財團法人中華經濟研究院

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH
75 Chang-Hsing St., Taipei, Taiwan, 106
Republic of China
TEL: 886-2-735-6006
FAX: 886-2-735-6035

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

THE DEVELOPMENT AND STRATEGY OF TAIWAN'S INFORMATION TECHNOLOGY INDUSTRY

CHIEN-NAN WANG

OCCASIONAL PAPER SERIES No.9405
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The Development and Strategy of Taiwan's Information Technology Industry

by

Chien-nan Wang

Research Fellow

Chung-Hua Institution for Economic Research

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Chung-Hua Institution for Economic Research

75 Chang-Hsing St., Taipei, Taiwan 106

Republic of China

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The Development and Strategy of Taiwan's Information Technology Industry

I. Introduction

After 1986, Taiwan's electronics industry surpassed the textile industry and became the largest industry in Taiwan, with an average yearly growth rate of 12.55%. The 1990 export value was US$17.3 billion (26.7% of total manufactured exports). The importance of this industry is thus very obvious. This crucial industry underwent several development stages.

Starting at the end of the 1960s, the FDI of foreign companies in Taiwan gave a big push to Taiwan's electronics industry. Taiwan learned the technology and from later OEM/ODM experience, forming the basis of the electronics industry. Meanwhile, the government provided a stable environment, a good incentive system and effective protection, which were also helpful.

Originally, the thriving sector of Taiwan's electronics industry was consumer electronics. At the end of the 1970s, however, the world information industry was rising and its externality on the entire fabric of production became clear. Taking Taiwan's conditions under consideration and the advice of foreign Chinese scholars and foreign consultants, the Taiwan government decided to target the computer industry as a strategic

Paper presented in the conference on "Information Technology Innovation and National Economy: Lessons for the Next Decade of Change," on October 8-9, 1993, in Korea.

industry. It set up a ten-year development plan (1980-1989) to promote it with quite successful results. As the whole electronics pie grew much larger, the computer share of the electronics industry expanded from 2.7% in 1982 to 23.9% in 1991. Meanwhile, household appliances declined from 12.3% in 1982 to 9.5% in 1991 while the share of electronics products dropped from 26.7% in 1982 to 11.3% in 1991.

The major government industrial plan for the 1990s is to promote ten emerging industries (refer to Table 1) based on the criteria of high market potential, extensive inter-industry linkages, high value-added, a high level of technology, low pollution and low energy dependence. The ten industries incorporate most of the sixty-six critical products and parts & components actively promoted by the government. Among the ten emerging industries, two electronics industries with high priority are telecommunications industry and information industry. They can also be categorized as the information technology industry. We shall focus on the development and strategies of these two industries.

Table 1 Development Goals of the Ten Emerging Industries

(US$ Billion)

Year/Area	1990 Production Value		2000 Production Value		Average Growth
Industry	World	Taiwan	World	Taiwan	Rate(Taiwan)
Telecommunication	111.1	1.85(1.6%)	302	8.15(2.6%)	16.0%
Information	340	6.85(1.9%)	900	28.0 (3.1%)	15.1%
Consumer Electronics	60.7	2.29(3.8%)	109	4.51(4.1%)	7.0%
Semiconductor	47	1.51(3.2%)	128	6.0 (4.7%)	14.8%
Automation	420	2.84(0.68%)	810	10.08(1.24%)	13.5%
Aviation	238.9	0.67(0.28%)	570	6.0 (1.05%)	24.5%
Advanced Material	69.1	1.79(2.6%)	141.3	6.82(4.82%)	14.3%
Chemical & Pharmacy	350	3.57(1.0%)	750	10.0 (1.3%)	10.8%
Medical & Health	61.8	0.27(0.43%)	121.57	1.46(1.2%)	18.5%
Anti-Pollution	189.62	1.02(0.54%)	308.86	3.74(1.2%)	13.9%

Note: Numbers in brackets are Taiwan's world market share.
Source: Industrial Development Bureau, Ministry of Economic Affairs.

II. Telecommunications Industry

The traditional Taiwanese telecommunications industry focused on switches and telephones and began in 1957. In 1981, the Directorate General of

Telecommunications (DGT) started using digital switches and moved toward full digitalization. The opening of the U.S. telephone market in 1983 created large expansion of Taiwan's telephone industry, causing some to label Taiwan the "Telephone Empire." Starting in 1987, consumer premise equipment (CPE) such as private branch exchanges (PBX), key telephone systems (KTS), fax machines, modems, and mobile phones were privatized in Taiwan. This liberalization stimulated further developments within the CPE market.

A. Current Development

In 1990, there were about 490 telecommunications firms. However, nearly three-fourths of them had fewer than 50 employees, and more than 82% of them had less equity than US$5.7 million. In 1990, the telecommunications share of the electronics industry in Taiwan was 9.4%, while Taiwan's share of the world's telecommunications industry was 2.2%. There appears to be much room for further development.

However, why should development priority be given to the telecommunications industry? The trends of integrating computers and communications (e.g., the personal information manager) and computer, communications and consumer electronics (e.g., multimedia) have made telecommunications an inseparable part of modern electronics development. Also, telecommunications forms an important part of the infrastructure for national economic development. Moreover, the world telecommunications market (even for CPE only) is immense and expanding. As world common communication standards are gradually formed in the open system environment, Taiwan can follow to reap the world market. Also, Taiwan has a good foundation in semiconductors, computers, various consumer electronics, and certain telecommunications equipment (especially in CPE). Once telecommunications becomes the focus of R&D, with the aid of internationalization, substantial development in the telecommunications industry can be made. Though telecommunications technology was not intensively developed in Taiwan until 1990, the research results afterwards reveal many technologically feasible and price-competitive products. Taiwan is good on the software application side of office switch systems, capable of developing some transmission facilities, and good in various corded, cordless & mobile CPE, and small network systems. Moreover, Taiwan's telecommunications law becomes more open; the newly built Industrial Science Park in Hsin-Chu attracted many foreign Chinese experts

in the communication field; and the VLSI development made the digital communication technologies available and cost-effective. Overall, many telecommunication technologies are ready and Taiwanese firms are awaiting a market.

Of Taiwan's 1991 telecommunications production (a total of US$1,784), switches and telephones were the two major products, accounting for 33.3% and 23.6%, respectively. Nonetheless, switches are provided mainly for the domestic market (90.2%), while telephones are mainly for export (73.8%). Due to the increasing pace of telecommunications construction, including digital switches, transmission equipment and cellular network systems, the 1990 production value and import value increased significantly (see Table 2). One can see that the foreign sales ratio is falling. This is due to increasing domestic demand and falling competitiveness because of the appreciation of the New Taiwan dollar and the increasing costs of labor, land and capital. However, the production value in 1991 fell by 4% due to the limited space for domestic demand and the slowdown of export growth.

Table 2 The 1987-1991 Production, Exports, and Imports of Taiwan's Telecommunications Industry (MUSD, %)

Communication Equipment	1987	1988	1989	1990	1991	CAGR
Production Value	937	1133	1439	1836	1784	17.5%
Foreign Sales Ratio	81.5%	72.8%	69.5%	56.7%	59.7%	-
Export Value	764	825	1000	1041	1052	8.3%
Import Value	340	402	420	732	525	11.5%

Note: Foreign sales ratio is the foreign sales portion of the total production value.
Source: Ministry of Economic Affairs (MOEA), Customs, Bureau of Economic Planning and Development (BEPD).

The size of the 1990 domestic telecommunications market was US$1.5 billion, and ranked number 15 in the world telecommunications market. 380,000 cellular phone lines were established, approximately equal to the U.K.. ISDN construction is currently at the testing stage (Wang, 1993). The National Six-Year Development Plan (1991-1997) will devote US$13.6 billion to telecommunication construction. A single item "Intelligent Network" will cost US$5.3 billion. The main focus of the six-year telecommunication construction is on building the ISDN.

Half of the domestic telecommunications demand comes from DGT purchases. Unfortunately, domestic firms supply only one-fourth of the products, focusing on corded/cordless CPE and a few transmission facilities. The rest is supplied by local branches of foreign companies or imports. In fact, all office switch equipments are supplied by the branches of AT&T, Siemens (Taicom), and Alcatel (Taisel). The office switch involves tremendous software requirements in terms of diagnostics, repairs, management, and upgrading to new editions. Because of their scale, the AT&T branch, Taisel and Taicom alone are incapable of handling the entire software requirement. However, Taisel and Taicom have developed a good applied software capability to provide a local edition of European switch equipments; they can also make some modifications and perform some assembly, testing and maintenance. With these capabilities, Taiwan Alcatel has stepped into the mainland China market, while Taiwan Siemens has helped establish the Vietnamese and Thai public switch systems. These three firms also have developed transmission equipments. The remainder of the Taiwan telecommunications industry is mostly composed of SMEs and their strength lies in CPE.

As for trade with different regions, Table 3 shows that for 1989 and 1990, Japan was the largest exporting country to Taiwan and the U.S. was the largest importing country from Taiwan. Taiwan has consistently had a trade deficit with Japan and a trade surplus with other areas. The reason for the deficit is the large import content of corded CPE, wireless equipment and components. The share of exports to Western Europe also increased substantially, demonstrating improving trade relations between Taiwan and Western Europe.

With regard to product analysis, we shall focus on the private market, and therefore on corded CPE, cordless CPE, and transmission facilities. The market for corded phones is shrinking due to low-cost ASEAN competition. As for KTS and PBX, they are both commercial phone switch systems. KTS design is appropriate for small- to medium-sized enterprises, while PBX (more lines and more complicated) is appropriate for large enterprises. Taiwan has 30-40 KTS firms and fewer than 5 PBX firms. The technology for producing KTS is well-developed and mature. Also, in 1991, ITRI, DGT, the Institute for Information Industry (III), and some private firms jointly developed a prototype for ISDN PABX (Ho, 1991).

The 70% compound annual growth rate (CAGR) of fax production

during 1985-1989 is expected to fall to 10% during 1990-1994. Nonetheless, the fax market is still attractive. One major barrier for Taiwan's fax manufacturing is the dependence on foreign suppliers for key components. The other is the competitive pressure from the dominant Japanese fax manufacturing firms (who takes 90% of the world market) and the competitive Korean fax products. Nonetheless, the charge coupled device (CCD) and the contact image sensor (CIS) have been developed and a laser fax is being developed.

Table 3 Taiwan's Trade of Communication Products Based on Geographical Area

Year/Trade / Country	1989		1990		1989, 1990
	Import	Export	Import	Export	Surplus/Deficit
U.S.	28%	52%	32%	48%	+
JAPAN	49%	9%	35%	8%	-
W. EUROPE	15%	18%	20%	24%	+
ASIAN PACIFIC	5%	14%	9%	15%	+
OTHER	3%	7%	4%	5%	+

Source: Customs, CCL.

Modem was so-called "after market product," which means that it is needed after the computer system is set up. However, the international environment has changed a lot since the second half of 1990. First, IBM produced PS/I, which embodied 2400bps modem into the PC system to become a standard equipment. Second, IBM directly sold this equipment in mass merchandise store, such as Price Club, Sears, etc. Other famous PC companies also followed suits. The new sales channel helped promote sales. Third, newly developed laptop and notebook PCs needed modems to communicate with distant mainframe computers. Therefore, new market opportunities abound.

Different countries have different communication standards to protect domestic communication industries. Modem is one protected item. Therefore, the world demand for modems belongs to the small-quantity, large-variety category. This is most suitable to the flexible and fast-responding Taiwanese small- and medium-sized enterprises. No wonder Taiwan's world market share for modem was about 15% in 1991 (Taiwan Institute of Economic Research 1992). Taiwanese firms had ample

experiences in producing the 2400 bps modem. The technology for modem building is not very difficult, and Taiwanese firms are good at producing medium- and low-end modems and also up-to-date radio modems. The V.32 data pump and modem chip have also been developed recently. More advanced DSP technologies can also be developed in the near future, especially with the participation of ample Chinese experts from the U.S..

Table 4 shows the geographic distribution of exports and imports for corded phones, KTS/PBX, faxes and modems in 1990. While Japan and US often rank high in imports or exports, we should pay special attention to Western Europe. Western Europe ranks first for Taiwan's KTS/PBX, fax , and modem exports, and second for Taiwan's corded phone exports. On the other hand, Western Europe ranks low for Taiwan's imports of these products. This highlights the importance of preserving this market.

Table 4 The 1990 Country Ranking of Exports and Imports for Telecommunications Products

Product/Trade	Corded Phones		KTS/PBX		Faxes		Modems	
Ranking	Export	Import	Export	Import	Export	Import	Export	Import
1	US	Japan	WE	Japan	WE	Japan	WE	US
2	WE	AP	Japan	US	R	AP	US	WE
3	AP	US	US	WE	AP	R	AP	Japan
4	Japan	WE	AP	R	US	-	Japan	R

WE: Western Europe; AP: Asian Pacific; R: the rest.
Source: Customs, CCL.

Taiwan is relatively weak in developing wireless phones due to the lack of radio frequency (RF) technology. Most RF is still used for military purposes. On the other hand, the AMPS System cellular car phone was developed in 1991, and pagers and small satellite communication systems were also developed. As the military frequencies are gradually open to private use, a much larger space for wireless industry development will be created.

The transmission sector is relatively small and underdeveloped, with multiplexers and small satellite receivers as the major products. The optical fiber technology was transferred from the U.S., and domestic firms start to design independently. The domestic market for transmission

equipment depends mainly on the DGT purchase. However, Taicom is cooperating with the Florida subsidiary of Siemens to develop Sonnet for the North American market. Nonetheless, Taiwanese firms' capability to produce the small-quantity but high-quality key components in telecommunications equipment is in general deficient. However, the digital loop carrier (DLC) and synchronous digital hierarchy (SDH) have good development potential.

Finally, Taiwan has developed world-class local area network (LAN) related technology, including Ether Net card, Arc Net card and Token-Ring card. Taiwan's world market share of LAN card is currently about 20%. Moreover, FDDI, CDDI and Bridge-Router have been developed. In a word, Taiwan is good at providing small network systems. As for internet linkage, an area with good development potential is the network access server *(Fourth National S&T Conference Proceedings, 1991).*

B. Future Prospects and Strategy

Three technology trends of telecommunication products in the 1990s are likely to prevail. One development is the integration of communication and computer (C&C) technology. That will lead to a unified approach to information storage, processing, and transmission, and to developing the so-called Intelligent Network (IN). In order to integrate telecommunications and computers, transmission needs to be digital, and the switch lies at the center of the digital process.

Another development will be the prevalence of the integrated service digital network (ISDN), which integrates the telephone network, the fax network, and the modem network on the same line. The consumer can use it to do multiple types of communication including sound, data, and image. This will also help users to access the Intelligent Network (IN) easily. All major industrial countries are preparing to provide extensive ISDN service in the 1990s. Taiwan is also planning to commercialize narrow band ISDN during the 1990s and wide band ISDN after 2001. Moreover, Taiwan plans to provide ISDN service in year 2000.(Chu, 1990)

The third key development is to integrate wireless communication technology with other communication facilities. The accompanying independence of place, time and medium promotes more extensive commercial transactions, and more rapid and timely information exchanges. The developments of cordless phones, cordless PBX, wireless fax, and

cellular modems are along this direction. In terms of personal mobile communication equipment, the pager, cordless telephone, and cellular mobile phone are three major products.

Considering these world trends, what are the products which are appropriate for Taiwanese firms to develop? Taiwan has a good tradition in producing CPE and has good digital capability. In Taiwan's technological domain, all corded communication equipment can be digitalized, as can most radio communication equipment. Moreover, Taiwan has developed ISDN CPE such as ISDN phoneset, PC add-on card, TA, and S/T interface Chipsets. Also, the video phone is under development. These developments provide a lot of high-end CPE cooperative opportunities between advanced countries and Taiwan, especially when ISDN construction is on almost every developed country's near-term agenda. Moreover, once the European GSM standard is set, the mobile phone handset is certainly a major category for Taiwan firms. Other possible items to develop include CT-2, GSP and PCN. Similarly, for not-so-difficult technology such as modems, key telephone systems and faxes, Taiwan is capable of managing most related technologies. Moreover, Taiwan is good for smaller network or internet items, where LAN is a niche that Taiwan is able to handle well.

Arthur D. Little (ADL) Consulting Co. has analyzed world technology and market trends and has used expert methods (questionnaires for experts) to find appropriate products for Taiwan to develop in the electronics industry. It has suggested four promising products in telecommunications: IN components; ISDN; fiber optical loops; and personal mobile communications. ADL has also made forecasts of the world market value and Taiwan's potential share in year 2000 for these four products (Table 5, which also includes forecasts of other major electronics sectors). Moveover, ADL provides a market forecast for different products for the year 2000 in Table 6.

Among these products, personal mobile communication is in a special position. Taiwan used to be the corded phone kingdom. Now, as its base has been eroded by the ASEAN countries, Taiwan needs to move to higher-end phones, and since the personal mobile phone is on the rise, this is exactly what Taiwan can and should develop. This is especially the case as Taiwan's RF is gradually open to private use. Having developed the AMPS system cellular phone (US CTTS standard), GSM system products (European cellular system standard) are the next major category to develop.

Taiwan's telecommunications capability is advancing fast. Many

Table 5 Year 2000 Promising Electronics Industries Forecast

(Unit: Billion USD)

Promising Industrial Products	World Market	Taiwan's Share
A. Telecommunications Industry		
Intelligent Network Components	20	0.6-- 0.7
ISDN	40	1.6
Fiber Optic Local Loops	10-- 20	1.0
Personal Mobile Communications	20-- 30	0.7
Subtotal	90--100	3.9-- 4.0
B. Information Industry		
Engineering Workstations	12	1.0-- 2.0
Mini Supercomputers	70--90	1.0-- 1.5
Optical Peripherals	54	6.0-- 8.0
Software	410	4.0-- 6.0
Subtotal	546--560	12 --17.5
C. Consumer Electronics Industry		
HDTV	11	0.5-- 1.0
VCR	15	1.4-- 2.2
Interactive Video	8	0.8-- 1.2
Electronic Still Cameras	0.4-- 1.6	0.1-- 0.5
Home Automation Systems	7	0.4-- 0.6
Subtotal	41.4--42.6	3.2-- 5.5
D. Automation Industry		
CAD/CAE/CAM		
Engineering Workstation	5 -- 7	0.5-- 0.7
Optical Scanners and Systems	1.0-- 1.5	0.2-- 0.4
Software Systems	2.0-- 3.0	0.1-- 0.2
Numerical Control Machine/ Numerical Manufacturing		
Flexible Machining Cells	5.0-- 8.0	0.7-- 1.2
Process Control Equipment		
Process Control Components	6.0-- 8.0	0.6-- 0.8
Industry Robot		
Robotic Components	1.0-- 2.0	0.5-- 0.1
Machinery Vision/Image Process		
Vision System Components	1.5-- 2.2	0.15-- 0.2
Engineer Drawing Info.System	0.2-- 0.5	0.01-- 0.03
Subtotal	21.7--32.2	2.3 -- 3.6
Total	699.1--750.8	21.4 --30.6

Note: There may be repeated calculations, for example, parts for engineering workstations may be included both in information industry and automation industry.

Source: Taiwan 2000: Industry Opportunities (Summary): prepared by Arthur D. Little for CEPD & MOEA, 1989.

promising products can be commercialized. The Six-Year National Development Plan provides great market opportunities and the direction of future development. Moreover, the Asian telecom infrastructure market is the fastest growing one in the world. All of these show that there will be a new wave of opportunities for Taiwan's telecommunications industry to develop.

Table 6 World Market for the Telecommunications Industry in the Year 2000

(Billion USD)

Product / Region	IN Components	ISDN	Fiber Optic L. Loops
North America	6.0	14	5-10
Western Europe	6.0	14	3- 6
Asia	5.0	10	2- 4
Eastern Europe	1.0	1.2	0.6
South America	1.0	1.2	0.6
Africa	0.5	0.6	0.3

Source: Arthur D. Little Co.

However, Taiwan faces some problems in developing its telecommunications industry. The internal problems of the industry include the dependence for key components and core technologies on foreign sources, the lack of advanced design and management staff and international marketing channels, and diseconomies of small scale. The source of these problems are the small size of the typical firm and the lack of system operation experience. These insufficiencies cause most companies to hesitate devoting energy to R&D when the market prospect is uncertain. Most companies cannot produce the key components, especially for small-quantity and high technical-level telecommunications.

Taiwan's comparative advantage lies in its ample OEM experience, which has thus nurtured a superior manufacturing and design capability. So long as there are mature core technologies, appropriate packaging and manufacturing are not a problem. With these, along with marketing channels, new markets can be created. (Project Report on Technology Transfer to the Science Park, 1991.) Moreover, the recent telecom technological advancement is quite fast, aided by the CCL of Industrial Technology Research Institute (ITRI). Another strength of Taiwan's small- and medium-sized enterprises lies in their "flexibility". They can adjust

their production lines quickly when new products are developed, both in terms of quantity and quality. This makes them especially suitable to compete for various OEM orders, even though many of them may be in small quantities.

With an understanding of the weaknesses and the strengths, Taiwan may need to do three things to improve its telecommunication industry. First, Taiwan needs some large, solid enterprises to effectively integrate the limited resources separately placed in small firms and to devote resources to produce their own key components and system products. This can also reduce the "time to the market," while the ITRI technology transfer is useful but time consuming. Moreover, a large enterprise can take large communications projects and contract smaller firms to jointly work on the projects, thus promoting the large enterprise's system integration capability. International joint venture with major telecom firms will suit that purpose. One way to induce this joint venture is through the offset program accompanied with Taiwan's government procurement. The terms and content of technology transfer and component sell-back should be carefully specified to match Taiwan's true demand. However, Taiwan should not depend much on offset program because it will be phased out after Taiwan becomes a GATT member. This can be induced by the offset program in Taiwan's government procurement.

Second, the government can help improve the telecommunications environment. A government-promoted private organization, the Institute for Information Industry (III), is currently in charge of the certification of standards. The cooperation of III with international certification and testing agencies is important for the export of Taiwan telecom products. The government can also help to promote the demand for ISDN by providing inexpensive multi-media CPE facilities (for example, learning from the subsidized Minitel VAN service provided by the French government).

Third, small- and medium-sized firms can use their OEM opportunities to improve manufacturing technologies and quality control. They can also form strategic alliances for R&D, including international partners. This is particularly feasible in the CPE field. For example, cooperation is needed for Taiwan's mobile phone handsets to match European GSM standard. In general, the alliances can include both horizontal and vertical integration. The latter can help the firms to produce key components and to develop systems products.

III. Information Industry

The first Ten-Year Information Industry Development Plan (1980-1989) was announced by the Taiwanese government, which was the real start of the Taiwanese information industry. The government targeted to promote microcomputers and other products. Since then, the industry has experienced tremendous growth during the 1980s. Production value rose from US$80 million in 1980 to US$61 billion in 1990. Taiwan's information industry production now ranks seventh in the world, behind the U.S., Japan, Germany, France, the U.K. and Singapore. Four factors may have contributed to this success: (1) the government's promotion efforts, especially through ITRI and III; (2) the existing electronics industry base (including components); (3) small- and medium-sized Taiwanese information enterprises are able to respond and adjust quickly to world market opportunities; and (4) Japanese firms did not choose to enter the IBM-compatible PC market.

The second Ten-Year Information Industry Development Plan (1990-2000) was similar to the first one. However, the first plan emphasized the infrastructure, while the second plan emphasized technology.

A. Current Development

In 1991, the first two of the ten major electronics products were monitors and microcomputers, both of which are information products. This is quite different from the earlier period (before 1987), when home electronics products took the lead.

In 1991, the production value of hardware was US$6.9 billion (US$0.8 billion for software), more than three times the value in 1986 (see Table 7). There are presently 700 information hardware manufacturers and 300 software service firms. Of them, 85% have fewer than 50 employees. About 95% of the information products have been exported in recent years. The contribution to GNP and the rank in production value are all given in Table 7.

In the second half of the 1980s, the most important information products were microcomputers, color monitors and computer components. In 1991, for example, they accounted for 89% of total exports (see Table 8). These items (especially color monitors) maintained high growth rates

even during the world recession from 1989 to 1991. The fast-growing "other peripherals" include keyboards, mouse items and scanners. There is a recent increase of OEM products as compared to own-brand products, which seems to be an appropriate response to the price-cutting of major world computer firms and to the global economic slowdown in order to preserve the market share and the economy of scale.

Information industry exports by geographic area are shown in Table 9. Apparently the major export areas are North America and Western Europe. In 1990, the export share for each area had an equal 40% share. In 1991, however, Western Europe became the leading export market for hardware products (for example, 51.3% for PCs). Nonetheless, Europe was entering a recession in 1992 as the US was emerging. Therefore, the relative position of Western Europe and the US regarding Taiwan's exports reversed in 1992. The Asian Pacific market (including Japan) also grew rapidly, which has been an engine of export growth. This is a dynamic area which holds great potential for Taiwan's exports. The Eastern European market also has good growth potential and has attracted small- and medium-sized Taiwan firms, such as Aquarius, to cooperate with the official Treuhandanstalt to explore new opportunities. As for imports into Taiwan, more than 75% came from the U.S. and Japan.

Computers

Taiwan's information industry started with hardware products. In 1991, more than 2.6 million sets of PCs were produced (mainly 386SX, 386DX, and some 486 models), and about 2.4 million sets were exported. The latter was 10% of the world market share. Moreover, if motherboards are added, the share becomes 25%. Taiwan used to depend on US firms (e.g. Intel) to provide CPUs. However, United Microelectronics Co. has recently developed a 486 CPU.

Two technology trends in computer development are miniaturization, and better function and value-added. Miniaturization is shown in the development of the laptop PC, notebook PC and handhold PC. Laptop PC production in Taiwan is levelling off from 195,000 sets in 1990 to 40,840 sets in 1991.However, the notebook PC has become quite popular after the first generation consortium between the Computer and Communication Laboratories (CCL) and 47 firms started in June 1990. The effective collaboration resulted in the completion of the motherboard, standards and the prototype, all within three months. Production in 1991 was more than

Table 7 Taiwan's Information Industry Indicators

Indicators	Explanation	1986	1987	1988	1989	1990	1991
Production value (MUSD)	Including export and domestic sales	2143	3839	5324	5484	6149	6908
GNP contribution (%)	Info. industry contribution to GNP	2.7	3.7	4.2	3.6	3.8	3.9
Production value ranking	Ranking among national industries	23	18	13	10	6	9
Export value (MUSD)	Export value of the info. industry	2063	3701	5152	5244	5873	6546
Export Contribution(%)	Info. portion of the total export	5.2	6.9	8.1	8.1	9.1	8.9
Export value ranking	Ranking among national industries	7	4	3	3	3	3
World production ranking	Ranking among int'l info. industries	7	7	6	6	7	7
World info. market share	Share of world info. industry market	1.5%	2.4%	3.1%	3.0%	3.0%	3.1%

Note: 1. The information industry here means hardware products and does not include software.
2. The 1991 world information hardware product market value was about US$224 billion.
Source: Market Information Center (MIC) of the Institute for Information Industry (III).

Table 8 Taiwan's Exports of Information Industry Products

Unit: MUSD, %

Products	1987	1988	1989	1990	1991	1987-91 CAGR
Mic rocomputers	761	1154	1244	1403	1729	22.8%
Magnetic Disk Drives	97	119	115	72	59	-11.7%
Printers	44	43	39	25	10	-31%
Terminals	414	505	458	362	243	-12.5%
Color Monitors	877	1081	1251	1550	1870	20.8%
Other Peripherals	80	81	102	231	549	61.9%
Computer Components	1458	2016	2035	2184	2086	9.4%
Total	3701	4999	5244	5873	6546	15.4%

Source: MIC.

Table 9 Taiwan's Information Industry Exports by Geographic Area

(MUSD, %)

Year/Value,% Area	1987 Export value,%	1988 Export value,%	1989 Export value,%	1990 Export value,%	Growth Rate,%
North America	1980.0(53.5)	2299.8(46.0)	2241.8(42.8)	2318.1(39.5)	5.4
Japan	55.5(1.5)	88.2(1.8)	114.8(2.2)	133.9(2.3)	34.1
Asian Pacific	310.9(8.4)	612.0(12.2)	696.4(13.3)	834.5(14.2)	40.0
Western Europe	1184.3(32.0)	1835.3(36.7)	2016.3(38.4)	2380.9(40.5)	26.2
Eastern Europe	-	24.6(0.5)	54.0(1.0)	75.2(1.3)	174.8
Latin America	170.3(4.6)	42.8(0.9)	39.9(0.8)	65.8(1.1)	-27.2
Other		96.3(1.9)	80.8(1.5)	64.6(1.1)	-18.1
Total	3701.0(100)	4999.0(100)	5244.0(100)	5873.0(100)	16.6

Note: Number in parenthesis is the percentage value of total exports. Does not Include software.
Source: MIC of III.

493,700 sets, more than twenty times up from 22,000 sets in 1990. However, key components such as liquid crystal display (LCD) were controlled by Japanese firms and the supply was limited. Taiwan's PC technology has reached world standards. The lag with major new PC products was 25 months in 1980. However, there is no time lag now. This is shown by both 486 and note book PC development.

The workstation, the multiprocessor (MP) system and the multimedia system have moved in the direction of better function and more value-added. Currently in the world, there are four major workstation technology alliances: Sun Sparc; ACE; IBM/Apple/Motorola; and HAPA-Forum. For Taiwanese firms developing workstations, except for ACER which is in the ACE alliance, and Winbond which just attended the HP Forum, all others are involved with the Sun Sparc alliance. Now the lag with Sun Sparc classic compatible workstations is only 2.5 months. Taiwanese firms are currently developing the MP System and the multimedia system. CCL is involved in a workstation alliance and a multimedia alliance to establish comprehensive technologies. Moreover, the development of a distributed computing environment (DCE) allows each user to use all resources on a network easily. Taiwan has started its DCE development, including server technology. (Information Industry Almanac, ROC, 1991.)

Software

Software technology in Taiwan is characterized by Chinese information processing, with good potential to extend to all Chinese-speaking areas (such as mainland China). The expert system, object-oriented technology, and document image processing are all in the development process. The software engineering environment development (SEED) plan (1989-1992) was aimed at developing software engineering in systems analysis, systems design, systems testing and case-oriented integration technology.

The Executive Yuan of Taiwan is promoting large-scale administrative information systems, partly listed in the six-year development plan. Currently, almost all the systems are contracted with IBM and DEC. The domestic content is nearly zero. Domestic software firms generally lack experience, thus making them unable to compete for these contracts which usually require much experience. If the administrative decree allows domestic firms to compete for contracts once they find experienced foreign partners (domestic participation can even be required for any contender), then: (1) these projects can nurture the systems capability of domestic large software firms (with large foreign software partners); and (2) these projects

can nurture special applied capability of domestic small software firms (with small foreign software partners). The timing and scale of the projects are listed in Table 10. (Chen, T.S. 1992)

Peripherals

The main peripherals include hard disk drives, optical disk drives, laser printers, faxes and scanners. For the hard disk drive, with the devotion of the Opto-Electronics & System Laboratories (OES), 2.5 inch and 3.5 inch 200 MB products have been developed. Currently only two firms are undergoing mass production.

For the optical disk drive, OES developed the 5.25 inch WORM prototype in 1991 and the ERASABLE prototype in 1993. OES has developed a low-speed laser engine and has transferred it to private firms, but the firms have not commercialized it yet. As for faxes, the main difficulty lies in the development of three key components: the Charge Coupled Device (CCD) or the Contacted Image Sensor (CIS); the Thermal Printer Head (TPH); and the modem IC. Taiwanese firms used to import these components from Japan. Now, Hua Loan can produce CCDs and Tung Nan can produce the CIS, Tung Hsin produces the TPH, and United Microelectronics Corp. can produce the modem IC. The laser fax alliance organized by OES involves eleven private firms and developed a plain paper laser fax (higher-end product) in 1991.

Taiwan's scanners have one-third of the world production value. However, the internal optical system is mainly controlled by the Japanese firms Omron and Mitsumi. Other components such as the interface card and CCD have been developed by CCL and domestic firms.

B. Strategy and Future Prospects

In year 2000, the information industry is expected to become the largest industry in the world, with a market size of US$900 billion. While the prospective world market pie is huge, Taiwan faces competition both from the low-labor-cost developing countries and the automated developed countries. The medium-high price product market still maintains double-digit growth. However, many key components and core technologies are still in Japanese or American hands. For these higher-end products, software for specific professions or purposes is often needed. Software is also a fast-developing area.

Table 10 Governmental Promotion of Large-Scale Information Systems

Item	Title of Project	Budget(MUSD)	Status
1	Population Information System Plan	340	Finished preliminary planning, currently evaluating equipment
2	Land Information System Development Plan (1992-97)	280	In first stage
3	Police Information System Development Plan (1991-93)	68	Centralized operation, to be decentralized
4	Taxation Automation 5-Year Plan (1989-93)	480	Fully executed
5	Custom Automation Plan (1991-94)	88	Promoted by the Planning group
6	National Business Management System (1990-98)	140	Finishing experiment with the business administrative system
7	Highway Monitor Computer-Connection Plan (1992-94)	36	First stage
8	National Medical Information Network System Plan. (1991-93)	500	First attempt in Hsin-Chu area
9	National S&T Information Network Development Plan	--	Executed
10	Weather Business Computer-ization Plan II (1990-95)	52	Finished first stage in December 1989
11	National Land Information System	--	Planning by the Ministry of Internal Affairs

Source: Second National Information Management Conference (5/31/1991).

The future trend of developments in miniaturization, workstations, multimedia and DCE will demand more technology- and capital-intensive investments. Often technology alliances (usually with the involvement of CCL or OES) are needed to break through the bottleneck of product development. In the next ten years, the information industry will also be more market-oriented which will provide products and services to match heterogeneous users' needs. The trend toward higher-end computer products and open network development leads us to the three high-priority information industry products: engineering workstations; optical peripherals; and software (refer Table 4.5). However, in Taiwan's case, advanced PC development is also important.

As mentioned earlier, Taiwan's PC technology is up to world standards. Taiwan is likely to jump into the new Pentium-based PC production quickly. Meanwhile, the engineering workstation is a higher-end product that Taiwan can develop. According to a Dataquest forecast,

the CAGR of the workstation from 1990-1994 will be 39.7%, making it first among computer products. Taiwanese firms participating in the Sparc International and the ACE alliances show great technology capabilities. Taiwanese workstation firms are very close to world standards. As the boundary between PC and workstation becomes blurred, Taiwan's choice between developing workstations and PCs will hinge on the market. As the market choice is not clear as to which side dominates (even if we include the Pentium PC on the PC side), Taiwan's simultaneous development of PCs and workstations seems appropriate.

Peripherals have high value-added within the information industry. Singapore's hard disk drive has 80% of the world market, placing Singapore sixth in the world's information industry. However, Singapore mainly provides cheap labor to undertake assembly for foreign companies. The R&D center for hard disks still lies in the US. Taiwan has difficulty competing in this arena both in sales channel (brand name) and technology. The opportunity to develop hard disks has probably gone already. The lower-end peripherals such as the mouse and scanner are still Taiwan's specialty, though.

The position of software has become more important with the development of open networks and applied software. In 1991, Taiwan's software was 10% of total information industry production, with 32% in computer system software and 68% in general service software. The world software/hardware ratio is expected to change from 36:64 in 1987 to 55:45 in 2000. Taiwan, with its ample human resources in software technology, needs to pick up the world trend in software development quickly. The Five-Y0ear Software Industry Development Plan (1993-1997) is a carefully designed action plan compatible with that purpose. This plan has substantial government involvement, intending to raise the production value of the software industry from US$1 billion in 1992 to US$3.5 billion in 1997, which includes system integration, software packages, turnkey system, network services, professional services, and processing services.

Taiwan's information hardware industry used to adopt a "fast follower" strategy. The shining record of PC and work station development represents achievement along that direction. While leapfrogging into the leading front may be beneficial but highly expensive, Taiwan's flexible SME firms can innovate differentiated products that is more compatible with their competitive advantage. Moreover, the comparative advantage of low value-added manufacturing portion, such as PC assembly and

mother board, gradually goes to mainland China and ASEANs. The high value-added key components hold Taiwan's future of the hardware industry. Acer's development of ASICs is a case in point. However, Japan and U.S. often control corresponding technologies and productions. Taiwanese firms have no choice but to devote more R&D or M&A funding to establish own technologies in key components. International technological collaboration may also be a possible route, but it will come after certain technological level is achieved by Taiwan's own effort.

The fast-growing information industry will demand large specialized manpower. Both the school system and the training system need to plan aggressively to accommodate this demand. Government's investment in frontier technologies is also important for the competitiveness of this industry. Moreover, in 1991, the "Industry Upgrade Act" replaced the "Investment Incentive Act." The latter provided tax incentives for specific products and for larger-size firms. The former provided incentives for R&D, automation and international brand name, which can help industry upgrade without discrimination among investment scale and products. As a strategic industry, the promotion of information and telecommunication products should be addressed in this framework.

A major government program to promote new product development by supporting financing is the "Promoting Measures for Leading New Product Development" starting from 1991. Promoting items in the information industry include advanced chipset, server, network controller, multimedia system, system software, CAM/CAD equipments, small hard disc, plain paper fax, high quality scanner, etc. Promoting items in the telecommunication field include SONET ADM 150, fiber digital loop carrier, digital mobile handset, network access facility, and ISDN CPE. Furthermore, the diffusion of computer technologies to industries was promoted by the five-year plan, Diffusion and Application of Industrial Computer Technologies, starting from 1990. Similar promoting measures addressing SMEs are also implemented.

Partly due to the GATT requirement and Taiwan's planning to become a GATT member, but mainly due to the threat of 301 retaliation, Taiwan has quickly raised her intellectual property right standard to be compatible with the standard of developed countries in the GATT framework (TRIPS). The Copy Right Act, the Trade Mark Act, the Integrated Circuit Protection Act, and the Industrial Design Act have recently launched. Taiwan ranked no.1 in the American list for the amount

of duplication in 1991, and 56% of Taiwanese cases involved information-electronics products. Therefore, in the 1992 Sino-American intellectual property right negotiation, the duplication of information products was a key issue. The U.S. asked Taiwan custom to inspect 30%-50% computer software exports. III became the executing body of this inspection system. Through the above arrangements, Taiwan proves to the international society her determination to enhance intellectual property right protection. Moreover, III keeps on improving the convenience and the efficiency of this inspection system.

IV. Conclusion

In the 1980s and 1990s, the information industry is the thriving force of Taiwan's electronics industry. Shining items include monitors, microcomputers and some peripherals. Government policies and the active SMEs are important for the rise of this industry. The higher-end PCs and workstations are the new areas for development. Key component developments such as CPUs and LCDs and the VLSI progress are important for the competitiveness of this industry.

Taiwan's telecommunications industry faces a new wave of opportunities. On the one hand, technological capability is promoted by Chinese experts back from the USA to the Science Industrial Park and by CCL of ITRI; on the othe hand, the Six-Year National Development Plan and the fast-growing Asian telecommunications market provide ample market opportunities. Telecommunications provides an important infrastructure for economic development. This, and its 2C and 3C linkages, induce Taiwanese government to place the telecommunications industry as the first among the ten emerging industries to be promoted in 1990s.

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