distribution of a firm's operations can be explained by categorizing geographical locations by their level of economic development. The world economy is divided into a core, periphery and semi-periphery, and countries can move from core to periphery, periphery to semi-periphery, etc. The core area is characterized by high wages, advanced technology and a diversified production mix. Quite the opposite is true of the periphery (low wages, little technology, narrow economic base), whereas countries in the semi-periphery have a combination of both sets of characteristics, exploiting peripheral countries while being exploited by core countries. Multinational enterprises have been moving standard and labour-intensive manufacturing activities from the core to peripheral regions, where more convenient geolocations and transport, lower costs in labour, land and other production input factors provide a competitive advantage. Core regions are used mainly for R&D, finance, retailing and administration activities.

This study recognizes that most of the previous studies focus on supply chain operation, freight transport planning and spatial economy, as well as their interactive relationships. However, there has been no deeply analysis for Taiwanese IT firms on the effects of freight traffic by supply chain adjustment and how these might change in the future. This paper will investigate supply chain adjustment factors through a survey of the international division of labour and supply chain reconstruction of the IT industry in Taiwan, and it aims to improve the understanding of how supply chain adjustment may affect transport demand. The findings may serve as the basis for future quantitative analysis. Section 2 gives a brief overview of previous research. Section 3 identifies the problems and domains of this study. It depicts the characteristics, the adjustment strategy of manufacturers' supply chain, and the propositions this study tries to verify. Section 4 explains the design of questionnaires, survey approaches, industry selection and sample analysis. Section 5 discusses the relevant results of the survey. To explore the link between strategic

corporate decisions, logistics' development and transport implications, Section 6 uses Acer's experience to describe a typical Taiwanese IT firm's global logistics' development. Section 7 offers conclusions and recommendations for future research.

## 2. Problem analysis and study domain

The 'supply chain' is defined first. The objectives and strategies of a firm's supply chain adjustment are also be stated. By reviewing previous studies, the potential relationships between product development characteristics and the supply chain changes can be described. At the end of the section, the propositions for investigation are developed.

### 2.1. Supply chain of manufacturing industry

In recent years, much research has focused on the performance, design and analysis of the supply chain as a whole, and the effects of the rising costs of manufacturing, the shrinking resources of manufacturing bases, shorter PLCs and the globalization of market economies (Beamon 1998, Chikan 2001). The supply chain is the network of organizations involved, through up- and downstream linkages, in the different processes and activities that produce value in the form of products and services (Christopher 1998). 'Supply chain management' introduces managerial components (such as planning and controls, organizational structure, information process) to the processes of supply chain operation, handling the mutual interrelationships between up- and downstream processes with suppliers and customers to provide lower costs and better services. Figure 1 shows the conceptual framework of the manufacturing supply chain. In figure 1, each node is an event of supply chain activities, and the links among nodes represent the supply chain processes. Together, the nodes and links comprise the entire supply chain network. For example, the main supply chain activities of the manufacturing industry include raw materials procurement and storage, parts' manufacturing, storage of the work-in-progress, assembling for semi-finished and finished products (labelling and packaging), warehousing for finished products, and retailing/distributing to customers. The semi-finished products have to be gathered at one location and

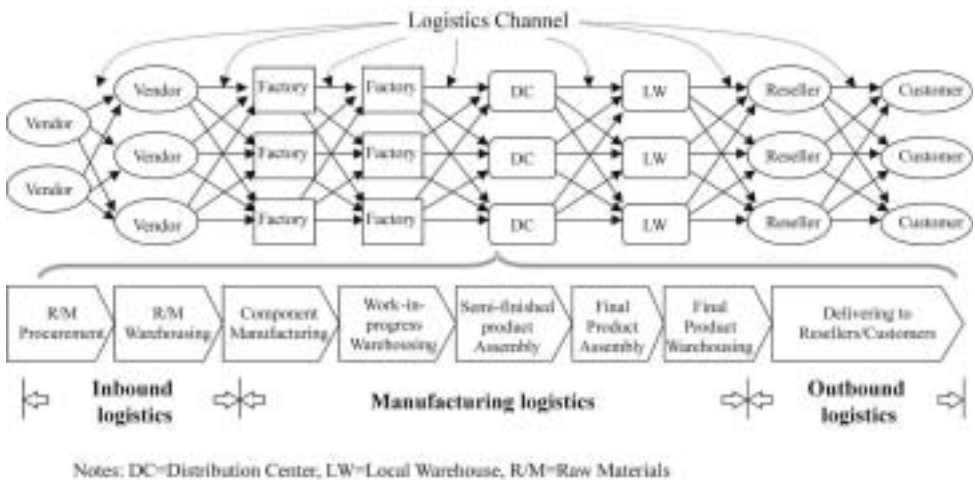


Figure 1. Supply chain of manufacturing industry.

assembled to become final products. This operation may take place in one factory, or in the distribution centre/local warehouse, mid- or downstream along the supply chain. The point of final assembly depends on the manufacturer's individual supply chain arrangement.

Moreover, logistics is defined as the process of managing the procurement, movement and storage of materials, parts and semi-/finished products through the organizing and distributing channels. The Council of Logistics Management (1998) defines logistics as 'part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption to meet customers' requirements'. Distribution of goods from one or more origins to one or more destinations is the core of logistics. Depending on the activities of supply chain, logistics can be segmented into three parts: (1) inbound logistics, i.e. the processes related to the raw material procurement; (2) manufacturing logistics, i.e. the processes covering the raw material/parts processing and the assembly for finished products; and (3) outbound logistics, i.e. the processes that deliver the finished products to the customers as soon as the orders received. All three logistics' segments demonstrate the demands toward transport services. The flow manoeuvre generated by the activities of logistics will use the existing transport networks. The main focus of this study is the downstream flow of the supply chain, from factory to the end customer.

## 2.2. *Supply chain adjustments*

### 2.2.1. *Purposes of supply chain adjustments*

The supply chain adjustments mentioned here include adding, removing and relocating activities (nodes) in the supply chain. These activities' rearrangement will alter the processes (links) of the supply chain.

In general, two purposes are important in adjusting the supply chain of a manufacturing firm. First, decreasing the cost requires that manufacturers look for inexpensive input factors to obtain comparative cost advantages or that manufacturers obtain benefits of scale economies by concentrating the supply chain activities. Second, the enhancement of the level of customer service requires that manufacturers offer customers more options by providing differentiated and customized products as well as faster display by delivering products to markets as early as possible.

### 2.2.2. *Basic principles of supply chain adjustments*

To meet needs, firms usually rearrange their supply chain activities by means of 'centralization' or 'diversification' in space and 'speculation' or 'postponement' in time. Centralization concentrates the activities of the supply chain at one site to obtain the economy of scale in manufacturing and the economy of cluster caused by the geographic proximity of up- and downstream production. This concept reduces manufacturing logistics by concentrating manufacturing activities. For example, the process from parts' manufacturing to final products labelling and packaging may be covered by the same factory. Certain production lines may also be located within close vicinity for mass production.

As to 'diversification', firms move some activities upstream to obtain cheaper input factors for reducing the production cost. Some may move downstream to

respond to customer's needs quickly. As manufacturing activities become more scattered, manufacturing logistics increases. In recent years, the international division of labour in global business has become an important 'diversification' in space for supply chain adjustment.

On the other hand, the logic behind 'postponement' is that risk and uncertainty costs are tied to the differentiation (form, place and time) of goods that occurs during manufacturing and logistics' operations. To the extent that parts of the manufacturing and logistics' operations can be postponed until final commitments have been obtained, the risk and uncertainty of those operations can be reduced or even fully eliminated. The notion of manufacturing postponement is to retain the product in a neutral and non-committed status as long as possible in the manufacturing process. This means to postpone differentiation of form and identity to the latest possible point. The notion of logistics' postponement is to maintain a full-line of anticipatory inventory at one or a few locations. This means to postpone changes in inventory location downstream in the supply chain to the latest possible point.

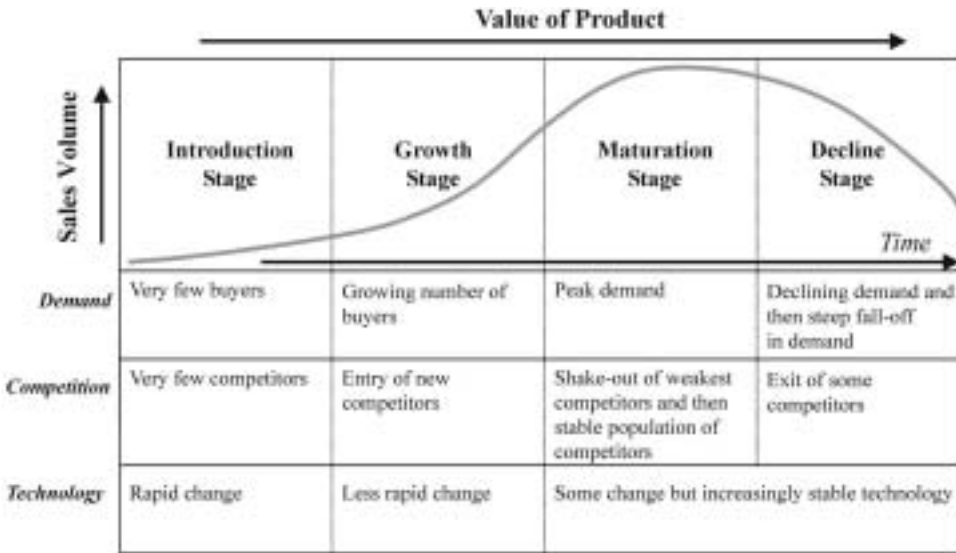
The converse concept to postponement is 'speculation', which holds that changes in form, and the movement of goods to forward inventories, should be made at the earliest possible time to reduce the costs of the supply chain. Speculation makes it possible to gain economies of scale in manufacturing and logistics' operations, and limit the number of stock outs. At the same time, the firm's speculations must meet the predicted market demands and customer services. Under this concept, manufacturing and logistics' operations are initiated earlier according to the prediction, thus risks and uncertainties increase relatively.

Many previous studies discussed the impacts of supply chain activities' speculation or postponement adjustments on the manufacturers' production performance. Cooper *et al.* (1998) identified four different supply chain postponement strategies for some global brands. Zinn and Bowersox (1998) proposed five different types of postponement strategies, four different strategies of form postponement (labelling, packaging, assembly, manufacturing) together with time postponement. Pagh and Cooper (1998) suggested four supply chain adjustment strategies, 'the full speculation strategy', 'the manufacturing postponement strategy', 'the logistics' postponement strategy' and 'the full postponement strategy', after he decided to combine activities in manufacturing and logistics based on related studies.

Basically, supply chain adjustments rearrange the combinations of activities and processes. The adjustment in 'space' varies activity location and the adjustment in 'time' varies the operation scheduling of the supply chain. Moreover, the processes change along with the adjustments in the supply chain activities.

### 2.2.3. *Relationships between product development and supply chain adjustments*

Since its initial conceptualization in the early 1950s, the PLC theory has gained significant recognition as a tool for effective marketing strategy formulation and implementation. The PLC, as defined by Dicken (1992), is the growth of sales of a product from initial innovation through a series of stages (figure 2). When a new product has just been introduced on to the market, the total volume of sales tends to be low because consumers are unaware and not confident about the product's quality and reliability. At this stage, few competitors exist in the market. Therefore, as long as consumers become aware



Source: (Dicken, 1992).

Figure 2. Profile of the product life-cycle (Dicken 1992).

of the product via its own quality and promotion, the product should enter the 'growth stage'. There is an increase in demand for the product. Other competitors may then enter the market as the demand/sales increase. Next, manufacturing techniques should stabilize under the growing competition among firms, and the manufacturing supply should reach its peak as market growth hits a ceiling. However, when the product attains maturity, demand begins to level out. New products often appear at this stage replacing the current one and there is shifting market demand. Thus, the sales of the old product decrease and enter the 'decline stage'. A product's life-cycle is a continuous development process. The divisions on the above life-cycles at various stages are conceptual but the differences in the demands, competition environments and technology developments are quite distinct.

At different stages of the PLC, a firm may have correspondingly different strategic plans for each activity in the supply chain due to the various manufacturing technologies and market needs. The life-cycle period is distinct from product to product. However, there is growing evidence that PLCs are tending to become shorter, industrial customers and distributors require JIT deliveries, and end customers are ever more willing to accept a substitute product if their first choice is not instantly available.

### 2.3. Propositions of this research

When reviewing the literature on the supply chain, freight transport, spatial economy and PLC concept, many discussions of manufacturing supply chain planning and the principles of supply chain adjustments prevail. However, few investigations discuss the following issues: whether globalization will affect the IT firm's supply chain adjustments; if the supply chain adjustment strategy should vary with the stage of the product's life-cycle; how supply chain adjustments affect the



decision-making of firms in modal choice and in freight transport O-D; and while the firms adjust the supply chain, what is the role of the availability of transport service.

Based on the previous discussion and literature review, the propositions to be investigated are as follows.

**Proposition 1: Globalization of industry and changing international division of labour will induce the Taiwanese IT firms' manufacturing activities to shift to overseas countries.**

Many studies recognize that firms will relocate their manufacturing sites due to cheaper raw materials procurement — or to respond to customers' needs quickly. Especially with the liberalization of international trade and the reduction of trade barriers, firms establish factories in overseas countries to manufacture products to meet local demand. Under this changing environment, whether the Taiwanese IT industry will undergo international collaboration and if adjustments will follow in the supply chain is the first issue of discussion here.

**Proposition 2A: The stage of PLC will indeed affect the firm's supply chain adjustment strategy in 'Space'.**

**Proposition 2B: The stage of PLC will indeed affect the firm's supply chain adjustment strategy in 'Time'.**

Since the nature of the production process tends to vary according to stages in the life-cycle, each stage will tend to have different production features: of technology, of market demand and of competition. Proposition 2A and B would like to depict the fact that for system optimization, the supply chain adjustment strategies in space and time will vary accordingly.

**Proposition 3: The supply chain adjustments will affect the manufacturers' modal choice and change freight transport O-D.**

The manufacturing industry supply chain is incomplete without transport services delivering raw materials, work-in-progress and finished products. All the adjustments in the supply chain will directly affect the manufacturer's distributing operations and then affect freight O-D patterns of a firm's transport demand as well as its modal choice.

**Proposition 4: The supply chain adjustments depend on the availability of international freight transport services.**

This proposition intends to depict that international freight transport service will not only affect the shipping time to the end customers, but also be the important factor manufacturers considered in adjusting their supply chains.

**Proposition 5: The transport cost will affect the firm's supply chain adjustment.**

This proposition intends to depict that transport cost will be the important factor manufacturers considered in adjusting their supply chains.

### 3. Questionnaire design and sample analysis

Since many of the previous studies are quite limited by data unavailability, this study designed and conducted a questionnaire survey on Taiwanese manufacturing industry to collect information concerning firms' supply chain adjustment strategies

and to obtain the relevant freight transport demand data. This section explains the rationale used in selecting respondents from the Taiwanese manufacturing industry, the empirical research methodology and the characteristics of the sample.

### 3.1. Industry selection

Industry selection was based on three criteria. First, the industry had a representative output share in the Taiwanese economy. Second, the supply chains used by firms in a particular industry had to be highly flexible to highlight the significance of supply chain changes under global conditions and the impact on freight transport. Third, the PLC of the industry had to be short to reveal the features of different life-cycle stages.

According to these criteria, relevant economic data and the Taiwan Standard Classification of Commodities, the IT industry was selected as the target industry for the survey. Investment in the Taiwanese IT industry has been growing rapidly and the production value has been increasing continuously. The IT industry's contribution to the total production value of the Taiwanese manufacturing industrial sector was 17.9% in 1989 and 30.3% in 1998. The manufacturing industry structure of Taiwan is shown in table 1. The IT industry in this study includes information hardware (computer hardware, key components) and semiconductors (semiconductor manufacturing, semiconductor service-IC testing, semiconductor's raw materials).

In general, because IT products have shorter life-cycles and the adjustment of the supply chain is more flexible, IT firms respond quickly to the comparative advantages of input factors and market demand. Furthermore, under this quick responding business model, it is easier to investigate the interactive relationship between freight transport services and the supply chain changes from IT firms' operations.

### 3.2. Research methodology

To explore issues of supply chain operations in Taiwanese business, a survey instrument was sent to 152 IT firms listed on the Taiwan Stock Exchange (TSE). In-depth interviews, desk and file research, and cost and quantitative studies of logistics and manufacturing strategies were also conducted. The objective of the interview process was to clarify the related details of firms' supply chain adjustments and to validate findings from the survey analysis. The survey was conducted from July 1998

Table 1. Manufacturing product structures (by production values).

Year	Information technology	Chemical	Metal	Consuming industrial	Total
1989	17.9	29.4	24.4	28.3	100.0
1990	18.6	29.0	25.0	27.4	100.0
1991	19.0	28.4	25.7	26.8	100.0
1992	19.2	28.2	26.8	25.8	100.0
1993	20.3	28.2	27.0	24.5	100.0
1994	21.7	28.6	26.5	23.2	100.0
1995	24.1	28.4	26.1	21.4	100.0
1996	25.2	29.1	25.3	20.4	100.0
1997	27.6	28.1	25.7	18.7	100.0
1998	30.3	27.3	24.9	17.5	100.0

Source: Directorate-General of Budget, Accounting and Statistics (2000). Data are percentages.

to September 1999. Before mailing the questionnaire, two companies were asked to pretest the survey and provide comments about the level of clarity and objectivity of the questions, the accuracy and applicability of the answer options, and the amount of time spent on the questionnaire. Suggestions were used to refine some of the questions and to add new answer options. The survey instrument was comprised of three sections. The first section contained questions asking respondents for basic information. The second section included questions about the manufacturing activities of the supply chain, including the respondents' opinions about the reasons driving the decision to establish offshore factories, and the number of the factories of the respondents. The final section questioned respondents about the strategies of manufacturing and logistics, including identification of products' characteristics and cost of logistics.

### 3.3. Sample analysis

A total of 45 usable surveys were returned each representing a unique firm for an effective overall response rate of 29.61% (i.e. 45/152). The low response rate may have been due to the very detail nature of the survey. Despite the low response rate, note that the total number of surveys returned represented a very large database for Taiwanese IT industry supply chain research.

Tables 2 and 3 summarize the basic information profile of respondents from selected industries. As shown in table 2, the positions held by the people who completed the questionnaire varied from top management to supervisors and engineers. The top management positions (2.22%) included chief executive officers, whereas the senior management positions (8.89%) included general and assistant general managers, technical directors, operations managers, and plant managers.

Table 2. Positions of surveyed respondents.

Title of position	No. of respondents	%	Responsibility for logistics operation			
			Yes	%	No	%
Top Management	1	2	0	0	1	2
Senior Management	4	9	3	7	1	2
Department Managers	25	55	20	44	5	11
Supervisors & Engineers	12	27	12	27	0	0
Others	3	7	0	0	3	7
Total	45	100	35	78	10	22

Source: survey in this study.

Table 3. Questionnaire survey response profile

Annual sales (US\$ millions)	No. of respondents	%
< 500 million	31	69
501 million – 1 billion	7	16
1 billion – 1.5 billion	5	11
1.5 billion – 2.0 billion	1	2
> \$2 billion	1	2
Total	45	100.0

Source: survey in this study.

The department managers (55.56%) were derived from control and logistics engineering; product engineering; and marketing and administration personnel, while the supervisors and engineers (26.67%) included those with the responsibility of handling manufacturing activities. Finally, the last category included the titles of executive assistant and executive secretary (6.66%). Based on the profile of the respondents, it is assumed the sample provides a representative profile and can be used to analyse the general practices and views within the Taiwanese IT manufacturing industry. After completing the survey, five respondents were contacted for personal interviews to clarify perceived misunderstandings or misinterpretations of the questionnaire, and to get a more in-depth understanding of their opinions. Furthermore, annual corporation sales per respondent ranged from US\$16 million to US\$3.06 billion (table 3), providing a wide coverage of the industry.

With regards to product lines, many firms carried multiple products, with some of these products accounting for only a small part of the total revenue. To simplify the analysis, only the products that took up to 5% of the total revenue were analysed. Among the respondents, there were 11 firms that carried a single product, 14 firms that carried two products, 13 firms that carried three products and seven firms that carried more than four products. Most Taiwanese IT firms carried three products on average. The vertical integration in the IT industry is obvious, and the degree of specialization is high.

#### 4. Survey results and analysis

This section discusses the respondents' survey results concerning supply chain adjustments to investigate the above propositions. In addition, it tries to identify the principles of supply chain adjustment.

**Proposition 1: Globalization of industry and changing international division of labour will induce the Taiwanese IT firms' manufacturing activities to shift to overseas countries.**

To examine the offshore relocation of supply chain activities, the respondents were asked to specify the location of their manufacturing factories. In this survey, the number of respondents and the related number of manufacturing locations were as follows: nine, 11, 11, eight and six respondents established their manufacturing factories at a single, two, three, four, five and more different locations, respectively. The respondent's factories within Taiwan were considered as at a single location. The above offshore factory relocation illustrates Taiwanese IT firms' international division of labour. About 80% (36/45) of the responding companies have already relocated part of their manufacturing activities to overseas countries. The results indicate that the supply chains of respondents have already been adjusted in 'space' diversification. In the survey, 92 offshore manufacturing factories had been established by 36 of the respondents. The distribution of those offshore factories is shown in figure 3. There are 44 offshore factories in China, 13 in the USA, six in Malaysia, six in Singapore, five in Thailand, four in the UK, three in Japan, three in the Philippines, three in Mexico, one in Hong Kong and four in other countries. Figure 4 shows the trend of foreign direct investment among respondents in recent years, which shows a continuous trend. In the IT products' manufacturing processes, most of the semi-products (component parts) can be independently manufactured. Therefore, the supply chain adjustments are relatively flexible and the activities of

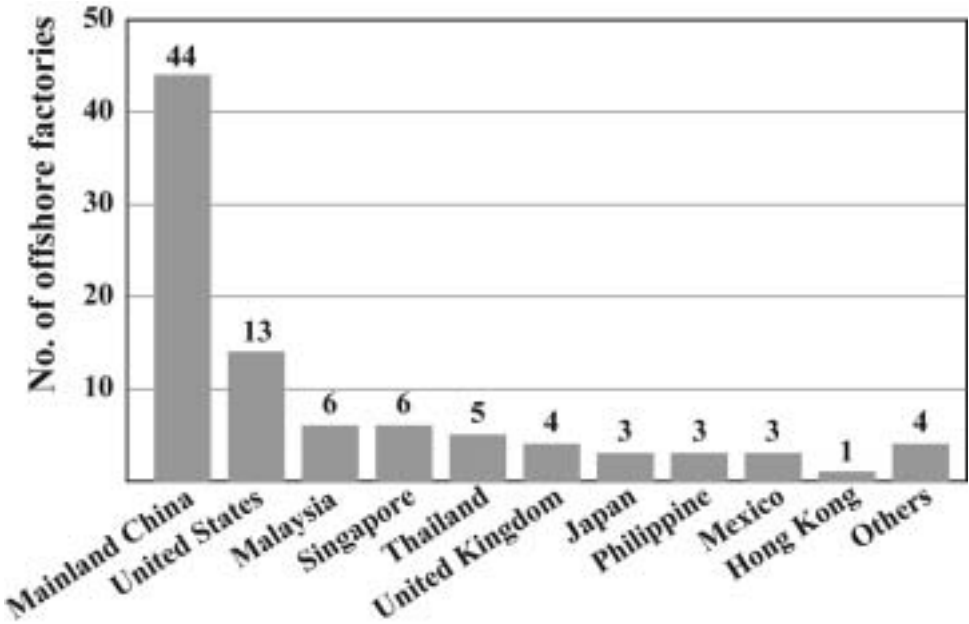


Figure 3. Distribution of surveyed IT firms' foreign investment.

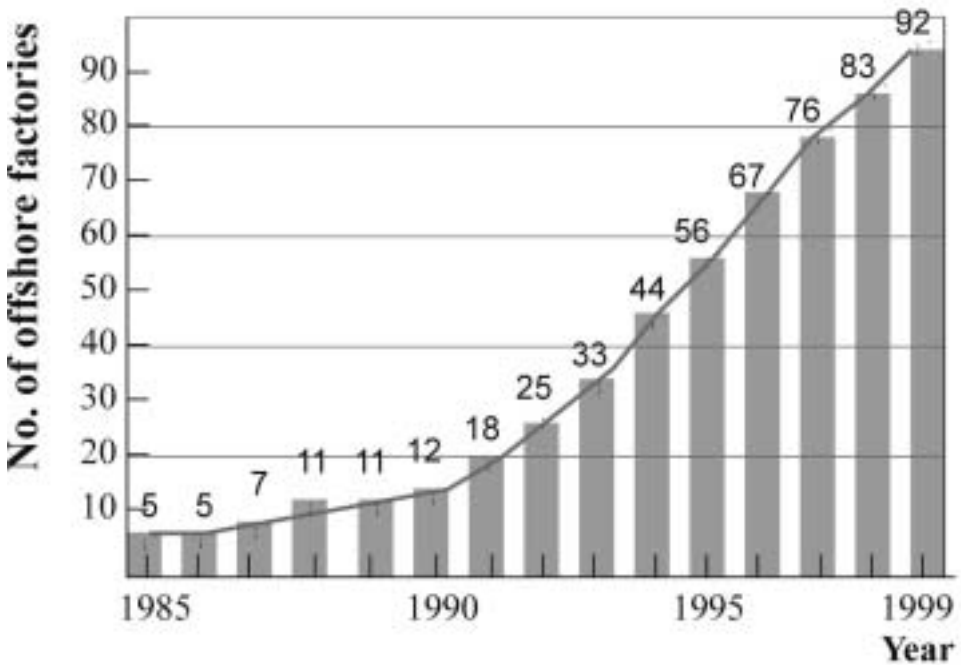


Figure 4. Trend of foreign investment.

the supply chain can be relocated with fewer restrictions. Taiwanese IT firms have been establishing their offshore factories to manufacture parts or products using the international division of labour. The results of the survey support Proposition 1.

In addition, table 4 highlights the reasons for the respondents to relocate their factories offshore. Respectively, about 45 and 16% of the respondents agreed that lower labour and land costs were major incentives for relocation providing long-term cost advantages. Moreover, about 3% of the respondents indicated that lower taxes and tariffs were the main reasons to relocate. Thus, about 64% of respondents indicated that labour and land costs as well as tax/tariffs savings were major cost considerations for the internationalization of the division of labour. Obviously, most firms want cheaper production input factors. However, some respondents indicated that other reasons instigated their location selection. The reasons included 'proximity to customer markets' (24%), 'easier to access new technologies' (7%), 'skilled labour availability' (3%) and 'others' (2%).

This research also tries to find the relationships between the reasons and locations of firms' foreign investment. As shown in table 5, in general the reasons given by the respondents for establishing their factories in China and South East Asia were 'cheaper labour costs', 'lower land cost' and 'lower tax/tariffs'. On the other hand, the reasons respondents established their factories in the UK, Japan, Singapore and the USA were 'proximity to customer markets', 'easier to access new technologies' and 'skilled labour availability'. In the former, most of the products of offshore factories were in the 'maturity' or 'decline' stage of their life-cycle, and in the later, the products were in the 'introduction' or 'growth' stage.

In conclusion, a majority of Taiwanese IT manufacturers relocated their factories to China and South East Asian countries for cheaper and cost-comparative advantages in production input factors, while manufacturers who established their factories in the UK, Japan, Singapore and the USA cited the ability to interact quickly with customers and advanced technology as the motivating factors. Although they are both foreign direct investments, the purposes and the products' characteristics are different. Different types of geographical relocation are relevant to different stages of the PLC.

**Proposition 2A: The stage of PLC will indeed affect the firm's supply chain adjustment strategy in 'Space'.**

To investigate Proposition 2, this research tried to identify the interrelationship between the manufacturing products' characteristics and the firms' supply chain adjustment strategies. There were 65 major products carried by the surveyed 45 respondents. In the survey, the definitions of the four stages of the PLC (figure 2)

Table 4. Reasons for offshore relocation.

Reasons	No. of respondents	%
Cheaper labour cost	41	45
Proximity of customer markets	22	24
Lower land cost	15	16
Easier to access new technologies	6	7
Skilled labour availability	3	3
Lower tax/tariff	3	3
Other	2	2
Total	92	100

Only the most major reason is considered for each offshore factory.

Source: survey in this study.

Table 5. Interrelationship analysis on the location selections, investment reasons and product characteristics for offshore factories. Unit: factory

Reasons	Mainland											Hong Kong			Others
	China	Thailand	Philippines	Malaysia	Singapore	Mexico	UK	Japan	USA	Kong	Others				
Cheaper labour cost	29	4	3	5	-	-	-	-	-	-	-	-	-		
Lower land cost	13	2	-	-	-	-	-	-	-	-	-	-	-		
Lower tax/tariff	2	-	-	1	-	-	-	2	3	-	-	-	-		
Easier to access new technologies	-	-	-	-	1	-	1	-	1	-	-	-	-		
Skilled labour availability	-	-	-	-	4	3	3	1	7	1	1	3	3		
Proximity of customer markets	-	-	-	-	-	-	-	-	2	-	-	-	-		
Others	-	-	-	-	-	-	-	3	13	1	3	-	-		
Total	44	6	3	6	6	3	4	3	13	1	3	-	-		
Life-cycle stage															
Introduction	0	0	0	0	1	0	0	1	1	0	1	1	1		
Growth	1	0	0	0	4	0	2	2	10	1	2	2	2		
Maturity	21	3	1	2	1	2	2	0	2	0	1	1	1		
Decline	22	3	2	4	0	1	0	0	0	0	0	0	0		

Source: survey in this study.

were introduced to the firms, and then the firms categorized each of their product's development. As identified by the respondents, out of the 65 products, there were two in the introduction stage, 19 in the growth stage, 35 in the maturity stage and nine in the decline stage.

Examining manufacturing locations, it was discovered that there were two products in the introduction stage; one product was made in Taiwan (50%) and the other was partially or fully made at an offshore factory. Of the 19 products in the growth stage, 15 products were made fully in Taiwan (79%) and four were partially or fully made at offshore factories (21%). Of the 35 products in the maturity stage, nine were made fully in Taiwan (26%) and 26 were partially or fully made at offshore factories (74%). At last, of the nine products in the decline stage, two were made fully in Taiwan (22%) and seven were partially or fully made at offshore factories (78%) (table 6). According to the survey results, as the life-cycle proceeds, manufacturing activities shift from Taiwan to offshore factories. More generally, along with the product life stage, firms adjust their supply chain in 'space', i.e. diversify to different locations instead of centralizing in Taiwan. The results of the survey support Proposition 2A.

**Proposition 2B: The stage of PLC will indeed affect the firm's supply chain adjustment strategy in 'Time'.**

In addition, this research also investigated whether firms adopted a 'speculation' or 'postponement' strategy in 'time' in manufacturing and logistic operations.

When analysing the data, the stage of the PLC was important in determining manufacturing and logistics strategies. The results took the following pattern (table 7).

- For the speculation strategy in manufacturing, there were two products in the introduction stage, 12 in the growth stage, 25 in the maturity stage and two in the decline stage.
- For the postponement strategy in manufacturing, there were no products in the introduction stage, one in the growth stage, two in the maturity stage and six in the decline stage.
- For the speculation strategy in logistics, there were two products in the introduction stage, seven in the growth stage, four in the maturity stage and none in the decline stage.
- For the postponement strategy in logistics, there were no products in the introduction stage, three in the growth stage, 26 in the maturity stage and seven in the decline stage.

Table 6. Analysis on product life-cycle stage and supply chain adjustments in 'space'.

Stage of product life-cycle	Introduction	Growth	Maturity	Decline	Total
No. of products	2	19	35	9	65
Made fully in Taiwan (%)	1 (50)	15 (79)	9 (26)	2 (22)	27 (-)
Partial or fully made in offshore factories (%)	1 (50)	4 (21)	26 (74)	7 (78)	38 (-)

Source: survey of this study.

Unit: no. of products



Table 7. Analysis on product development and supply chain adjustment strategies in 'time'.

Stage of product life-cycle	Introduction	Growth	Maturity	Decline	Total
No. of products	2	19	35	9	65
Manufacturing strategy:					
Speculation	2	12	25	2	—
No action	0	6	8	1	—
Postponement	0	1	2	6	—
Logistics strategy:					
Speculation	2	7	4	0	—
No action	0	9	5	2	—
Postponement	0	3	26	7	—
Made fully in Taiwan	1	15	9	2	28
Manufacturing strategy:					
Speculation	1	9	7	1	—
No action	0	5	1	0	—
Postponement	0	1	1	1	—
Logistics strategy:					
Speculation	1	4	1	0	—
No action	0	8	1	0	—
Postponement	0	3	7	2	—
Partially or fully made in offshore factories	1	4	26	7	37
Manufacturing strategy:					
Speculation	1	3	18	1	—
No action	0	1	7	1	—
Postponement	0	0	1	5	—
Logistics strategy:					
Speculation	1	3	3	0	—
No action	0	1	3	2	—
Postponement	0	0	19	5	—

*Source:* survey of this study.

Unit: no of products

Following the survey results, four types of 'time' adjustments were applied by Taiwanese IT firms. (1) For products in the introduction stage, the 'speculation' strategy or no action was taken in manufacturing and logistics. However, the feature was not significant due to a lack of samples. (2) The speculation strategy or no action was mostly applied to products in the growth stage for manufacturing and logistics. (3) For products in the maturity stage, most of the firms apply the speculation strategy in manufacturing, while some take no action. In logistics, they tend to use the 'postponement' strategy. (4) For the products in the decline stage, the speculation strategy is taken in both manufacturing and logistics.

Owing to the limited number of surveyed respondents, the statistical significance test was not applied on the questionnaire results. In particular, there were too few samples of products in the 'introduction' and 'decline' stages. However, this survey offers considerable support that supply chain adjustments in 'time' are functions of the PLC. Proposition 2B is supported.

**Proposition 3: The supply chain adjustments will affect the manufacturers' modal choice and change freight transport O-D.**

In the manufacturing supply chain network, freight transport demand occurs when materials, works-in-process and finished products are moving among nodes. It

includes 'inbound logistics', 'manufacturing logistics' or 'outbound logistics' as mentioned above. The supply chain adjustments of the firms in this survey may be divided into 'space' and 'time'. The influences that the supply chain adjustments have on freight transport will be discussed for both approaches.

As to the 'space' adjustments, the respondents diversified their supply chain activities to different locations through the establishment of offshore factories. Owing to the supply chain manufacturing activity dispersion and relocation, new freight transport demand was generated. The O-D pairs of freight transport varied as those supply chain activities shifted in 'space'. The products' weight and value also changed within the supply chain activities' movement.

As to the 'time' adjustments, manufacturers applied 'speculation' or 'postponement' strategies to manufacturing and logistic operations according to the stages of the PLC. If manufacturing activities were speculated, which is traditionally the method most often used by firms (Pagh and Cooper 1998), all manufacturing operations would be performed before the product being differentiated by location. Thus, the inventory for supply chain increases, but the impact on freight transport demands decreases. If postponement was applied, firms choose faster transport services to compensate for the loss in time caused by the postponement of operations in manufacturing. If speculation is applied to logistic operations, no significant impact on freight transport demand and the speed of transport services is observed. However, when logistic operations were postponed, manufacturers may have had to use faster transport services to compress shipping time. In general, supply chain adjustments affected the shipping time and the modal choice. Manufacturers tend to select faster transport services to compensate for the shortened response time. For such cases, transport costs are usually not major considerations. On the other hand, 'speculation' strategy provides longer response time, firms may select less speedy and transport services with cost advantage.

Table 8 shows data from respondents about the average lapse of time from receipt of a customer's order through to delivery (i.e. response time), average transport time, and modal choice. The results of the cross-analysis for average response time and products' life stages, at 'introduction', 'growth', 'maturity' and 'decline' was 8.2–8.5, 6.9–7.5, 4.9–5.1 and 5.3–5.4 days, respectively. The average transport time was 7.2–7.5, 5.7–5.9, 3.5–3.6 and 1.6–1.8 days, respectively. In modal choice, most of the respondents used airfreight transport services; only a few products were transported by sea freight. For most of the IT products, the transport cost accounts for a low portion of the sale price. Different manufacturing/logistics strategies were adopted in relation to the different stages of the PLC, and the status of products differed with the time that orders were received. The survey discovered that the products in the 'introduction', 'growth' and 'maturity' stages were completely finished when the orders were received, but the products in 'decline' stages were still works-in-progress.

From the results of the survey, the supply chain 'space' adjustment indeed affected the freight transport O-D. Newly induced transport demand was generated by the fragmentation of the supply chain's manufacturing activity. As to the 'time' adjustments in supply chains, if 'speculation' was adopted, there was no significant impact on the transport demand. If 'postponement' was adopted in manufacturing or logistics, to compress the response time, firms chose a faster transport mode. Under this changing trend, the faster transport services increased and the slower transport services decreased.

Table 8. Statistics on transport service demand versus product development.

Stage of product life cycle	MS	LS	Location of factory	No. of samples (product)	Required delivery time after ordered (day)	Final assembly time after ordered (day)	Average transport time (day)	Mode choice		No. of products in each group of transport cost/sales price				
								Air (%)	Sea (%)	I	II	III	IV	V
Introduction	S	S	Taiwan	1	8.5	1.0	7.5	100.0	0.0	1	0	0	0	0
			Offshore	1	8.2	1.0	7.2	0.0	100.0	1	0	0	0	0
Growth	S	S	Taiwan	15	6.9	1.2	5.7	80.0	20.0	8	5	2	0	0
			Offshore	4	7.5	1.6	5.9	75.0	25.0	3	0	1	0	0
Maturation	S	P	Taiwan	9	4.9	1.3	3.6	89.9	11.1	2	3	2	1	1
			Offshore	26	5.1	1.6	3.5	96.2	3.8	4	4	8	8	2
Decline	P	P	Taiwan	2	5.3	3.7	1.6	100.0	0.0	0	0	1	0	1
			Offshore	7	5.4	3.6	1.8	100.0	0.0	0	0	1	4	2

MS, manufacturing strategy; LS, logistics strategy; S, speculation; P, postponement.

I, Unit transport cost/product sale price  $\leq 0.01$ ; II,  $0.01 < \text{unit transport cost/product sale price} \leq 0.05$ ; III,  $0.05 < \text{unit transport cost/product sale price} \leq 0.10$ ; IV,  $0.10 < \text{unit transport cost/product sale price} \leq 0.15$ ; V,  $0.15 < \text{unit transport cost/product sale price}$ .

Source: survey in this study.

**Proposition 4: The supply chain adjustments depend on the availability of international freight transport services.**

As shown in the analysis, the respondents adjusted their supply chain in 'space' and/or 'time'. This research also investigated the impact on supply chain adjustments with transport services availability in the two approaches mentioned above.

In the survey, respondents were posed with the following question, 'In selecting the region/country for offshore manufacturing factories, would you consider the availability of the international transport services in that foreign country?' None of the 36 respondents with overseas factories considered the availability of international transport services as an important decision-making factor. However, as the questionnaire moved to the question, 'In selecting the city for the establishment of a new factory, would you consider the availability of international transport services in that city?' There were 32 respondents out the 36 who took this consideration seriously. It seems that the availability of international transport service did not affect the decision-making for international division of labour but it was an important factor for selecting factory sites. It was found that today's international freight transport network has been well developed at the country/region level, but not every city has been well linked/served.

If firms adopted a 'postponement' strategy in 'time' adjustment, the average transport time ranged from 1.6 to 3.5 days (table 8). Therefore, we may conclude that if no fast transport service is available in a region, it would be impossible to ship products on time and the 'postponement' strategy could not be applied to supply chain adjustments.

According to the above analysis, the availability of transport services seemingly does not constitute a reason for firms to relocate manufacturing factories to other countries. However, once the relocation decision is made, the availability of international freight transport services becomes an important decision-making factor in selecting the relocation cities. In 'time' adjustments for the supply chain, availability of fast transport services is a necessary condition for firms to adopt the 'postponement' strategy.

Therefore, the information from this survey offers partial support for Proposition 4. The results for space adjustments do not support Proposition 4. However, when manufacturers had decided to relocate their factories overseas, the transport services availability of each alternative site will be the evaluation criteria. Furthermore, when the factory applies the 'postponement' strategy, the Proposition is also supported.

**Proposition 5: The transport cost will affect the firm's supply chain adjustment.**

From table 8, we found that the respondents' supply chain adjustments affected the shipping time and mode choice, but transport cost was not a major consideration. Even the value of (transport costs/product sales prices) in the 'maturity' and 'decline' stages were higher than the value in the 'introduction' and 'growth' stages, the respondents in the stages of 'maturity' and 'decline' chose the faster but more expensive airfreight transport services. Therefore, this survey of IT firms does not support Proposition 5.

In addition, it recognizes that the response time in the supply chain is inversely proportional to the level of customer services, as shown in the upper part of figure 5. The lower part of the figure presents the relationship of transport speeds vs. response time with various distances ( $Dist_1$   $Dist_2$   $Dist_3$ ) between the manufacturing factories and customer markets.

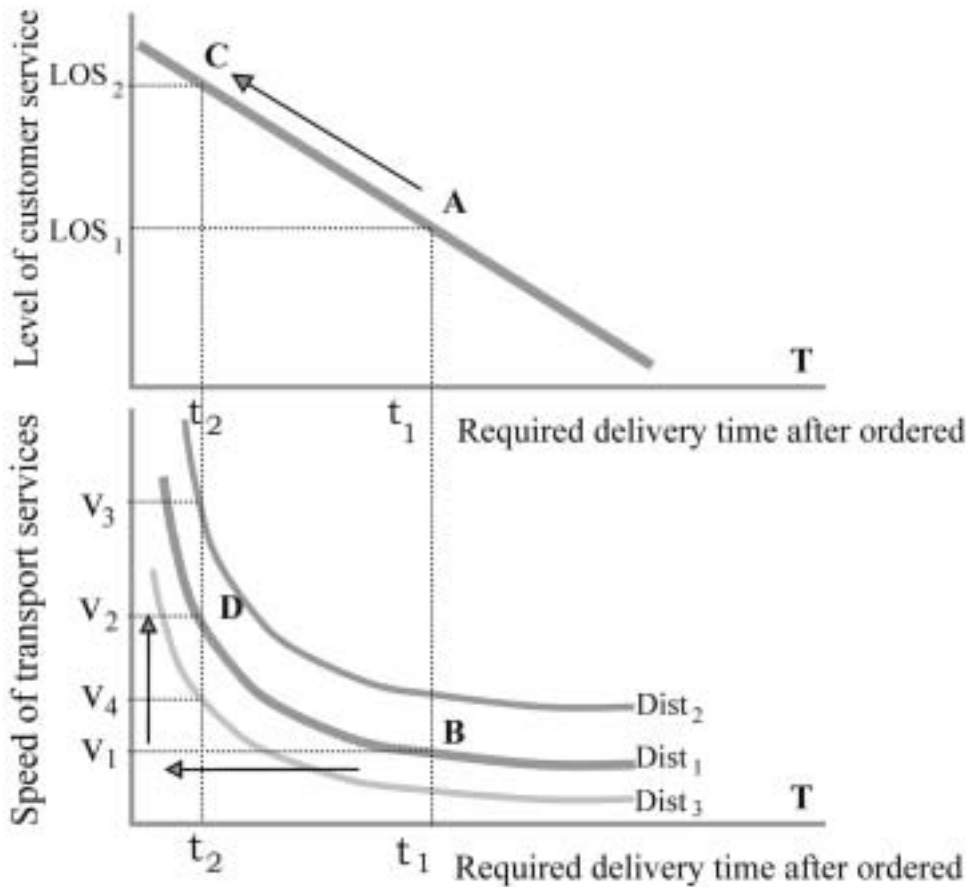


Figure 5. Relationships among response time, transport speed and the level of service.

When a new product is first introduced to the market, the demand is low. Manufacturing and logistics' operations stay on schedule. The response time to customers or retailers is not rushed. See Point A in figure 5, where the response time  $t_1$  will map the customer service level  $LOS_1$ . The transport service provides speed  $v_1$  delivers the products from manufacturer to the customer/retailer ( $Dist_1$ ) during period ( $t_1$ ).

Moreover, as the PLC proceeds, firms adjust their supply chain in 'time', from 'speculation' strategies to 'postponement' strategy. In the meantime, the customer service requirements increased from Point A to C in figure 5. In this case, the response time is shortened from  $t_1$  to  $t_2$ . If the distance  $Dist_1$  remains unchanged, then a faster transport speed  $v_2$  is needed.

No matter whether 'centralization' or 'diversification' is adopted in supply chain 'space' adjustments, the transport service has to increase its speed to  $v_3$  due to the increased distance  $Dist_2$  as long as the response time is unchanged. This is quite a common situation for firms seeking cost advantage input factors to relocate factories overseas. On the contrary, if the reason for factory relocation is to locate 'close to the customer market', then the distance between factory and customer/retailers is shorten from  $Dist_1$  to  $Dist_3$ . For this case, to maintain the same response time  $t_2$ , slower transport speed  $v_4$  is satisfactory.

In general, the transport service requirements will change both when the supply chain adjusted in 'time' and 'space'. Especially, to resolve the incurred pressure caused by the response time, faster transport services are needed to deliver the products to the end customers and retailers on time.

The survey also finds that a lot of Taiwanese IT products are in the maturity stage of the life-cycle. Many manufacturers conduct their business operations as 'original equipment manufacturer (OEM)'. In figure 5, the Taiwanese IT manufacturers mostly scatter around Point C. The firms always shorten the response time to enhance the level of customer services. In other words, faster transport services are applied to reach the above goals. 'Build to order' (BTO) is another most conventional business model for supply chain operation taken by the manufacturers. Therefore, Taiwanese IT firms have to improve their manufacturing technology as well as come up with fast and highly efficient logistics' operations to meet the requirements of the global customers. This explains the phenomena of why Taiwanese firms, one after another, build up global logistics management systems.

### 5. Logistics' operations of Taiwanese IT firms: Acer's experiences

To explore the transport implications of the changes in supply chain adjustment, we used Acer's experience to describe a Taiwanese IT firm's globalized logistics' development.

Because logistics strategies are dependent on a firm's supply chain operation, we divided Acer's logistics' development into four stages in relation to changes in the supply chain (figures 6 and 7). Before the late 1980s, during the first stage of Acer's logistics' development, the company concentrated all its production activities at a single geographical location and served its world markets through traditional logistics network. At this stage, the main freight transport demand was from Taiwan to the market countries. Moreover, the value density — the value of a product in relation to its weight and volume — was low; as well as time was not considered to be a critical supply chain operation variable, leading to a large part of the finished products being transported by sea.

Since the 1990s, the second stage of Acer's logistics' development, Acer adjusted its supply chain as factories were relocated to Mainland China and South East Asian countries to use cheaper and cost comparative factors. Materials, semi-finished products, components and finished products were transported to the geographically dispersed manufacturing factories. In this stage, the output of a primary manufacturing factory in one country may simply be the input for a subassembly factory of Acer located in another country. The semi-finished products may be transported back to Taiwan for final assembly, then re-export to foreign markets. The increment of transport demand of semi-finished products  $\Delta Q_1$  (figure 7) was generated along with the process of supply chain operation.

In the third stage, each of Acer's offshore manufacturing factories performed an independent operation in the supply chain and ships output to a final assembly factory in Taiwan. After final assembly, the finished products were exported to the markets. Because the offshore factory was operated independently, the increment of transportation demand ( $\Delta Q_2$ ) was fully reflected in the freight flow from Mainland China and South East Asian countries to Taiwan.

But in recent years, the ability to respond to customers' requirements in ever-shortening time-frames has become critical, has lead Acer to further adjust their supply chain operation. All of the outputs from each offshore factory are shipped

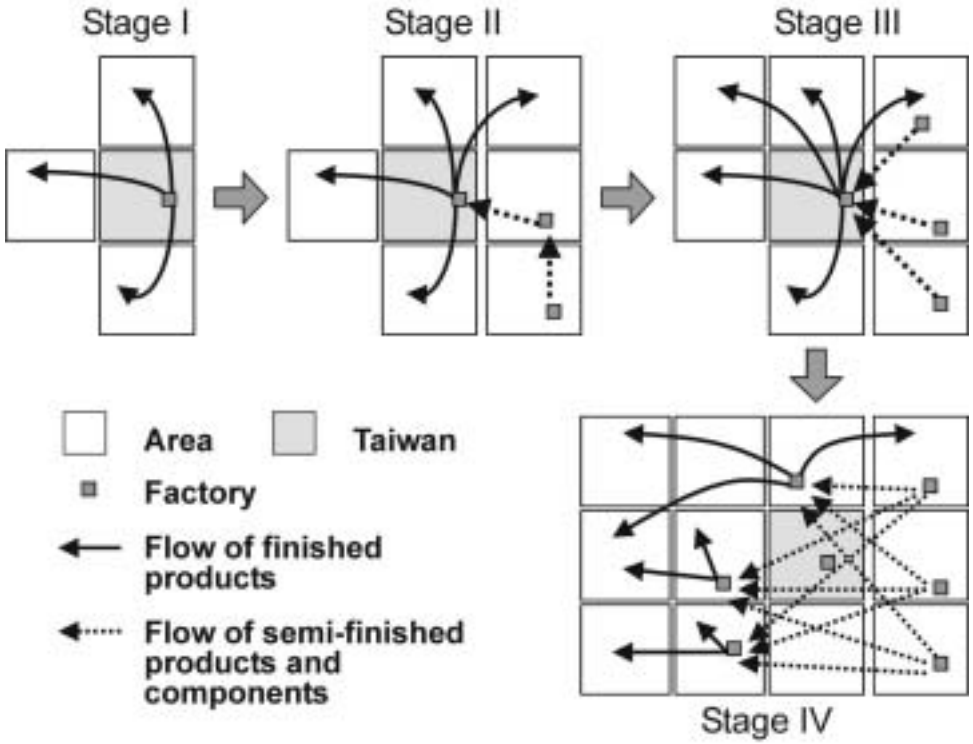


Figure 6. Acer's global logistics' development.

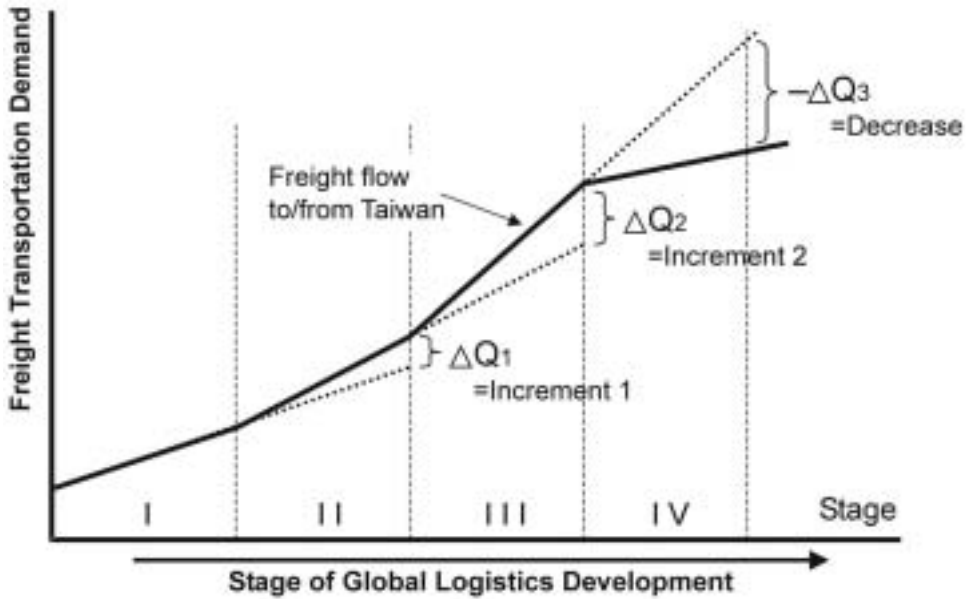


Figure 7. Acer's logistics' development and freight transport demand to and from Taiwan.

directly to the final assembly factories in locations near the marketplace. This is the fourth stage of Acer's logistics' development, the physical flow of components and semi-finished products are not transported to Taiwan, freight flow between the offshore factory to the marketplace has increased and the freight flow to and from Taiwan has decreased ( $-\Delta Q_3$ ). In the decision of modal choice, because the response time of IT industry operation has become shorter, air transport services demand is increasing and sea transport demand is decreasing.

Because all of the movements of materials, semi-finished products, components and finished-products determine the freight transport demand, the various stages of logistics' development mentioned above will create different freight transport demands in terms of trip generation and distribution. In Acer's experience, the freight transport demand to and from Taiwan will indeed fluctuate according to the firm's international division of labour as well as the various supply chain adjustment strategies.

## 6. Conclusions and recommendations

Many traditional freight transport researches that implied the assumption of firms' manufacturing activities are concentrated at a single location cannot well-describe the supply chain operations of today's globalized manufacturing firms. Moreover, since the industries globalized and transport demand is a derived demand, the understanding of firms' supply chain adjustment will be the basic information of transport demand analysis. This paper compared supply chain adjustment practices at 45 IT firms in Taiwan and investigated five Propositions.

As to Proposition 1, the survey indicates that Taiwanese IT firms are indeed involved in international collaboration. Firms actually diversify and adjust their manufacturing activities in their supply chains with respect to space factors. Also quite a few manufacturers have established offshore factories for cheaper, cost advantage production input factors. Since this study used only the respondents' main reason as the analytic basis for offshore relocation, some information may be missing as a result of problem simplification. However, the main purpose of this proposition in this study was to find the reasons for supply chain 'space' adjustment, the simplified analysis still provides material to achieve the goal of the research.

Propositions 2A and B are supported. The firms apply different supply chain adjustments to the products according to their PLC. The supply chain adjustments in 'space' do appear according to the stages of the PLC. The adjustments in space migrate from domestic 'centralization' to 'diversification' at various sites. As to the adjustments in 'time', there are four basic types, which correspond to the various stages of the PLC. Regarding the PLC, we are aware that it is a more or less subjective judgement for respondents to identify at what stage of the life-cycle their products are positioned. However, this study concentrates on clarifying if the decisions directed at the supply chain adjustment were related to the various PLC stages. From the results of the survey, we found that the analysis allows for exploration of the firms' decision-making information to clarify the propositions.

Proposition 3 for supply chain adjustments that affect freight transport O-D and modal choice is supported. The supply chain adjustments in 'space' will actually affect the transport demand between origin and destination. In the meantime, if the postponement strategy is adopted, faster transport services will be needed.

Proposition 4 contains two layers. Not until the firms decide to undergo the adjustments in 'space', does this proposition find support. However, once the firms



decide on foreign investment, the international freight transport service availability becomes one of the considering factors for factory offshore relocation. Additionally, when firms apply 'postponement' strategies, this proposition is also supported.

Finally, this study found that the transport cost was not a major consideration for the respondents' supply chain adjustments.

In general, this study discovered that the concepts of centralization/diversification in 'space' and P/S in 'time' do exist in the supply chain adjustments of the IT manufacturing industry. The adjustment strategies of global supply chain will affect a firm's modal choice, and that the space diversification will affect the trip generation and distribution. How to establish the quantitative model for supply chain adjustment and freight transport demand would be an interesting focus for future research.

The 'OEM' and 'BTO' business models are popular among many Taiwanese IT manufacturers. Most of the products manufactured under these models have entered into the maturity life-cycles. Firms not only have to lower the manufacturing costs, but also have to enhance the transport efficiency to satisfy the level of service. Any product steps in the maturity or decline stages will more rely on faster transport services when the manufacturing locations diversify. If the 'postponement' strategy is applied, the turnaround time gets shorter once the order is received. Fast transport services will be necessary to meet the supply chain operations. In terms of the influences that the supply chain adjustments have on the transport demand, the diversification in 'space' will lower the total quantity in freight transport in the host country. The postponement strategy will increase the demand for faster transport services.

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