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Exploratory Study of Stage Dependent Critical Success Factors in the Taiwanese IC Industry

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Abstract

In common with a number of other developing industries, the growing significance of IC industry development in Taiwan is notable for its CSFs that have helped it develop from labor-intensive, technology-intensive and capital-intensive stage during the 1970s to the highly profitable period of the 1990s. This paper identifies palpable correlationships of extracting factors among the dependent stages by factor analysis through an empirical work. Manufacturing capability is the only common extracting factor among all stages. Notably, six sets of extracting factors are two stages dependent. One stage dependent takes technology migration and market requirement extracting factors in the1970s; unique characteristics of family-like culture extracting factor in the 1980s; and six extracting factors in the 1990s, namely: powerful industrial talent, strategic alliances, development momentum based on entrepreneurship and so on as the unique stage dependent factors that drive the development of each stage of the Taiwanese IC industry.

Keywords: Critical success factors; IC industry; Stage dependent; Industrial development; Technology migration; Strategic alliance

1. Introduction

The past decades have seen the IC (Integrated Circuit) industry become the key driving force in this crucial endeavor of a remarkable epoch. IC industry development is unprecedented in the history of industrial development. Analyzing the development of the Taiwanese IC industry based upon historical evolution leads us to the reveals where major developments are driven by some critical factors to invent and vitalize themselves. This seemingly indicates a structural shift in this industry, thus creating a new paradigm in Taiwan.

Taiwan has effectively developed its IC industry and constructed an effective model for success. The evolution of IC industry development in Taiwan began from a period of exploratory formation during the labor-

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intensive stage in the 1970s, and then moved through a strategic transition during the technology-intensive stage in the 1980s, finally entered into the preemptive inspiration of the capital-intensive stage in the 1990s. Most important, this industry also has succeeded proven itself successful in underlying the networking of national intra-organizational system, vertical disintegration of upstream and downstream of sub-industries, and strategic alliances with advanced foreign leaders. This research attempts to identify the most significant CSFs (Critical Success Factors) in the success of the IC industry, rather than guessing key elements during Taiwan's IC industry development.

The objective of this study is to explore the CSFs for Taiwanese IC industry by stage dependent-labor intensive, technology intensive and capital intensive from 1970s, 1980s and 1990s. The previous literatures [2,11,12, 13,17,27,29,34,38,39,47] had revealed and discussed only generalizing the successful factors and not examined the individual stages in the success of the Taiwanese IC industry. Taiwanese IC industry was developed from ground, to growth and nature step by step. Industry development is progressed phase by phase and they are fulfilled the different factors in each stage to perform. Stage dependent CSFs study is instrumental to the further study of strategic inflection point in each phase contingent upon the developing process itself. This paper aims to address and stress the successful factors of the IC industry that have significantly impacted industrial development during each stage leading to its success.

2. Critical Success Factor Approach

Extensive research has focused on CSFs at the industry and organizational levels to find out how to succeed in the different environments. The CSF approach helps top management penetrate the fog of dynamics and complexity and identify the areas that are critical to policy effectiveness and the benchmark of success in the competitive market. The CSF is defined as "the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization" [49]. Restated, CSF refers to the "few things that must go well to ensure success for a manager or an organization" [5]. The CSF approach represents an accepted top down methodology for corporate strategic planning, and which it identifies few factors, it can highlight the key information requirements of top management [7,49]. The CSF method directs top management to determine those things that must go right in order to succeed in achieving the set goals and objectives. The ultimate value that the CSF method brings is the ability to focus management attention on the tasks and activities that need to be done well to achieve success [6]. CSF analysis is a methodology that assists an analyst in identifying those activities that are crucial for a business that is those activities where the organization must excel, and by exclusion those where it must merely be competent [56]. CSFs are those factors that are critical to the success of a project or undertaking. CSFs must be unique and few, feasible, controllable and reasonable. In any project, the relative importance of these factors may differ with the stages of the project cycle [43]. The CSFs approach is a tool for exploring factors that attract academic interest and further research.

This study examines empirically the factors crucial to success using the CSF approach that gets the decent marks of the IC industry. The industrial analysis is employed, and the basic factors in each stage that significantly influence the successful development of the Taiwanese IC industry are stressed. What it meant surfacing in the literature was to concern with why the organization had the opportunity to succeed, and what the research had explored the key elements of the successful framework.

3. Industry Emergence and Development

There are numerous ways for different industries to develop contingent upon their dynamic environment and background. Do right things rather than do things right is to elicit the stem of leadership for the top management of policy officials and industrial leaders. National economic development is based on the cumulative performance of all industries in the country. Industrial economists typically define an industry as "the group of firms producing products that are close substitute for each other." [45]. At the aggregate system level, industry emergence represents the cumulative achievements of a new "community" of symbiotically-related firms and actors who, through individual and collective action, invest resources in and transform a technological invention into a commercially viable business [54]. From the revolutionary perspective, the continuous social achievements and resources investment configured the emergence of industry. These social systems are hierarchically stratified with different subsystems specializing in different functions: (1) Institutional legitimization and governance function (2) Resource procurement function, and (3) Technical instrumental function [40]. These functions identified the factors of influences on industry development in the revolutionary construction level but do not disclose the environmental processing elements of industry. Environmental shift curbed the social stratification and the transition of industry from the burgeoning to the development and natural phases. Timing is another element that should be considered in the emergence of industry. Different development periods have their different and correlated factors that are implemented on timing considerations basis.

From the perspectives of organization and strategy, the key influences on industry development should include the following: (1) Industrial policy (2) Industrial environment (3) Basic elements of industry development (4) Enterprise strategy [50]. These items identified most factors related to industry development, but do not include the unique characteristics of each different phases of industrial development. Industry development has individual characteristics at each stage and inevitably evolves during the growth process.

The major influences on the development of the Taiwanese IC industry include: (1) Successful transfer of IC technology (2) Cultivating IC industry talent (3) Organizational culture of ERSO/ITRI (Electronic Research Service Organization / Industrial Technology Research Institute) (4) Continuous innovation of self-own IC technology and (5) Constant government policy and financial support [13]. These factors identified the elements of industry development at the organizational level but do not clearly describe the unique characteristics at the industrial level. Overall industrial development is an aggregation comprising the operations of individual organizations within the industry. Exploring the factors within an industry and the correlation of the external and internal influences on the development process will truly reveal the facts that we needed.

Three factors are attributed to the CSFs of IC industry development in Taiwan: (1) Government determination (2) Incentive policy (3) Support of research institutes and universities (4) Entrepreneurship [54]. This category comprises the nature of CSFs in the system level but do not describe the critical success factors that were differentiated in each stage. Stage dependent CSFs are variables that depend on the timing and process considerations. The CSFs explored in each stage represented a new recognition to the dynamic changes during industrial development. The study of each phase of the development stage invokes further understanding of industrial development and may inspire further research on this industry. This study explores the stage dependent CSFs of Taiwanese IC industry development not only filling the void of academic research on this field but also providing another perspective on the Taiwanese IC industry underlying the miracle of Taiwanese economic development during the past decades. One of further research can be studied to explore that is there any same pattern happened if we apply the result of this paper with three stages dependent CSFs. Other industries or countries have the same pattern or not is another fairly interesting study. Comparing the IC industry with other industry to map the stage dependent CSFs and find out what is the difference between them is another interesting subject to study too.

4. Research Methodology

4.1 Research Framework

This study analyzed the Taiwanese IC industry to understand the historical development over the last three decades. Potential explanations for the success of the industry were examined via literature reviews and focus group discussions before the questionnaire survey was prepared. A significant CSF study was proposed by scanning external and internal environments to explore the effectiveness of critical elements in successful IC industry development. There are 42 potential explanatory factors for all three stages factors that came from the panel discussion with experts. For the potential explanatory success factors of each stage, there are a combination of experts' comments (coming from design company, official, professor and researcher) and personal professional perception, those who are of great experience in IC design industry over 10 years and even 20 years. Different factors are fairly unique in the different stage although some of them have the same composed factors and some have not after extracting. Those that have not the same composed factors are intrinsically homogeneous in factors analysis. Different extracting factors are underlying the different stages by weightings and attributions. Potential explanatory success factors were found through the literature review, the opinions of the focus group in this study and the observations that was listed in Table 1.0 and 1.1 (as appendix). The focus group discussion was held at the Hsinchu Science-Based Industrial Park on January 10, 2002. The discussion panel included six experts including two company vice-presidents, a university professor, government official, researcher of research institute and venture capitalist. The discussion lasted approximately two hours, and included exchanges of viewpoints, personal observations and general interaction. Although the discussion did not arrive at any firm and indisputable conclusions, it did make some valuable general points. These results were consistent with the items of the questionnaire survey.

The proposed framework of this research is to examine the development process to identify the CSFs for each decade from the 1970s through to the 1990. Methodology used in this paper is rather flexible and elaborate for each different stage and the individual relationship among them respectively. Forty-two factors were identified as the variables or potential explanatory success factors for factor analysis. The common factors or critical successful factors can be found by covariance using the factor extraction method. A questionnaire survey is conducted following the aggregation and analysis of collected success factors. Statistical analysis of the empirical survey data provides the basis for evaluation. The analytical result demonstrated how the stage dependent CSFs of the IC industry are derived and established. Factor attribution for each stage from 1970s, 1980s to 1990s are listed in Table 1.2-1.4 (as appendix). Extracted factors compositions are listed in Table 1.5-1.8 (as appendix).

4.2 Population and Sampling

The working population of Taiwanese IC industry can be classified into the following five groups. The first group includes top management, namely presidents, vice-presidents, directors and managers who worked with the IC companies over 10 years. Members of top management have much experience and are more familiar with the trend of development in the industry. The development policy of industry is usually geared by the strategies or decisions set by top managements both of government and industry. There were 79.2% of the total questionnaires were distributed to top management of IC companies. Meanwhile, the second group included government officials who directed the policy or strategy related operations of the IC industry in government units. Those officials set government policy goals that influence the overall IC industry operations. This group received 5.8% of total questionnaires distributed. The third group included university professors who generally had the knowledge of IC industry development. Academic opinions are usually taken as a key reference of policy making by government. There were 4.7% of total questionnaires distributed to this group. Moreover, the fourth group included researchers working in research institutes. Industry reports produced by research institutes are major reference for decision making in the industry. This group received 5.8% of total questionnaires sent. Finally, the fifth group included various other individuals with experiencing of observing and studying the IC industry over a number of years, including venture capitalists, reporters and so on. Investors of venture capital play the role of investing potential and profitable companies for their shareholders. Such investors generally ob- served movements and changes in industry development very carefully. This group accounted for 4.3% of total questionnaires sent.

This study selected a total of 275 samples as the sampling of this research from the five groups to represent the whole organizations in this industry. The samples of IC companies collected as listed in the " 2001 Yearly Book of Semiconductor Industry" published by IEK (Industrial Economic and Knowledge Center)/ITRI and issued by Technology Department, Ministry of Economic Affairs. All IC companies listed in the 2001 yearly book with total number of 218 were selected as samples for survey. According to the database provided by IEK, yearly revenues of top 10 IC companies shared around 65% of total industry revenue and top 50 shared 85% of total yearly revenue in 2002. The sampling number of government officials, university professors, research institutes and others in total of 57 were selected from those well-known personages in the industry to represent the non-IC industry opinions in this field. Total 275 survey targets can be classified into two groups: one is IC industry group (218) and non-IC industry group (57) (including government officials, professors, researchers and others). For these two groups, one-way ANOVA (Analysis of Variance) is exercised. It can be found that under the significance level $\geqq 0.05$, there are 3 factors out of 42 factors in 1970s, 4 factors out of 42 factors in 1980s and 7 factors out of 42 factors in 1990s that given the significance level $<$ 0.05. It means that there is no evidence to show the significant difference between IC industry group and non-IC industry group.

4.3 Questionnaire Survey

A questionnaire was specially designed for this study. To maximize validity, the questions were developed on a combination of literature reviews and a group discussion basis. Items in the questionnaire survey were randomized for each individual to prevent any order effect. Respondents completed the questionnaire via an anonymous postal survey. Respondents were asked to indicate the degree of importance for each of 42 factors that could be possible contributors to the CSFs on a five-point Likert scale ranging from "weak" to "strong" [48]. The Likert measurement examined the perception of respondents regarding the importance of each factor.

This questionnaire was intended to determine the influence of successful factors. At the end of January 2002, the questionnaires were distributed by postal mail to top management who were identified as qualified candidates for answering the questionnaire. Specifically, the postal questionnaires were attached with an official letter describing the purpose of this research. Data collection was performed using self-administrated mail surveys. Total of 275 questionnaires were mailed out of which 218 were sent to the chairman or president of semiconductors companies. The remaining 57 questionnaires were sent to non-IC company organizations or individuals including government officials, university professors, researchers in research institutes, venture capitalists and so on. This questionnaire survey was intended to collect the original and first hand individual data for CSFs study.

5. Empirical Results

The 275 samples yielded a total of 115 responses of which 106 were effective and 9 were ineffective. The total response rate was 41.8% with he effective response rate being 38.5%. Table 2.0 showed the survey results. The average response rate in the IC industry was 36.1%. Manufacturing was the sub-industry with the highest production value obtaining a response rate of 60%. Meanwhile, the packing and testing sub-industry obtained a response rate of 38.7% and the design sub-industry got a response rate of 30.8%. The datum collected from these sub-industries fully represents the industry opinion. The response rate of government officials, university professors, research institutes and venture capitalists averaged 47.9%, and uniformly exceeded 43.7%. The above response rates demonstrated that the survey data represented the de facto viewpoint of informed observers regarding CSFs in the IC industry and also provided a useful database for further study of this area.

Table 1 Statistical Analysis of Responded Questionnaires

Items		Copies Sent	Effective Copies Responded	Responded Rate
IC Industry	Design	120	37	30.8%
	Manufacturing	20	12	60%
	Packaging and Testing	62	24	38.7%
	Wafer Materials	8	4	37.5%
	Optical Masks	4	1	25%
	CAD Tools	4	1	25%
Government Officials		16	7	43.7%
University Professors		13	6	46.1%
Research Institutes		16	7	43.7%
Others (Venture Capital, Reporters etc.)		12	7	58.3%
Total		275	106	38.5%

Remark: There are 9 copies ineffective out of total responded copies 115.

Based on the basic data of questionnaires listed in Table 3.0, 49% of all presidents or vice presidents of IC Companies participated in this questionnaire survey. The top management managed businesses at the frontier of the market that understood the industry very well. Most of the top management was entrepreneurs and being the pioneers of IC industry development in Taiwan. The total of 106 respondents included 86 professional managers who answer the questions rating at 81.1%. Meanwhile, government officials, researchers and professors accounted for 18.8% of respondents. As for the educational background of respondees, 19.8% held a Ph.D. degree, 51.8% held a master degree and 28.3% held a BS degree. It indicates that all respondees are elites and professionals in the Taiwanese IC industry. The average number of years of working experience of the respondees was 15.5 years. Given this rich work experience, their perspectives and insights are due legitimacy, and their comments will undoubtedly prove very worthwhile. This data demonstrates that the survey results mostly represent the views of industry elites and thus are likely to be valuable and reliable. Consequently, the survey results accurately reveal the perspective of industry in this field.

The random rating of interesting variables was analyzed using the SPSS (Statistical Package for the Social Sciences) computer software. A factor analysis method of variance was employed in the dimension of each development stage to test the degree of importance of the CSFs. The individual mean value of the Likert rating scale was the popular sage indicator for mea-

Table 2 Basic Data of Questionnaire's Response Analysis

Job Title		Q'ty	Percentage
Industry	President, VP	52	49%
	Director	15	14.1%
	Manager	14	13.2%
	Others	5	4.7%
Government	Government Officials	7	6.6%
Research Institute	Researcher	7	6.6%
University	Professor	6	5.6%
Total		106	100%
Education Background		Q'ty	Percentage
PhD. Doctor		21	19.8%
Master		55	51.8%
BS		30	28.3%
Total		106	100%
Averaged years of working experiences in IC industry out of 106 Responded persons		15.5 years	

suring the importance of items, without considering other items. Degree of value indicated the item importance. A three-stage factor analysis with an orthogonal rotation was conducted to achieve a stable factor structure. Moreover, principal component analysis was used for factor extraction, and Varimax with Kaiser normalization was used for rotation. The KMO (Kaiser-Meyer-Olkin) measure of sampling adequacy was 0.804, 0.717 and 0.717 for the 1970s, 1980s and 1990s respectively. The eigenvalue from a Varimax rotation for which the extracting factors were retained was set at 1.0. The analytical results are rather important for industry analysts and others in crosschecking results obtained in related research.

Scores of apparently unrelated potential factors were analyzed. During the 1970s, 15 potential factors out of a total of 42 were selected to indicate the factors correlated with the labor-intensive stage, and five extracting factors with loading factors exceeding 0.489 were conducted. The rotation sums of the squared loading reached at 63.357%. Five extracting CSFs were conducted, and contained the correlated 15 items dealing with the emergence of the external environment of the IC industry, namely: (A1) Manufacturing capability advantages (A2) Government policy (A3) Foreign aid (A4) Technology migration from foreign companies and (A5) Market requirements. These CSFs figure prominently in the requirements for the industry itself and the surrounding environment during the labor-intensive stage.

During the 1980s, 25 potential factors out of 42 potential factors were chosen to indicate the factors correlated with the technology-intensive-stage, and eight extracting factors were conducted with loading factors exceeding 0.451. The rotation sums of the squared loading were obtained at 63.907%. Eight extracting CSFs were conducted that contained the correlated 25 items dealing with the issues of the preemption of the internal capabilities of the IC industry, namely: (B1) Capability of production flexibility (B2) cooperation with foreign companies (B3) attraction of global talent (B4) unique characteristics of family-like culture (B5) government support (B6) start-up confidence (B7) strategic planning of industry policy and (B8) Attractiveness of the HSIP (Hsinchu Science-based Industrial Park). These CSFs boosted capability improvement and infrastructure construction within IC industry.

During the 1990s, 32 potential factors out of a total of 42 were selected to indicate the factors correlating with capital-intensive stage, and eleven extracting factors were conducted with loading factors exceeding 0.344. The rotation sums of the squared loading were obtained at 67.095%. Eleven extracting CSFs that contained the correlated 32 items dealing with the issues of coherence of internal and external environments of IC industry were conducted, namely:(C1) Momentum of potential entry (C2) Rich pool of talent for industry (C3) Clear positioning and business model (C4) Profit sharing and stock ownership system (C5) Strategic alliances (C6) Encouragement of success stories (C7) Vertical disintegration (C8) Attractiveness of HSIP (C9) Global vision (C10) Sufficiently large to attract global talent and (C11) Mass production capabilities. These CSFs are the basic elements for the competitiveness and competence of local IC industry.

6. Findings and Discussion

The development of the IC industry has clearly had a revolutionary impact on the Taiwanese electronics and information industries. In an intensely competitive industry, the success was based on government intervention, enhanced research and development, ample supply of capital, and rapid technological change. Success of IC industry in Taiwan had been achieved because of active government support, vast financial resources, strong demand from the domestic electronics industry, abundant capacity in the local foundry industry, and tight collaboration between design houses and foundry providers [42]. This study clearly verified this point.

From the result of this study, extracting CSFs of each stage confirms the existence of stage dependent correlation among the various stages as displayed in Table 4.0. Manufacturing capability has been found to maintain the three stages dependent correlation or only one common CSF from the labor-intensive stage through to the technology-intensive stage and capital-intensive stage. Six sets have two stages correlation in the cross-stages, two from the 1970s to the 1980s and four from the 1980s to the 1990s. Regarding one stage dependent factors, two extracting factors were noted in the 1970s, one in the 1980s and six in the 1990s.

6.1 Three Stages Dependent CSFs

Manufacturing capability was important as the common driver for all industry development phases. Manufacturing assembly is essential in the development of new industry providing the basic resources for the development of high technology industry. This CSF includes three stages with cost considerations being the first priority in the formation and development of such industry. It has the advantages both of cost effectiveness and market attractiveness, which explains why leading foreign companies are interested in assembling products in the under-developed countries. The

Taiwanese IC industry was based on the IC packaging sub-industry because of its significance to manufacturing assembly.

Historical analysis of the development of the Taiwanese IC industry had revealed five critical events driving the development of the industry occurring in 1974, 1980, 1987, 1994 and 2001 respectively. A specific organization or company initiated each event. First, ERSO/ITRI obtained technology from RCA (Radio Corporation of America) IC technology in 1974, marking the official beginning of the Taiwanese IC industry. Second, UMC (United Microelectronics Corporation) was spun off from ERSO in 1980, establishing the first private local IC company, and starting the commercialization of 4-inch wafer manufacturing technology. Third, TSMC (Taiwan Semiconductor Manufacturing Company) established the first dedicated foundry fabrication service in the world in 1987, and simultaneously introduced 6-inch wafer manufacturing technology to Taiwan. Fourth, VISC (Vanguard International Semiconductor Corporation) was spun off from ERSO to produce own brand DRAM (Dynamic Random Access Memory) in 1994, and simultaneously introduced the first mass production of 8-inch wafer manufacturing technology to Taiwan. Fifth, TSMC was the first company in the world to conduct pilot run of 12-inch wafer fabrication in 2001. These events in the evolution of the IC industry underlie the critical success factors of IC industry development in Taiwan.

Table 3 Stage Dependent Extracting Factors in Three Stages

<table>
<tr><th>Stages</th><th>Three Stages Dependent</th><th>Two Stages Dependent</th><th>One Stage Dependent</th></tr>
<tr><td>1970s</td><td rowspan="3">A1, B1, C11</td><td>A2, B5
A3, B2</td><td>A4
A5</td></tr>
<tr><td>1980s</td><td rowspan="2">B3, C10
B6, C1
B7, C7
B8, C8</td><td>B4</td></tr>
<tr><td>1990s</td><td>C2
C3
C4
C5
C6
C9</td></tr>
</table>

The pattern of the above five critical developments in IC manufacturing technology in Taiwan reveals that wafer manufacturing technology in Taiwan has a life cycle of seven years. One explanation for these phenomena is that a successive technological innovation is adequate and necessary for the successful development of a high technology industry. A technological innovation represents a new technological trajectory [35] that diverges from and is often rejected by an existing industry because of its discontinuous rupturing effects on the established technological paradigm [54]. The technological trajectory sketched above includes the key turning points in the successful development of the Taiwanese IC industry.

6.2 Two Stages Dependent CSFs

Six extracting factor sets cover two stages:

6.2.1 Government Support Established the Roadmap of Industry Development

The government has provided strong strategic support for the development of the Taiwanese IC industry since the 1970s. Government guidance in industry development policy and the operations of research institutes and universities has postured the industry to make enormous progress. Government has not only conducted the research projects through research institutions such as: ERSO/ITRI, but also provided tax exemptions and sound infrastructure to companies selected according to strategically encouraging considerations. The strong support coming from government for programs in the IC industry not only offered substantial benefits to local industry companies themselves, but also set off the offshore interests including potential companies and entrepreneurs.

The key contribution of the Taiwanese government to develop the local IC industry lays in acquiring technology from abroad and conducting pioneering in-house research through a series of national research projects [17]. Except government support for ITRI, other factors that contributed to the successful development of the IC industry in Taiwan included: (1) Government and ITRI choosing appropriate "vehicle products" to develop submicron meter fabrication technology to test its feasibility, and establishing market potentials. (2) The role of research project leaders was instrumental in overcoming obstacles. (3) Government provided incentives to promote private investment in the IC industry [39]. Government support for the industry has became the most crucial factor in facilitating the emergence and success of this new industry.

Government assistance for the IC industry was especially crucial during the technology-intensive stage. MOEA (Ministry Of Economic Affairs) was heavily involved in the planning and implementation of domestic infrastructure development for the strategic sectors of the high technology Industry. One of the major achievements of state planning was the establishment of HSIP (Hsinchu Science-based Industrial Park) in 1980. The HSIP was built on the concept of California's Silicon Valley [34]. The establishment of the HSIP encouraged overseas entrepreneurs, technological team and corporations to relocate their businesses from the US to Taiwan. The administrator of HSIP supports this movement as does the TAC (Technology Advisory Office), a consulting group of MOEA, which acknowledges that Taiwan's relationship with overseas Chinese, particularly in California, has been crucial to its industrial development [3]. The government played a major role in promoting the HSIP through various policies and incentive schemes. Local investment grew strongly after HSIP was established and propelled by policy stimulation and strong inflows of foreign investment.

6.2.2 Aids from Foreign Companies Were Inevitable

In the early 1970s, the introduction of foreign transistor and IC assembly technologies was essential to train the skills of technical engineers then diffused to local companies. The industry was started from American General Instrument Corporation to establish a factory at Kaohsiung, in the south of Taiwan, in 1966. Other plants followed, being built by Philips, Texas Instruments, RCA and Mitsubishi [17]. By the benefits of government policies, the IC development in 1970s saw a reduction of tariffs to 35 percent and the establishment of the first EPZ (Export Processing Zone) at Kaohsiung, Taiwan. The EPZs were established to have minimum regulations in return for exporting all of their production [30]. This period marked the most significant phase in the development of the IC industry. The foreign companies were primarily USA, Holland and Japan that focused on labor-intensive IC assembly. These foreign companies benefited from Taiwan's low cost labor, but simultaneously they helped Taiwan to establish basic IC packaging technology through the introduction of IC assembly, testing and quality controls technologies [55]. Engineers who worked in these companies offered the first seeds for the subsequent electronics industry development in Taiwan from the 1980s. Another essential momentum to Taiwan's electronics industry development laid in the numerous yearly modern engineering seminars held in Taiwan during 1970s, helping to bring the newest and most up to date technological concepts and foreign knowledge into Taiwan, especially form USA and Japan. These events brought on the first-tier technological seed of the Taiwanese IC industry.

6.2.3 Global Talent Was Necessary in the Development Stages

Technology transfer involves four elements, namely: people, information, resources and capital. Among the four elements, human resource is the most important because they are essential in the acquisition of new technologies and the integration of old and new technologies during the process of technology transfer [26]. It not only established and improved production yield targets, but also trained engineers and managers in general industrial technology and in engineering and management operations. This was the preliminary building block for the future development of the Taiwanese IC industry [37]. The well-trained and talent engineers cultivated via the process of technology migration became the pillars of the IC industry development in Taiwan. Talented human resources provided the technological and managerial prowess to enable industry development.

Numerous talented master's and doctoral students went to USA to pursue advanced study in 1960s and 1970s because of the poor environment in domestic academy. This exodus of talent ultimately turned into a global talent pool with roots in Taiwan who were of much experience in leading international companies. Many of these individuals returned to Taiwan and heartedly involved in the development of local IC industry, being attracted by the lure of the HSIP and the opportunities opened to entrepreneurs during the 1980s and 1990s. Taiwan has an abundance of electronic engineers, many of whom are US-trained and thus have plenty of valuable engineering experiences. An effort is underway by universities, government and ITRI to promote an idea of research parks because that it brings industry, universities and government together to realize the anticipated knowledge-based economy. This is why Taiwan is capable of generating more intellectual capital [14]. Taiwan is able to attract a lot of global talent to join IC industry only if it has the large scale and profitable companies. Talented engineers are absolutely necessary for technological innovation and providing the core competence to allow the local industry becoming a global leader in the high technology industry.

6.2.4 Confidence Was Required to Enter into the Business Market

Confidence to enter into the industry and market is needed for entrepreneurs and industry new comers, and it is essential to provide startups with the required momentum to run business assuredly and aggressively during the initial phase of the high technology industry development.

ERSO/ITRI successfully completed its design of the core IC for electronic watch production in 1976 and the first IC chip made its debut in 1978 in the demonstration plant [16]. It was not proven to be commercially viable until the first domestically owned IC chip was produced using CMOS (Complementary Metal Oxide Semiconductor) process technology in 1978 and bipolar process technology in 1980. ERSO chose timekeeping, melody and telephone ICs as product vehicles instead of memory ICs, that was easily to be mass produced and given a strong confidence for the IC industry and all peoples outside and inside Taiwan [52]. Adopting low-end consumer products as the development vehicle was a wise decision in developing a new technology.

ITRI took the responsibility of IC technology diffusion to domestic private companies. In selecting from among various methods of targets for transferring its technologies, ITRI considered the status of its own technology, as well as the requirements, and existing technological capacities of private electronics firms [17]. The first privately held IC Company – UMC, which was spun-off from ERSO/ITRI in 1980, demonstrated a successfully significant milestone and index of the development of the Taiwanese IC industry during the initial technology-intensive stage. Starting such a private IC company voluntarily was impossible on account of the high capital and high risk involved. It also was evidence that the IC technology transferring from government's research institute to industry is feasible and applicable. Spin-off provides an effective method for boosting domestic technology during the development stage of this new industry.

6.2.5 Strategic Alliances Were the Key to Industry Development

The establishment of TSMC, the world's first foundry-only wafer fabrication company, indicated a new wave of strategic alliances in Taiwan. TSMC was originally established as a foundry joint venture between the Taiwanese government and Holland's Philips Electronics N.V.. In 1995, the first private IC manufacturer, UMC, a competitor of TSMC, had recognized the trend of compartmentalization and specialization of IC industry and strategically transformed itself from an IDM (Integrated Design Manufacturer) into five foundry-only fabrication companies and four IC design houses using strategic alliances with leading foreign companies to achieve its objective. In 1996, another new foundry-only manufacturer WSMC (World Semiconductor Manufacturing Corporation), was also established. The foundry sub-industry, as one part of IC industry, provided the first-class professional services to another sub-industry, namely: design houses that did not invest heavily in fabrication. The Taiwanese semiconductor sector combines the attributes of high added value, low risk, and the innovative use of strategic alliances, and thus is well adapted to the new trend of "fabless" and "chipless" operations. The rise of this business model owes much to the role of the government, which helped overcome market failures to launch new ventures in each stages of the evolution of the industry [2]. As firms recognize that the environment become more and more uncertain, the momentum for them to create strategic alliances as a strategic response to the environmental change will become stronger and stronger [4]. Strategic alliances help to keep companies to be more competitive and capable in a rapidly changing market.

In the IC industry, high added value, low R&D costs, short development cycles, and fast production periods are all critical to business. Strategic alliances play an import role in upgrading the technological gap generated by Taiwanese IC companies. Research on the Taiwanese semiconductor industry has agreed that the industry follows a dynamic development strategy favoring collaboration [17,27,38]. Two major three-cornered and two-way strategic alliances exist: the first involves Taiwan's Winbond Electronics with Japan's Toshiba and Fujitsu, along with cooperative arrangements among ProMos, Mosel Vitelic and Infineon, a spin-off of Siemens; the second involves Powerchip and Mitsubishi, along with cooperative arrangements between Nan Ya technology and IBM. In addition to inter-firm strategic alliances, major Taiwanese firms have limited Japan's operating strategy of vertically integrating all aspects of value-added activities from upstream component production to mid-stream assembly, to downstream marketing and distribution [15]. Strategic alliances have formed a series of value chains in the industry that provides key research and technological know-how to foster development efforts and expand tentative market share.

6.2.6 The HSIP Provided a Platform for Industry Development

The establishment of HSIP provided a sound industrial infrastructure including standard factory buildings and workshops represented an excellent source of support to the new start-ups. The HSIP attracted numerous high technology companies owing to the administrative conveniences and operation benefits. The significant contribution of HSIP's production has been widely recognized and confirmed in the literature [8,20,29]. Critical factors for prosperous IC industry development required an ample supply of operating necessities including land, electricity, water and administrative facilities and the sound educational systems both of professional organizations for workers and elementary to senior high school for their children, which turned out a legions of highly trained and skilled personnel who were willing to work in the HSIP. The continuous growth of the HSIP in terms of revenue and investment has been recognized as a successful model of technology park development [12]. The HSIP is one of the most important business platforms underpinned the research and development of the Taiwanese IC industry.

6.3 One Stage Dependent CSFs

6.3.1 Unique CSFs in the 1970s

In the 1970s, there are two unique CSFs.

6.3.1.1 Technology Migration from Foreign Leaders Is Essential to Initiate a New High Technology Industry

During the labor-intensive stage, migration of technology know-how is crucial. Following the oil crisis occurred in 1974, a strategic plan was proposed by the TAC, MOEA that Taiwan decided to transfer the first IC technology to employ seven-micron meter design rule, and CMOS process technology from RCA, USA. The decision bet on CMOS technology paid off handsomely by enhancing Taiwan's ability to synchronize the development of semiconductor technology and its PC (Personal Computer)-based information technology to achieve high synergy between those two Industries [27,39]. Integrating the IC technology – semiconductor component technology and system end-product technology provided an excellent solution to upstream and downstream industry development. CMOS process technology also experienced significant enhancements, as the design and fabricating capabilities improved from seven- micron meter to 1.2-micron meter, an advance that was achieved through cooperation between the industry and ITRI during the late 1980s [37]. Viewing technology as a functional capability implies the need to develop a technology strategy. For technology, such a strategy is defined by a set of interrelated decisions encompassing of technology choice, level of technology competence, level of funding for technology development, timing of technology introduction in new products/services, and organization or technology application and development [31]. Far-sighted government's officials provided the best impetus to the industry, and adopted timely and correct technology strategies, thus helping to achieve a well transformation from the labor-intensive stage to the technology-intensive stage of IC industry development.

6.3.1.2 Market Requirements Are a Major Driving Force of the Industry

Taiwanese IC industry inspired the continuous economic growth and technological upgrading from the 1970s through the 1990s. This period saw the Taiwanese economy move into the production of more sophisticated consumer goods due to the rapid growth of domestic IC component sourcing services. This period was characterized by the importance of sub-contracting for Taiwanese industry [30]. Souring of key components figured prominently in the development of system products. IC technology was booming and diffusing throughout other industries, and Taiwan posturing itself as for the second largest source of foreign IC leaders because of its lucrative conditions and strong competitiveness. Average annual growth in domestic IC product production value exceeded 18% from 1978 to 1986, driven by the huge requirement of strong market that attracted more people to involve in this industry [52]. The strong demand came from the domestic and foreign market attracting more capitals to flush into this industry.

Just one CSF was extracted for the 1980s. While EPZ created numerous jobs, mainly filled by single young female factory workers, HSIP created more highly paid jobs that attracted married couples with a higher education level to join [9]. Not only were technologies diffused from ITRI, but so too were human resources. Individuals who came from ITRI were characterized by ITRI's family culture with the same attitude of treatment and cognition of working style and consensus, and cooperation among individuals and companies were frequent. This kind of cooperative culture muscle was extremely important and effectiveness to the progress of IC industry development in Taiwan during the 1980s and 1990s.

6.3.2 Unique CSFs in the 1980s

During the 1980s, the family-like culture that developed at ITRI represented a unique CSF. Management in engineering and manufacturing is the strength of Taiwanese IC companies. Leadership is a contextual factor, which impacts on behavior and attitudes of subordinates through their perceptions of jobs [18,19]. The strong success intention of entrepreneurial spirit has helped top management to inspire their subordinates to be aggressive, hardworking, practical and effective. With such a leading position in technology development and strong government support, the management philosophy in ITRI places more emphasis on autonomy and may, thus influence its managers to adopt a highly supportive style to lead its creative workers [47]. The adaptability of leader significantly influences work and organizational effectiveness. Taiwanese managers have a fairly high level of trust in their employees with a predominant [51]. By the most formal and non-formal ITRI spin-off IC companies sharing the same organizational culture, communication cost is decreased and operational efficiency between individuals and organizations is increased. An organizational culture evolves over time based on the accumulated background of the organization, which is intangible and strongly impacts on organizational success. A good knowledge of the local culture and a great effort to minimize the difference will help to build long-term cooperative relationship and trust and will enhance the level of satisfaction and performance [36]. Taiwanese IC industry reveals this kind of unique characteristics.

6.3.3 Unique CSFs in the 1990s

During the 1990s, six unique CSFs were extracted:

6.3.3.1 Powerful Talent Pool Offers Optimum Resources to Industry Sustainedly

Despite Taiwan demonstrating little indigenous innovative ability in semiconductors during the 1970s and early 1980s, its diffusion-oriented infrastructures helped them quickly assimilate acquired technologies, standing its local semiconductor industry in a good stead as it sought to catch up technologically with international competitors [11]. Even minor innovation requires a spectrum of skills, knowledge and capacities for searching, selection, assimilating and adopting techniques [1]. The flow of technology and manpower from ITRI, combined with the second stage transfer within the industry, contributed significantly to Taiwan's semiconductor output, as well as making the industry more competitive in the world area [17]. The abundant talent pool of Taiwan is one of the key factors to the success of its industrial development. Taiwan has sought to establish a foothold by way of leveraging its expanded infrastructure and skilled workforce to become a powerhouse in the developmental phase of the IC industry, where production cost, quality level and delivery effectiveness have all attracted international business interest and capital investment.

From the 1980s, the government has implemented a policy of increasing brainpower to industry, directed by the Ministry of Defense, under which those who majoring in science and engineering post-graduate students can fulfill their compulsory military service in high technology research institutes and corporations rather than in military unit. This policy provides an environment where the talent can work for industry at least four years for future research and development that supplies a stable pool with the availability of high-quality human resources. This is a very effective and creative system for helping the IC industry to progress steadily and for upgrading its level of engineering capabilities.

6.3.3.2 Clear Positioning and an Effective Business Model Is the Top Priority

The Taiwanese IC industry has successfully grown along with its customers and generated the profits required to buy, improve and invent through successive technology generation. The Taiwanese IC industry thus has caught up with having a lead in getting the updated advances into production. Taking TSMC as an example, it positioned itself as a dedicated fabricator of wafer foundry, not only providing adequate manufacturing capacity for local IC design houses, but also creating a new business model that foundry company played an independent integral part of design, testing and packageing houses in IC industry stream. This model helped contribute to rapid growth of the industry, with TSMC operating six wafer fabs and achieving annual sales growth rate of 70 percent in 1989 [24]. A Clear positioning and an effective business model can allow companies to obviously segment the target market and obtain a unique competitive advantage what set those one apart strategically.

A reverse pattern of technology transfer occurred when American IC maker National Semiconductor Corporation licensed technology from TSMC in 2000. In the mid-1990s, UMC had spun off its design division to become new IC design companies, and dedicated in foundry fabs mainly through joint ventures with offshore fabless companies. UMC was more inclined than TSMC to enter into the joint ventures, such as its 12-inch development with Hitachi Corporation of Japan, and also to enter agreements to develop the lucrative technological market by cooperation with the world's IC industry giants such as IBM Corporation, USA. Taiwanese firms have significantly more internal money for investment and extremely business connections with the US and European semiconductor industries, which has enabled them to enhance their technical capabilities and gain rapid access to the latest information [39]. The development of the Taiwanese IC industry has demonstrated that a long-term focus reaps excellent rewards by its original style of business model. .

6.3.3.3 Profit Sharing and Stock Ownership System Is Indispensable

The past two decades have seen the development of a uniquely Taiwanese bonus system that allows employees to become stockholders that was regarded as impossible before 1980s. UMC was the first Taiwanese IC company to introduce the profit sharing and stock ownership system to employee in 1985. Taiwanese employees are becoming extremely cost-conscious, company-oriented and collaborative because of the profit sharing scheme. Employees can share a certain percentage of net annual operating profit and dividends by way of stock issued. This system makes employees to become company stockholders, and it is far better than the stock option schemes favored by US companies. This system is indispensable in providing the key momentum for rapid company progress and development. Almost all of companies in the Taiwanese high technology industry adopted this system since 1990s.

6.3.3.4 Vertical Disintegration and the Cluster Effect Create a Competitive Edge

The Taiwanese IC industry developed a combination of high value-added chains of vertical disintegration in 1990s. Based on the history of IC development in Taiwan, most of Taiwanese IC manufacturing companies during the 1980s were IDM (Integrated Design Manufacturer). However, the situation changed during the 1990s owing to the professional technology increasingly required in each segment. The distinctive leading-edge propriety that technologically paranoid develop in particular areas corresponds to start intellectual property in design [32]. Individual sub-industries from system integration, IC design, and wafer fabrication to assembly and testing are separately operated to achieve the segmental benefits of low cost, high quality and fast delivery. However, special SIP (Silicon Intellectual Property) is in especially strong demand because of the design requirement of SOC (Silicon-On-Chip) which comprises millions of transistors that beyond individual capability and timing considerations. It is beneficial to national competitive advantage to develop a cluster of related industries to stimulate the generation of technology synergy [45]. The formation of clusters enhanced the cooperative activities among sub- industries. Clusters are geographic concentrations of interconnected companies and institutions in a particular field [46]. Vertical disintegration and clustering of upstream and downstream companies offers high-quality and efficient customer services with total solutions. Link fabrication factories and related sub-industries become the most economical when they are concentrated in clusters like the Hsinchu Science-based Industrial Park, where they can share logistics services, and still more important can attract circles of suppliers and demanders to form a value chain. In the broadest sense, a firm’s “technology” encompasses the entire set of technologies employed in the sequence of activities that constitute its value chain [44]. The regional characteristic cluster effect in the IC industry is its key competitive edge in the world market that Taiwan has proven it successful.

6.3.3.5 The Momentum Built up by Entrepreneurship Encourages Investment

While semiconductor markets are rapidly growing, the investment risks are also soaring. Industry executives must make huge gambles on billion-dollar factories, on multimillion-dollar development for innovative semiconductor process tools, or on acquisitions to fill out product lines [21]. The Taiwanese IC industry is characterized by significant venture capital involvement, which has fostered the rapid development of high technology industry. During the 1990s, venture capital boomed in Taiwan due to the success of IC industry development during the 1980s. Many traditional industries strategically moved in the high technology sector especially the IC industry because of its high potential for profit and although it is intrinsically high-risk. Consequently, there was an unprecedented flow of capital flushing into the IC industry in search of new opportunities. In the semiconductor industry, relatively large infusion of capital must be periodically bestowed on equipment and research, with each infusion exponentially larger than the one before [23]. However, the entrepreneurship of Taiwanese are still existing and stepping forward. The confidence and persistence of Taiwanese entrepreneurship has significantly improved the prospects of the Taiwanese IC industry.

6.3.3.6 Global Vision Outlines the Industry Development in Perspective

To keep up with the industry demand and maintaining the competitive advantage of IC producers, capital spending in the IC industry is traditionally high averaging around 20% of total IC sales. IC companies typically overestimate their budget requirements to allow them to meet the dynamic market movements. The inherent lag time to get a new IC facility built and productive that coupled with the usual industry wide overspending and underpinning has created the history of volatility in IC capacity [33]. Changes between conditions of wafer oversupply and undersupply have created the IC industry business cycle. Nevertheless, Taiwanese chipmakers have been making plans to continue their investments in new fabrication and equipment on the basis of strategic planning and global vision. The aggressive investment strategy of Taiwan has pursued since 1994 has paid off in relative market share against Korea [10]. A continuing structural change in the IC industry has been brought out through the high initial investment in building fabrication, whereby the second-tier companies will go on to rely on pure-play foundry services. Because of this phenomenon the industry is displaying a trend of the big companies in the industry becoming bigger whereas the small companies becomes smaller.

During the capital-intensive stage, upgrading basic technology and continuing on technology investment were the keys for sustaining success. Strategic and vertical disintegration based on cross capital investment was the first business strategy considered for sustaining a competitive advantage. In a diffusion-oriented economy, firms have more pervasive opportunities to exploit the results of their R&D and thus are more willing to make further investments in R&D activity [41]. In 1997, there were 15 Taiwanese IC manufacturers individually announced a total of 10 years US$80 billion investment program. Sustainable development that had repercussions on the industry itself was the main ingredient of success. TSMC announced its intention to invest as much as US$14 billion to build six new 8-inch and 12-inch wafer fabrication, plus mask production, assembly/test and R&D support facilities in the Tainan SBIP (Science Based Industrial Park), southern of Taiwan, over the next ten years [22]. Favorable tax treatment and infrastructure offered by the Taiwanese government and accompanied with the massive investment have brought Taiwanese IC manufacturers into a strong position to win in global markets. Taiwanese companies are moving the technological forefront, a development that could see leading corporations like TSMC and UMC further increase their market share in the world.

The willingness of Taiwanese fab to spend money on the best and latest in IC fabrication equipment has placed them at the forefront of global IC production. Another part of the reason for Taiwan's phenomenal strength, prosperity and growth in IC fabrication may be due to the industry's willingness to expand while others stood still [9]. Taiwan has a stronger base than other countries and moreover has a stable monetary market that facilitates the raising of venture capital funds. This is one of the main factors in the success of the Taiwanese IC industry [25]. Taiwan financed its entire gross domestic capital formation entirely from its own domestic savings rather than from foreign capital inflows [28]. Chilled by an IC industry slowdown in 1996-1998 as well as by technical concerns, most USA, European and Japanese IC manufacturers have hesitated to invest in 12-inch wafer technology. However, Taiwan's TSMC and UMC have forged ahead with developing 12-inch wafer technology, undeterred by a steep downturn in orders. The Taiwanese IC industry thus is capable of becoming a world-class leader in the IC industry in the years ahead.

7. Conclusion

Taiwan has experienced a remarkable period of development of its IC industry, including the labor-intensive, technology-intensive and capital-intensive stages, in the 1970s, 1980s and 1990s, respectively. Taiwan began to develop its IC industry based on active support from aggressive government policy, smart entrepreneurship, and industry efforts helping the Industry to score significant achievements in the 1980s and 1990s. Different CSFs shaped the development profile of the industry during each of the labor-intensive, technology-intensive and capital- intensive stages. Exploring the stage dependent CSFs provides a method of clearly identifying the success factors in each phase.

Manufacturing technology was the only CSF that that was present during all three stages. Taiwan had no semiconductor industry before the 1970s, but it has now become the third largest semiconductor manufacturing center in the world through the efforts of government, research institutes, universities and industry during the past three decades and nominated as its successful development of IC industry. The development of Taiwanese semiconductor industry has mostly been dominated by manufacturing technology capability. The development of the industry started with assembly for foreign electronics industry leaders in the 1970s, followed by technology transfers from foreign companies, the establishment of local manufacturing demonstration plant, and technology diffusion to industry and strategic alliances with foreign leaders. The Taiwanese semiconductor industry is famous for its manufacturing capability, and provides the leading example of Taiwan's economic miracle.

The factors of government support, strategic alliances with foreign leaders, and confidence in aggressive entry to new markets were the CSFs that covered two stages. Government support is inevitable during the Industrial development, particularly in the emerging stage. The government strategically introduced high technology and technical teams from leading foreign companies to trigger local technology development and innovation for the emerged industry is a good resort. Additional strategic alliances with semiconductor pioneers to acquire necessary technology is the best means of future development. However, such developments should be accompanied by aggressive capital investment by government and industry. The government established EPZ to stimulate economic growth during the labor-intensive stage, and then established the Hsinchu Science-based Industrial Park during the technology-intensive stage to attract advanced foreign technology and talent to facilitate the technological localization of the Taiwanese IC industry. During the capital intensive stage, the Tainan Science-based Industrial Park was set up to encourage further semiconductor development, simulating the successful model of the Hsinchu Science-based Industrial Park. Sound infrastructure attracted entrepreneurs entering into this industry with high confidence and strong intention. Spin-off companies from research institutes and divisions of big companies provided another momentum for the development of the IC business in Taiwan. Nevertheless, it is better for government to reduce interference during the capital-intensive stage on account of the industry being strong enough to they can do what they want to do effectively basing on the business considerations. This point gives the key suggestion to the government unit. The industry does not require many clauses to prevent it from promotion, otherwise the government out-of-date policy will become a blockade for industry development.

Factors of technology migration and market requirements were underlying the labor-intensive stage dependent CSFs; unique characteristics of family-like culture was underlying the technology-intensive stage dependent CSF; and attracting first class talent, clear position, profit sharing ownership system, cluster effect and entrepreneurship, and global vision were underlying the capital-intensive stage dependent CSFs. Technology procurement was necessary to spur the industrial development in order to meet the global market requirement during the 1970s. Availability of engineering talent is the key to develop the staggering proliferation of new technologies. Through the efforts of research institutes and universities, the Taiwanese IC industry has ready for talent human resources to follow successful technology migration from abroad. With government support, ERSO diffused technology and skilled personnel to industry continuously during the 1970s, 1980s and 1990s. Individuals from the same place and with similar backgrounds and a common organizational culture were capable of effectively enhancing the efficiency of inter-company communications, and were extremely confident in creating new business teams as working partners. This factor represented the unique CSF in the development of the IC industry during the 1980s. A system of industrial service in place of military service for technology related masters or doctoral degree graduates provided a strong source of professional talent for the IC industry. Generally, after the completion of their military term, most of these professionals devoted themselves to work in private companies to launch their professional careers and gradually become the IC industry elite. The long-term competitiveness of the industry depends on a pool of well-trained professional talent, something that can be achieved through sound education provided by universities, government training center and research institutes. The profit sharing and stock ownership systems employed by Taiwanese IC companies provide an excellent bonus system for allowing employees to share in company profits. With all employees also being shareholders of company, it will help to immunize the gap of all people of intracompany. Under such a system, employees are more likely contribute their all to the company. This system provides excellent momentum for employees to work hard and willingly to contribute to the organization and regarding it as their own company. The successful application of this system by the Taiwanese IC industry has led a new wave in the business model. Subsequently, various kind of profit sharing and stock ownership systems will be emerged and stimulating the high technology industry whether in Taiwan or elsewhere. The integration of sub-industries from the upstream to the downstream of the IC industry has proven itself feasible to be a competitive advantage of organization especially in 1990s. The Taiwanese IC industry has become a national strategic industry based on its evolution and prospects. Upgrading and enhancing global competitiveness are crucial issues ahead. From the perspective of globalization, competition will come from the supply and demand chains between industries and countries. These competitive chains will be configured on a cross-country of trans-industry basis regardless of location. Taiwanese logistics operation on a supply and demand basis will cause a positive change in the development of the IC industry.

A global-oriented strategy will ensure that Taiwan maintains its competitiveness in a rapidly changing global environment. The successful business model of the Taiwanese IC industry provides a stable foundation for globalization. Starting from the IC wafer supply, and then the circuit design, wafer fabrication, photo masking, testing, packaging and other IC related companies would play their segmental critical roles in this industry. The Taiwanese IC industry is endeavoring to gain a strong competitive position, impacting Taiwanese economic vicissitudes, as well as affecting the development of the global IC industry.

References

[1] Adityawan, Chandra, Zulkieflimansyah. 2003. The dynamic of technological accumulation at the microeconomic level: Lessons from Indonesia–a case study. *Asia Pacific Management Review* **8**(3) 365-407.

[2] An-chi, Tung. 2001. Taiwan's semiconductor Industry: What the State

did and did not. *Review of Development Economics* **5**(2) 266-288.

[3] Arensman, R., G. Grane, C. Brown, D. Wilson. 1991. Asia turns on to R&D. *Electronic Business* **17**(24) 14-16.

[4] Bou-wen, Lin, Chung-jen, Chen. 2002. The effects of formation motives and interfirm diversity on the performance of strategic alliance. *Asia Pacific Management Review* **7**(2) 139-166.

[5] Boynton, A.C., R.W. Zmud. 1984. An assessment of critical successful factors. *Sloan Management Review* **25**(4) 17-27.

[6] Bullen, V. Christine. 1995. Reexamining productivity CSFs. *Information System Management* **12**(3) 13-19.

[7] Byers, C.R., D. Blume. 1994. Trying critical success factors to systems development. *Information & Management* **26**(1) 51-61.

[8] Chi-yo, Lin, S.P. Yang. 1994. Technology park and local economic development. *Proceedings of International Symposium on City Planning*, 491-498, Japanese City Planning Association, Fukuoka, Japan.

[9] ______, S.P. Yang. 1995. Foreign direct investment and local direct investment in Taiwan. *Proceedings of International Symposium on City Planning*, Korean Urban Planning Association, Kwanju, Korea.

[10] Carroll, L. Mark, Quan, Margaret. 1998. Reversal of fortunes has Taiwan reeling. *Electronic Engineering Times* 07/13/98 **1016** 1-2.

[11] Cheng-fen, Chen, Sewell, Graham. 1996. Strategies for technological development in South Korea and Taiwan: The case of semiconductors. *Research Policy* **25** 759-783

[12] Chien-yuan, Lin. 1997. Technopolis development: An assessment of the Hsinchu experience. *International Planning Studies* **2**(2) 257-173.

[13] Ching-tang, Ho. 1998. *A Study of IC industry development on Taiwan*, Ph.D. dissertation, Graduate School of Business, National Taiwan University, Taiwan (in Chinese).

[14] Chin-tay, Shih. 2000. Innovation and development of Taiwan's hi-tech industry. *Euroview* **70**, May-June 2000.

[15] Chung-shing, Lee, Pecht, Michael. 1997. Recent development in Taiwan's electronics industry. *Circuit World* **3**(3) 16-19.

[16] ______, Pecht, Michael. 1997. *The Taiwan Electronics Industry*, Florida: CRC Press LLC.

[17] Chung-yuan, Liu. 1993. Government's role in developing a high-tech industry: The case of Taiwan's semiconductor industry. *Technovation* **13**(5) 299-309.

[18] Ferris, G.R., K.M. Rowland. 1981. Leadership, job perceptions, and influence: A conceptual integration. *Human Relations* **34**(12) 1069-

1077.
[19] Griffin, R.W. 1979. Task design determinants of effective leader behavior. *Academy of Management Review* **4** 215-224.
[20] Haavind, Robert. 1995. Decisions, decisions, decisions…. *Solid State Technology* **38**(8) 12.
[21] Hardie, Christa. 1997. TSMC eyes $14B expansion. *Electronic News*, 04/14/97, **43**(2163) 1-2.
[22] Huang, T.L., C.T. Hong, M.R. Chen, K.R. Yen. 1987. *Industrial Impact Analysis of IC Project*, ITRI, Taiwan (in Chinese).
[23] Hutcheson, G. Dan. 1997. Technology and economics in the semiconductor industry. *Scientific American* **8**(1) 66-74.
[24] ITRI. 1992. *1992 Semiconductor Industry Yearbook*, Taiwan, Ministry of Economic Affairs (in Chinese).
[25] ______. 1998. *1998 Semiconductor Industry Yearbook*, Taiwan, Ministry of Economic Affairs. (in Chinese).
[26] Jon-chao, Hong. 1994. Technology transfer and human resource development. *Industrial and Commercial Training* **26**(11) 17-21.
[27] Jong-tsong, Chiang. 1990. Management of national technology programs in a newly industrialized country–Taiwan. *Technovation* **10**(8) 531-554.
[28] Levi-faur, David. 1998. The development state: Israel, South Korea, and Taiwan compared. *Studies in Comparative International Development* **33**(1) 65-94.
[29] Luger, M.I., Y.J. Lee. 1994. The role of science parks in East Asia economic development. *Proceedings of the 1994 International Symposium on Industrial Park Development Policy and Planning* **VI**-1-19, National Taiwan University, Taiwan.
[30] Maguire, Keith. 1999. Taiwan: From sub-contractor to regional operations center. *European Business Review* **99**(3) 162-169.
[31] Maidique, M.A., P. Patch. 1978. Corporate strategy and technological Policy. *Harvard Business School*, Case #9-679-033, rev. 3/80.
[32] Masahide, Kimura. 2001. The view from Japan: Chipmakers giving up on doing it all themselves. *Solid State Technology* **44**(4) 40.
[33] McLean, Bill. 1998. 1998 capital spending trends: Boom to bust. *Solid State Technology* **41**(10) 54-59.
[34] Meaney, C.S., J.D. Aberbach, D. Dollar, K.L. Sokoloff. 1994. *The Role of the State in Taiwan's Development*, E. Sharpe, New York, 170-192.
[35] Nelson, R.N., S.G. Winter. 1977. In search of a useful theory of innovation. *Research Policy* **6** 36-76.
[36] Oliver, H.M., Yau, Raymond, P. M. Chow. 2002. In search of comple-

mentarity. *Asia Pacific Management Review* **7**(1) 61-84.

[37] Pao-long, Chang, Chien-tzu, Tsai. 2000. Evolution of technology development strategies for Taiwan's semiconductor industry: Formation of research consortia. *Industrial and Innovation* **7**(2) 185-197.

[38] ______, Chang, Chiung-wen, Hsu. 1998. The development strategies for Taiwan's semiconductor industry. *IEEE Transaction on Engineering Management* **45**(4) 349-356.

[39] ______, Chin-tay, Shih, Chiung-wen, Hsu. 1994. The formation process of Taiwan's IC industry–method of technology transfer. *Technvation* **14**(3) 161-171.

[40] Parsons, T. 1964. *The social system*, New York, Free Press.

[41] Patel, P., K. Pavitt. 1991. Large firms in the production of the world's technology, an important case of non-globalization. *Journal of International Business Studies* **22**(1) 1-21.

[42] Pecht, Michael. 2000. Trends in China's semiconductor industry. *Semiconductor International* **23**(10) 134-141.

[43] Pinto, J.K., D.P. Slevin. 1989. Critical factors in R&D projects". *Research Technology Management* **21**(1) 31-36.

[44] Porter, E. Michael. 1985. *Competitive Advantage*, New York, Free Press.

[45] ______, Michael, E. 1990. *The Competitive Advantage of Nations*, Free Press, New York.

[46] ______, Michael, E. 1998. Clusters and the new economics of competition. *Harvard Business Review*, November-December, 1998, 77-90.

[47] Quey-jen, Yeh. 1995. Leadership, personal traits and job characteristics in R&D organizations: A Taiwan case. *Leadership & Organization Development Journal* **16**(6) 16-26.

[48] Rai, A., S. Borah, A. Ramaprasad. 1996. Critical success factors for strategic alliances in the information technology industry, an empirical study. *Decision Sciences* **27**(1) 141-155.

[49] Rochart, J.F. 1979. Chief executives define their own data needs. *Harvard Business Review* **57**(2) 81-92.

[50] Seh-hwa, Wu. 1988. *Industrial Policy and Enterprise Strategy: Industrial Development History of Taiwan*, Research Institute of China Economic Enterprise, Taipei, Taiwan (in Chinese).

[51] Silverthrone, Colin. 2000. Situational leadership in Taiwan: A different culture perspective. *Leadership & Organizational Development Journal* **21**(2) 68-74.

[52] Tso-sheng, Hsu, Yao-geng, Hsu, Tze-chiang, Cheng, I-chia, Chiu. 1999. National innovation system and competitivity–empirical study of

Taiwanese IC industry. *Review of Taiwan Economics* **5**(3) 31-56 (in Chinese).

[53] Van, de, Ven, Andrew, H. Garud, Raghu. 1989. A framework for understanding the emergence of new industries. *Research on Technological Innovation*, *Management and Policy* **4** 195-225.

[54] Wang, H.K. 1991. An analysis of the living periphery of HSIP's employees. *Taipei: Institute of Building and Planning*, National Taiwan University, Taiwan (in Chinese).

[55] Ya-ming, Lee. 1999. *The Story of Semiconductors*, New News Culture Enterprises Company, Taipei, Taiwan (in Chinese).

[56] Zink, A. Ronal. 1993. Information resources management. *Information System Management* **10**(2) 59-61.

Appendix

Table A Potential Explanatory Success Factors of IC Industry Development in Taiwan

1:Bring in foreign IC companies to Taiwan
2:Establishment of Export Processing Zone for IC companies to deduct tax
3:Building up the demonstration plants in research institute (like: ERSO) to start the development of local IC industry
4:Technology transferred from foreign companies to build up the local technology directly
5:Government takes the IC industry development as a important national industry policy
6:Government provides incentives policy for IC companies
7:Design houses invest in foundry fab to get wafer capacity guarantee
8:Hsinchu SIP (Science-based Industrial Park) provides a sound business environment for business founders
9:Hsinchu SIP attracts many of abroad engineers to work with the companies within the park
10:HSIP provides the good education environments to help the children of overseas Chinese who come back to Taiwan to join the companies in HSIP
11:Subcontracting from the foreign big company on an OEM basis
12:Stable monetary environment and saving market
13:Family-like culture of the research institutes that bring over the spin- off companies and entrepreneurs
14:Taiwan's close relationship with overseas Chinese and semiconductor industries
15:Recruit personnel of ministry duty service into the IC industries instead of into the general military units
16:Students returned back to Taiwan from their abroad studies
17:Design house cooperated with foundry fab by way of technology interaction between process and design
18:Fast product development time in design house
19:Business model of pioneering pure foundry
20:Start IC industry by way of simple and high volume products (examples: melody, watch ICs chips)
21:The success of UMC gives a strong confidence for the involvement of more IC companies

Table A.1 Potential Explanatory Success Factors of IC Industry Development in Taiwan (Continued)

22:Limitation of Semiconductor Trade Agreement Between Japan and USA to provide a good business opportunity for Taiwan IC industry
23:All employees are shareholders of the companies
24:Foundry houses are large enough in scale to attract the international talent people to work for them
25:As a spin-off company, UMC licensed most of ERSO's products to sale into world market easily in the beginning stage
26:Business project training in research institute (like: ERSO) letting people who worked with industries later to have more confidence to run IC business
27:Strong entrepreneurship is one of the characteristics of Taiwanese IC industry
28:Industry leader's (like: Morris Chang) global vision brings Taiwanese IC industry into a worldwide competitive market
29:Vertical integration from IC design, foundry, testing and packing to system product houses
30:Many of successful stories that encouraged the late comer to join IC industry aggressively
31:Taiwanese IC companies are capable of low-cost manufacturing
32:ERSO withdrew from IC market strategically
33:TSMC's target is positioned as the biggest capacity foundry houses in the world
34:Taiwan IC industry involved in the memory (like: DRAM, SRAM) to get the mass production capability
35:The growth of IC production capacity continues to a great extent
36:Taiwanese IC companies are capable of fast delivery for products production
37:High profitability of IC companies supported the advanced R&D activities
38:Taiwanese IC companies are capable of high flexibility in production
39:Employee can share the divide stocks
40:Classmates came from the same universities worked together letting the working environment to be more comfortable
41:Clustering effect takes places in the IC industry that the same segmented companies located together to get the timing and cost advantage
42: Capitalism is one of the most important driving force for the IC industry

Table A.2 Factors Attribution

Factors attributable to 1970s
1:Bring in foreign IC companies to Taiwan 2:Establishment of Export Processing Zone for IC companies to deduct tax 3:Building up the demonstration plants in research institute (like: ERSO) to start the development of local IC industry 4:Technology transferred from foreign companies to build up the local technology directly 5:Government takes the IC industry development as a important national industry policy 6:Government provides incentives policy for IC companies 11:Subcontracting from the foreign big company on an OEM basis 12:Stable monetary environment and saving market 14:Taiwan's close relationship with overseas Chinese and semiconductor industries 16:Students returned back to Taiwan from their abroad studies 20:Start IC industry by way of simple and high volume products (examples: melody, watch ICs chips) 31:Taiwanese IC companies are capable of low-cost manufacturing 35:The growth of IC production capacity continues to a great extent 40:Classmates came from the same universities worked together letting the working environment to be more comfortable 42: Capitalism is one of the most important driving force for the IC industry
Factors attributable to 1980s
4:Technology transferred from foreign companies to build up the local technology directly 5:Government takes the IC industry development as a important national industry policy 6:Government provides incentives policy for IC companies 8:Hsinchu SIP (Science-based Industrial Park) provides a sound business environment for business founders 9:Hsinchu SIP attracts many of abroad engineers to work with the companies within the park 10:HSIP provides the good education environments to help the children of overseas Chinese who come back to Taiwan to join the companies in HSIP 11:Subcontracting from the foreign big company on an OEM basis 12:Stable monetary environment and saving market 13:Family-like culture of the research institutes that bring over the spin- off companies and entrepreneurs 14:Taiwan's close relationship with overseas Chinese and semiconductor industries 15:Recruit personnel of ministry duty service into the IC industries instead of into the general military units 16:Students returned back to Taiwan from their abroad studies 20:Start IC industry by way of simple and high volume products (examples: melody, watch ICs chips) 22:Limitation of Semiconductor Trade Agreement Between Japan and USA to provide a good business opportunity for Taiwan IC industry 23:All employees are shareholders of the companies

Table A.3 Factors Attribution (Continued)

25:As a spin-off company, UMC licensed most of ERSO's products to sale into world market easily in the beginning stage 26:Business project training in research institute (like: ERSO) letting people who worked with industries later to have more confidence to run IC business 31:Taiwanese IC companies are capable of low-cost manufacturing 32:ERSO withdrew from IC market strategically 35:The growth of IC production capacity continues to a great extent 36:Taiwanese IC companies are capable of fast delivery for products production 38:Taiwanese IC companies are capable of high flexibility in production 39:Employee can share the divide stocks 40:Classmates came from the same universities worked together letting the working environment to be more comfortable 42: Capitalism is one of the most important driving force for the IC industry
Factors attributable to 1990s
4:Technology transferred from foreign companies to build up the local technology directly 5:Government takes the IC industry development as a important national industry policy 6:Government provides incentives policy for IC companies 7:Design houses invest in foundry fab to get wafer capacity guarantee 8:Hsinchu SIP (Science-based Industrial Park) provides a sound business environment for business founders 9:Hsinchu SIP attracts many of abroad engineers to work with the companies within the park 10:HSIP provides the good education environments to help the children of overseas Chinese who come back to Taiwan to join the companies in HSIP 12:Stable monetary environment and saving market 13:Family-like culture of the research institutes that bring over the spin- off companies and entrepreneurs 14:Taiwan's close relationship with overseas Chinese and semiconductor industries 15:Recruit personnel of ministry duty service into the IC industries instead of into the general military units 17:Design house cooperated with foundry fab by way of technology interaction between process and design 18:Fast product development time in design house 19:Business model of pioneering pure foundry 21:The success of UMC gives a strong confidence for the involvement of more IC companies 23:All employees are shareholders of the companies 24:Foundry houses are large enough in scale to attract the international talent people to work for them 27:Strong entrepreneurship is one of the characteristics of Taiwanese IC industry 28:Industry leader's (like: Morris Chang) global vision brings Taiwanese IC industry into a worldwide competitive market 29:Vertical integration from IC design, foundry, testing and packing to system product houses

Table A.4 Factors Attribution (Continued)

30:Many of successful stories that encouraged the late comer to join IC industry aggressively
31:Taiwanese IC companies are capable of low-cost manufacturing
33 :TSMC's target is positioned as the biggest capacity foundry houses in the world
34:Taiwan IC industry involved in the memory (like: DRAM, SRAM) to get the mass production capability
35:The growth of IC production capacity continues to a great extent
36:Taiwanese IC companies are capable of fast delivery for products production
37:High profitability of IC companies supported the advanced R&D activities
38:Taiwanese IC companies are capable of high flexibility in production
39:Employee can share the divide stocks
40:Classmates came from the same universities worked together letting the working environment to be more comfortable
41:Clustering effect takes places in the IC industry that the same segmented companies located together to get the timing and cost advantage
42: Capitalism is one of the most important driving force for the IC industry

Table A.5 Extraction Factors Composition

Composition	Extracted Factor
12:Stable monetary environment and saving market 20:Start IC industry by way of simple and high volume products (examples: melody, watch ICs chips) 31:Taiwanese IC companies are capable of low-cost manufacturing 40:Classmates came from the same universities worked together letting the working environment to be more comfortable	A1 Manufacturing capability Advantages
5:Government takes the IC industry development as a important national industry policy 6:Government provides incentives policy for IC industry	A2 Government Policy
11:Subcontracting from the foreign big company on an OEM basis 14:Taiwan's close relationship with overseas Chinese and semiconductor industries 16:Students returned back to Taiwan from their abroad studies	A3 Foreign aid
1:Bring in foreign IC companies to Taiwan 2:Establishment of Export Processing Zone for IC companies to deduct tax 3:Building up the demonstration plants in research institute (like: ERSO) to start the development of local IC industry 4:Technology transferred from foreign companies to build up the local technology directly	A4 Technology migration from foreign companies
35:The growth of IC production capacity continues to a great extent 42: Capitalism is one of the most important driving force for the IC industry	A5 Market requirements.
25 :As a spin-off company, UMC licensed most of ERSO's products to sale into world market easily in the beginning stage 36:Taiwanese IC companies are capable of fast delivery for products production 38:Taiwanese IC companies are capable of high flexibility in production 39:Employee can share the divide stocks	B1 Capability of production flexibility.
10:HSIP provides the good education environments to help the children of overseas Chinese who come back to Taiwan to join the companies in HSIP 11:Subcontracting from the foreign big company on an OEM basis 22:Limitation of Semiconductor Trade Agreement Between Japan and USA to provide a good business opportunity for Taiwan IC industry 31:Taiwanese IC companies are capable of low-cost manufacturing	B2 Cooperation with foreign companies

Table A.6 Extraction Factors Composition (Continued)

14:Taiwan's close relationship with overseas Chinese and semiconductor industries 15:Recruit personnel of ministry duty service into the IC industries instead of into the general military units 16:Students returned back to Taiwan from their abroad studies	B3 Attraction of global talent
12:Stable monetary environment and saving market 13:Family-like culture of the research institutes that bring over the spin- off companies and entrepreneurs 40:Classmates came from the same universities worked together letting the working environment to be more comfortable	B4 Unique characteristics of family-like culture
6:Government provides incentives policy for IC companies 8:Hsinchu SIP (Science-based Industrial Park) provides a sound business environment for business founders	B5 Government support
20:Start IC industry by way of simple and high volume products (examples: melody, watch ICs chips) 26:Business project training in research institute (like: ERSO) letting people who worked with industries later to have more confidence to run IC business 35:The growth of IC production capacity continues to a great extent	B6 Start-up confidence
4:Technology transferred from foreign companies to build up the local technology directly 5:Government takes the IC industry development as a important national industry policy 32:ERSO withdrew from IC market strategically 42:Capitalism is one of the most important driving force for the IC industry 35:The growth of IC production capacity continues to a great extent	B7 Strategic planning of industry policy
9:Hsinchu SIP attracts many of abroad engineers to work with the companies within the park 23:All employees are shareholders of the companies 35:The growth of IC production capacity continues to a great extent	B8 Attractiveness of the HSIP (Hsinchu Science-based Industrial Park).
4:Technology transferred from foreign companies to build up the local technology directly 5:Government takes the IC industry development as a important national industry policy 7:Design houses invest in foundry fab to get wafer capacity guarantee 31:Taiwanese IC companies are capable of low-cost manufacturing	C1 Momentum of potential entry.

Table A.7 Extraction Factors Composition (Continued)

12:Stable monetary environment and saving market 13:Family-like culture of the research institutes that bring over the spin- off companies and entrepreneurs 14:Taiwan's close relationship with overseas Chinese and semiconductor industries 15:Recruit personnel of ministry duty service into the IC industries instead of into the general military units 42: Capitalism is one of the most important driving force for the IC industry	C2 Rich pool of talent for industry
12:Stable monetary environment and saving 17:Design house cooperated with foundry fab by way of technology interaction between process and design 18:Fast product development time in design house 19:Business model of pioneering pure foundry 37:High profitability of IC companies supported the advanced R&D activities 40:Classmates came from the same universities worked together letting the working environment to be more comfortable	C3 Clear positioning and business model
23:All employees are shareholders of the companies 39:Employee can share the divide stocks	C4 Profit sharing and stock ownership system
27:Strong entrepreneurship is one of the characteristics of Taiwanese IC industry 36:Taiwanese IC companies are capable of fast delivery for products production 41:Clustering effect takes places in the IC industry that the same segmented companies located together to get the timing and cost advantage	C5 Strategic alliances
8:Hsinchu SIP (Science-based Industrial Park) provides a sound business environment for business founders 21:The success of UMC gives a strong confidence for the involvement of more IC companies 30:Many of successful stories that encouraged the late comer to join IC industry aggressively 35:The growth of IC production capacity continues to a great extent 38:Taiwanese IC companies are capable of high flexibility in production	C6 Encouragement of success stories
6:Government provides incentives policy for IC companies 29:Vertical integration from IC design, foundry, testing and packing to system product houses	C7 Vertical disintegration

Table A.8 Extraction Factors Composition (Continued)

9:Hsinchu SIP attracts many of abroad engineers to work with the companies within the park 10:HSIP provides the good education environments to help the children of overseas Chinese who come back to Taiwan to join the companies in HSIP	C8 Attractiveness of HSIP
33:TSMC's target is positioned as the biggest capacity foundry houses in the world 28:Industry leader's (like: Morris Chang) global vision brings Taiwanese IC industry into a worldwide competitive market	C9 Global vision
24:Foundry houses are large enough in scale to attract the international talent people to work for them	C10 Sufficiently large to attract global talent
34:Taiwan IC industry involved in the memory (like: DRAM, SRAM) to get the mass production capability	C11 Mass production capabilities.