A 4D Analysis Framework of Competitive Advantages and Development Strategies of Urban Science and Technology Parks: The Examples of Taipei Neihu Technology Park and Nankang Software Park

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Abstract

With the development trend of global urbanization, the number of urban science and technology parks (STPs) is gradually increasing. This paper reviews the relevant literature on STPs, innovation systems, competitive advantages, and strategies of STPs in the context of urban development, and we propose a four-dimensional analysis framework of the competitive advantages and development strategies of an urban STP. The first dimension consists of 20 actors and 30 factors divided into five aspects: economic, technological, social, environmental, and political and multifaceted. The second dimension comprises the different scales of space and network where the actors are located, from STPs to the region/urban, nation, and the world. The third dimension is the relationship and interaction between the actors of different scales, and the fourth dimension is time, which follows the life cycle of STPs.

We examined two STPs in Taipei City of Taiwan—the Neihu Technology Park and the Nankang Software Park—using survey and statistical data from 2003 to 2019. We found that the growth rate of enterprise revenue and employees of urban STPs are high and that urban STPs have competitive advantages, such as the presence of numerous universities, skilled labor, talent with foreign experience, and a large global market. At different stages of the STP life cycle, the reasons for attracting enterprises are different, and the competitive advantages change. Public or private STPs have different competitive advantages, and paying attention to global opportunities and threats and formulating appropriate strategies will help develop STP enterprises. Finally, we propose three suggested strategies to promote the development of urban STPs: planning the future scalability of the STP, applying ICTs to construct a smart STP, and creating an STP ecosystem with sustainable development.

Keywords: Science and technology park, Innovation system, Competitive advantage, Information policy, Urban development

1 Introduction

Located in the southern part of the San Francisco Bay area of California, Silicon Valley is the most famous urban science and technology park (STP). San Francisco was also rated the highest-tech city in the world. [1] Silicon Valley's success has attracted the attention of numerous countries, and new STPs are being established. To encourage the research and innovation of industrial technology and develop high-tech industries, Taiwan's government established Hsinchu Science Park and officially opened it in 1980. With the entry of information vendors, the development of Taiwan's computer industry had been promoted. In 1986, Taiwan was ranked the world's largest supplier of computer products. To launch Taiwan's semiconductor industry, the government, universities, and the Industrial Technology Research Institute cooperated to establish Taiwan Semiconductor Manufacturing Co., Ltd. (TSMC) in 1987. [2-3]

The primary industries in Hsinchu Science Park include the integrated circuits industry and computers and peripherals industry, but the information software and service industries were less developed. [4] In 1992, The Ministry of Economic Affairs (ROC) started planning smart industrial parks and launching two phases of the Software Industry Five-Year Development Plan. Nankang Software Park (NKSP) is a smart industrial park that aims to develop Taiwan into an Asia-Pacific software center under the country's national information policies. It was established in the Nangang District of Taipei City as a public-private partnership, and the surrounding

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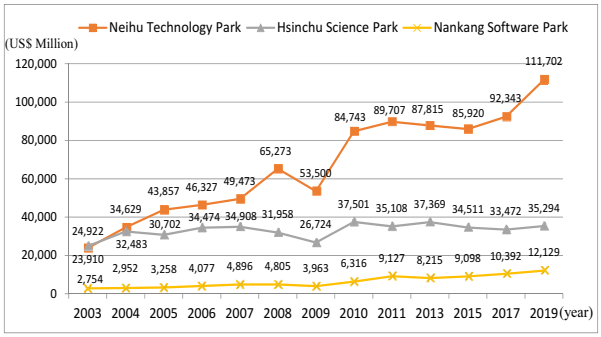
Nangang Economic and Trade Park was planned for overall development. [5] In 1999, the first NKSP building was completed, and knowledge-intensive industries, such as information software, IC design, digital content, and biotechnology industries, took hold. [6]

Local governments also hope to establish STPs to promote local industrial upgrading and economic growth. The Taipei Neihu Technology Park (NHTP), initially the Neihu Light Industrial Zone, was developed as a production area for automobile repair and metal products. As of 1995, construction developers started building factories and office buildings named Science Park, which has attracted many high-tech companies in the biotechnology, information and communications, catering, and venture capital industries. [7] In 2002, the Taipei City Government changed the urban plan of the district and formally established Taipei NHTP, the first municipally planned, privately funded technology park in Taiwan. [8]

According to the Global Competitiveness Report 2019, Taiwan ranked first in the world for macroeconomic stability and fourth for innovation capability. The state of cluster and patent applications per one million population were both ranked third. [9] Taiwan performed well in this report, mainly due to the development of the three STPs mentioned above. The contribution of Hsinchu Science Park to Taiwan's economic development is well known, but few people understand the contributions of Taipei NHTP and NKSP. [10] According to a survey conducted by Business Insider, Taipei City was ranked fifth among the world's highest-tech cities because the NHTP had gathered many high-tech companies. [1] NKSP was also rated as the best performer among the four software parks in Asia by the Economist Intelligence Unit. [11] In the official statistics, there were 513 companies in Hsinchu Science Park in 2019, with an annual enterprise revenue of US$35,294 million, accounting for 5.8% of Taiwan's GDP. However, there were 5,202 companies in NHTP, with an annual establishment revenue of US$111,702 million, accounting for 18.2% of Taiwan's GDP, and NKSP had 471 companies with an annual establishment revenue of US$12,129 million, accounting for 2.0% of Taiwan's GDP. (Figure 1) [12-14]

Comparing the development status of the three STPs, we find that since 2004, NHTP's annual revenue has been higher than that of Hsinchu Science Park, and there is a trend of substantial growth. The NKSP's average revenue per person engaged is more than twice that of Hsinchu Science Park (Table 1). [12-14] Along with the process of urban development, what are the competitive advantages of these two STPs? Why do they show such high growth? What development strategies are in place for the future? These issues are worthy of in-depth study to inspire other STPs.



Note1: The original data unit is NT$, and the authors converts it to US$ on the base of the annual exchange rates.
Note2: Because the financial cirisi occurred in 2008, the revenue of STPs fell sharply in 2009.

Figure 1. Annual revenues of NHTP, NKSP, and Hsinchu Science Park (2003-2019)

2 Literature Review

2.1 Science and Technology Park

According to the International Association of Science Parks and Areas of Innovation (IASP), "a science park is an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions." An STP thus stimulates knowledge and technology flow among universities, R&D institutions, and companies; helps create innovation-based companies; and provides value-added services with high-quality facilities. We use STP to refer to a science park, research park, technology park, science industrial park, smart industrial park, innovation park, innovation and technology center, and area of innovation. [15-16] There were an estimated 534 STPs worldwide by 2017, and the main sectors were ICT, biotechnology, computer science and hardware, electronics, and software engineering. [17-18]

The establishment of STPs originated from the concept of industry clusters. Marshall claimed that similar activity-intensive areas create an agglomeration economy because of the availability of skilled labor, professional suppliers, and knowledge spillovers from competing companies. [19] Weber divided the agglomeration economy into the internal economy and external economy. [20] Hoover further divided agglomeration economies into three types: scale economy, localization economy, and urbanization economy. The urbanization economy, also called the regionalization economy or diversity economy, refers to the economic benefits created by the clustering of different industries with the concentration of human resources, the decline in operating costs, and innovation in cross-industry interaction. [21]

Table 1. Basic information of NHTP, NKSP, and Hsinchu Science Park

Park	Neihu Technology Park	Nankang Software Park	Hsinchu Science Park
Establishment year	It was formerly known as Neihu Light Industrial Zone. The land rezoning was completed in 1995, and the urban plan was changed to Taipei Neihu Technology Park.	The development plan was approved in 1992. In 1992, the building NKSP I was completed to attract investment, and the NKSP II & III were completed in 2003 and 2007, respectively.	It was approved in 1976 and officially opened in 1980. After 1999, Jhunan Park, Longtan Park, Tongluo Park, Yilan Park, and Hsinchu Biomedical Park were added.
Land Area (hectare)	149	10	1300
Industries	electronics, ICT, culture and creative, biotechnology, venture capital, food service, enterprise operational headquarters.	software, IC design, biotechnology, digital content, culture and creative.	integrated circuits, computers & peripherals, communication, magnetic and optical media, precision machinery, biotechnology.
Number of enterprises 2019	5,202	471	513
Total revenue of enterprises 2019 (US$ Million)	143,750	31,050	10,916
Number of establishments 2019	5,299	482	513
Total revenue of establishments 2019 (US$ Million)	111,702	12,129	35,294
Number of persons engaged 2019	166,322	22,606	152,250
Average revenue per establishment 2019 (US$ Million)	21	25	69
Average number of persons engaged per establisment 2019	31	47	297
Average revenue per person 2019 (US$ Thousand)	672	537	232

Note. The original data unit is NT$, and the authors converts it to US$ on the base of the annual exchange rates.

An STP is a collection of highly innovative networks that provides links to science, technology, education, and business while also enhancing the region's development. The functions act as a catalyst for regional economic development by introducing high-tech industries and S&T professionals, strengthening regional innovation integration momentum, elevating the innovation of domestic high-tech industries, and promoting the development of new technology companies. An STP can transfer knowledge from universities to companies to achieve joint research and development between research institutions and enterprises and promote the communication and informal connection of human resources to form an environment of continuous innovation and knowledge development. [22-26]

Meseguer-Martinez et al. found that the definitions of STPs consider the organization's natures and objectives of regional competitiveness and economic development, address the stock of physical resources, and support essential services for tenants. [27] Massey and Quintas listed 10 goals of STPs, including linking higher education institutions (HEIs) and STP companies to transfer S&T achievements, thus encouraging the creation of spin-off firms in academia, promoting the development of new technology-based firms (NTBFs), enhancing the growth of existing high-tech firms, encouraging the development of competitive technologies, promoting the competitiveness of existing manufacturers, creating synergy between companies, increasing local economic development, improving regional image, and creating job opportunities. [28]

The collaboration between governments, private firms, and universities is known as the "triple helix" model, which forms the basic structure of an STP. The universities offer research experience and access to expensive equipment. Private firms and entrepreneurs offer business experience, market knowledge, and opportunities to commercialize research results. Governments formulate innovation strategies and incentivize R&D and knowledge-intensive environments. [16, 29] In follow-up research, the "quadruple helix" model added the fourth helix, "media-based, culture-based public, and civil society," and the "quintuple helix" model added the fifth helix, "natural environment." [30] Therefore, the study of STPs should explore the relationships between governments, companies, universities, the public, and environments.

Bahrami and Evans described six success factors of Silicon Valley: universities and research institutes, venture capital, support infrastructure, talent pool, entrepreneurial spirit, and lead users. [31] According to

the *IASP General Survey 2015*, the most critical success factors are the STP's image and prestige, location, institutional presence and support, and links to universities. [32] In the era of the digital economy, there are new opportunities for STPs. ICTs will facilitate cooperation among partners within and beyond STPs and further promote innovation and industrial development. [16]

2.2 Innovation System

An STP attaches great importance to the transfer and innovation of knowledge and technology, which we can understand from the theory of innovation systems. Freeman stated that an innovation system is a "network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." [33] Lundvall proposed that the national system of innovation is dynamic and characterized by both positive feedback and reproduction. [34-35] The OECD proposed five types of knowledge flows in the national innovation system (NIS): industry alliances, industry/university interactions, industry/research institute interactions, technology diffusion, and personnel mobility. [36] Six aspects identify the structure of NIS: education and training, science and technology capabilities, industrial structure, science and technology strengths and weaknesses, interaction within the innovation system, and absorption from abroad. [37]

Industry clusters are usually developed in specific areas, and their technological innovation and industrial development are greatly affected by regional factors. OECD experts noted that "the process of creating new knowledge is concentrated in the regions," and that knowledge transfer is more effective at the regional level than at the national level. [38] Based on regional society, economy, and culture, Cooke proposed the framework of the regional innovation system (RIS), including the knowledge application and development system and the knowledge generation and diffusion system, with flows of knowledge, human resources, and capital between them. RIS is a regional organizational system generating and supporting innovation formed by geographically related companies, R&D laboratories, HEIs, vocational training organizations, technology transfer agencies, chambers of commerce, business associations, relevant government agencies, and appropriate government departments. [39-40]

Zhu and Tann stated that an STP is a small RIS, and the interactions and linkages between actors enhance the region's localized learning and competitive capabilities. [41] Sudrajat and Syarif proposed five functions of STPs: developing innovative businesses; supporting local economic revitalization; strengthening partnerships in science, technology, and innovation (STI); supporting the increased fulfillment of local basic needs; and supporting the advancement of the local region. Three of the five functions relate to the region, and thus, the STP and regional development generate positive feedback. [42]

With globalization, the convenience of international transportation and the Internet have allowed the flow of capital, personnel, and knowledge to surpass that of countries. Lundvall recognized that R&D cooperation and the process of innovation have increasingly become multinational and transnational. For multinational companies (MNCs), setting up R&D centers around the world involves applying a global innovation system (GIS). [35] The OECD developed a framework to describe the interactions of actors and linkages in the innovation system. The central part of the framework describes knowledge generation, diffusion, and use, with four aspects: the firm's capabilities and network, other research bodies, supporting institutions, and the science system. The clusters of industries, RIS, NIS, and global innovation network are surrounded the central part. The periphery of the framework has five environmental factors: product market conditions, education and training systems, macroeconomic, and regulatory contexts, communication infrastructures, and factor market conditions. [43] Dahlman proposed a GIS cutting across NIS with eight aspects: trade in goods and services, activities of MNCs, activities of other international organizations, global research networks, global information and communication networks, global diaspora networks, global flow of people, and global education networks. [44]

Still et al. used innovation ecosystems to refer to "the inter-organizational, political, economic, environmental, and technological systems of innovation through which a milieu conducive to business growth is catalyzed, sustained and supported." [45] Granstrand and Holgersson stated that "an innovation ecosystem is the evolving set of actors, activities, artifacts, and the institutions and relations, including complementary and substitute relations." [46] Pidorycheva et al. claimed that "the innovation ecosystem can be built at many levels of economic activity-from a single project to an enterprise, at the national, regional and global levels." They proposed a four-dimensional conceptual model of the regional innovation ecosystem with the following four dimensions as the goal of the ecosystem: the actors, the innovation-friendly environment, the system of relationships among actors within the ecosystem, and the system of relationships among actors with the external environment. [47]

2.3 Competitive Advantage

Although an STP has the advantages of industry clusters and innovation systems under the institutionalized arrangement and can build a reputation for high-tech company clusters, it must compete with other domestic STPs or industrial zones

and STPs in neighboring countries. Porter claimed that the geographical clustering of industries has four competitive advantages: reducing costs to enhance the competitiveness of the entire cluster, strengthening the cooperative relationship between enterprises in the cluster and promoting informal interaction of knowledge transfer, enhancing the innovation capabilities of enterprises and reducing the innovation risks of small and medium enterprises (SMEs), and forming location brands to encourage the government to be more willing to invest in infrastructure. [48] The competitive advantages of high-tech companies are mainly technical superiority, reputation for quality, customer service/product support, an installed base of satisfied customers, strong management and engineering staff, and low-cost production with automated manufacturing. [49]

Four attributes, which resemble the four points of Porter's Diamond Model, explain the quality of the national business environment: factor conditions, demand conditions, related and supporting industries, firm structure, and strategy and rivalry. Two other factors, government and chance, were added to support and complement national competitiveness. Porter claimed that, for some industries, the scope of the diamond system is closer to certain regions because there are different environmental conditions in different regions. If customers in the home market have high requirements, the competitiveness of the products can be improved. If the company has forward-looking strategies, good corporate governance, and great domestic competitors, it will have a better competitive advantage. [50]

The government also has three kinds of industrial innovation policy tools: supply-side tools, demand-side tools, and environmental tools. [51] When developing an STP, the government can provide the appropriate environment to promote R&D activities, education, and training, and to expand innovation networks to increase the dynamic competitiveness of enterprises. [52]

2.4 Information Policy & STPs

National information policy is closely related to the development of STPs. NKSP is a smart industrial park established according to the Software Industry Five-Year Development Plan. The primary industries of NHTP and NKSP, such as ICT manufacturing, IC design, information software, and information service, conformed to national information policy priorities. In 2017, the Executive Yuan (ROC) started the Digital Nation and Innovative Economic Development Program to promote innovative digital development, inject smart technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data, and hasten the transformation of Taiwan into a smart nation. [53] In 2019, the National Development Council proposed the Smart Government Action Plan, of which the core idea was "based on data, establish a public-private governance model for the next stage to increase the trust between government and people." [54]

The smart city is the information policy emphasized by the urban government in the digital age. A smart city is typically defined as "an environmentally conscious city that uses information technology to utilize energy and other resources efficiently." [55] There are six basic directions for smart city action: smart economy, smart government, smart environment, smart mobility, smart people, and smart living. [56] Brochler and Seifert claimed that every smart city should integrate STP concepts to improve its features and services. "There are new demands for each STP being in or close to a smart city as they have a continuous demand for feeding the technology base." First, STPs must be transformed into a digital innovation hub ecosystem and integrated into a holistic concept of smart cities. We should connect STPs as the innovation front end and be a part of the innovation ecosystem (smart cities). [57]

2.5 Urban Development & STPs

The United Nations estimated that 55.3% of the world's population lived in urban settlements in 2018. By 2030, urban areas are projected to house 60% of people globally, and one-third of the world's population will live in cities with at least 500,000 inhabitants. [58] From an economic perspective, the role of the agglomeration economy and the scale economy has promoted urbanization. Owing to more infrastructure and better business functions, urbanization forms industry clusters and increase job opportunities. Workers migrate to cities for job opportunities, and the increase in population increases the degree of urbanization and promotes economic growth. In addition to having more extensive and flexible labor markets, urbanization will also create more commercial benefits, allowing the knowledge economy to generate more rewards and be more conducive to technology innovation. [59-60]

The IASP General Survey 2015 showed that 39.8% of STPs are located in large cities (with over 1 million inhabitants), 16.6% in medium-sized cities (500,000 - 1 million inhabitants), and 37.6% in small cities (under 500,000 inhabitants). [32] Almaamory and Slik claimed that STPs were first established by universities, and then established in urban environments under development strategies. [61] Haselmayer found that the third generation of STPs operates interactive innovation models embedded in diverse urban environments with scientific partners, public or institutional participation, and financial or legal instruments. [62] Generally, the urban environment brings more competitive advantages to STP companies.

The STP is often believed to be a critical setting for spearheading urban economic growth, and the development of an urban STP will influence regional

and urban areas. [17] Zouain and Plonski showed that STPs function as laboratories of innovation that generate solutions applicable to urban development and that they are rapidly becoming hubs of innovation ecosystems in cities. [63] To make use of urban public service functions, integrate with existing STPs, and jointly promote regional industrial upgrading and innovation, the Ministry of Science and Technology (ROC) announced a special chapter for the selection of urban STPs in 2020. The evaluation dimensions included three aspects: environmental conditions, development potential, and development execution. [64]

Although an STP enables companies to obtain better economic benefits, it also impacts the region and local society. For example, the development of Silicon Valley has caused problems such as traffic congestion, rising land prices, and environmental pollution, which have decreased the effect of agglomeration economies. [65] In 2015, United Nations member states adopted Agenda 2030 and the Sustainable Development Goals (SDGs), of which goal 9 is to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation; and goal 11 is to make cities and human settlements inclusive, safe, resilient, and sustainable. [66] To create future development strategies for urban STPs, we should consider sustainable industrial development in the global context, build infrastructure to foster innovation, make cities inclusive and resilient, and promote sustainable economic growth.

3 Analysis Framework & Method

3.1 4D Analysis Framework of Urban STPs

This paper establishes a four-dimensional analysis framework for STPs to explore their competitive advantages and development strategies. The first dimension is the actors and factors of STPs, which we list based on the definitions and functions of STPs. We divide 20 actors and 30 factors into five aspects: economic, technological, social, environmental, and political and multifaceted (Table 2).

Table 2. Actors and factors of the analysis framework of urban STPs

Aspects	Internal actors/factors	External actor/factors
Economic	STP companies/tenants (start-up, spin-off, NTBF, SME, large enterprise, MNC)	*International trade agreement*
	Entrepreneurial spirits	*National industry policies*
	firm stategy	*Regional industry policies*
	Suppliers/providers, related and supporting industries, channel distributors	
	customers or downstream companies	
	competitors/rival or new entrants	
	business associations or chambers of commerce	
	financial institutions and investment companies	*Domestic stock market*
	Investment Incentives	*International finance market*
	R&D/rent subsidies	*International venture capital fund*
Technological	universities/HEIs/vocational training organizations	*global education networks*
		global research networks
	R&D institutions/laboratory	*global ICT development*
	Innovation and incubation center	*smart country/smart city*
	smart STP	
Social	talents and workers	social public
	Living & consumption functions	community organizations
	STP social activities	*residential areas*
	Staff training courses	*degree of internationalization*
Environmental	Landlords and construction developers	environmental groups
	land/space/hinterland	*national/regional/urban land plan*
	future scalability	*national/urban environmental protection plan*
	location	
	Infrastructure & public facilities	*transportation environment*
Political & multifaceted	STP management/service center (funding/production/marketing/business service)	govenments (national/central, regional/urban/local)
	Single window of govement	*chance (opportunities/threats)*
	STP goals/image & prestige	*Sustainable Development Goals*

Note 1: Because STP services and chance usually affect different aspects, so they are classified in the aspect of political & multifaceted.

Note 2: The actors in the table are presented in Times New Roman font and the factors in Arial font.

After identifying the actors/factors of the STPs, we can begin to construct the 4D analysis framework. The *IASP General Survey 2015* showed that 42.9% of companies located in STPs were local, 22.6% were regional, 21.0% were national, and 13.5% were international. [32] Since STP companies have globalization or localization characteristics, different development strategies through STP innovation systems for GIS must be discussed. Taking an STP as the center, the second dimension extends to the outer regional/urban, national, and global scale. Then we compare the competitive advantages between STPs/industries/enterprises composed of actors/factors in different scales. Applying the analysis framework, STP companies can choose special conditions on different scales and combine them into the most competitive business model.

To discuss the relationship and interaction between the actors/factors as the third dimension, we refer to the quintuple helix model and innovation ecosystem. We discuss the relationship between an STP company and its providers, customers, and supporting industries on the economic aspect. Then we discuss the interaction of actors on different aspects, such as talents on the social aspect and incubation center on the technological aspect, to establish the mechanism of the innovation ecosystem. Considering the complementary and substitute relations of actors, factors, and activities carefully, and thinking about the positive feedback mechanism, we propose the development strategies of STPs. [46]

Following the life cycle of an STP, time is the fourth dimension in which we explore trends and characteristics and propose development strategies for STPs in the context of urban development. The establishment of STPs is a long-term STI policy, but there is usually a lack of regular assessment of industrial prospects and market demand. As an urban area grows and changes, the STP's internal and external conditions and competitive advantages also change. Therefore, we need to dynamically assess the performance of the STP and revise strategies to promote sustainable development (Figure 2).

3.2 Methods & Materials

This research uses the secondary data analysis method to find out the characteristics and competitive advantages of urban STPs. We find that an urban STP is in line with the national STI and industry policies and urban development plans, taking advantage of the excellent talents, technology, industry chain, market, and global networks of the urban area to achieve the goals of supporting R&D and innovation, developing high-tech industries, promoting economic growth, and advancing sustainable urban development.

Taiwan is a critical base for the global information and semiconductor industries, and its economic stability and innovation capabilities have been recognized

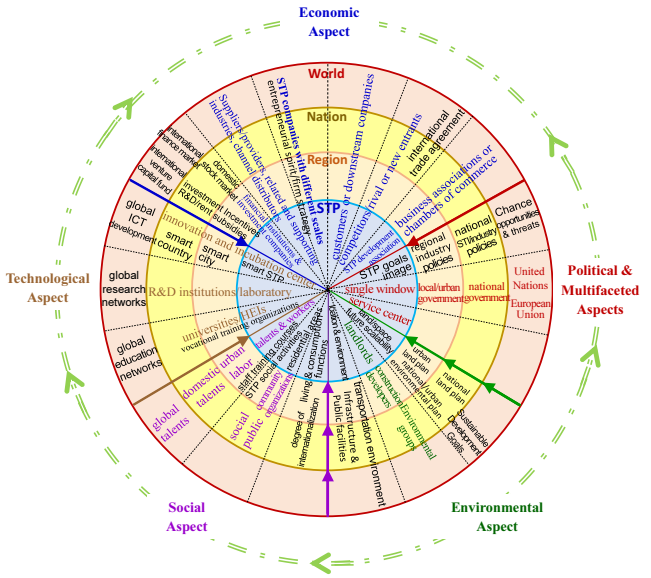


Figure 2. 4D analysis framework of urban STPs

internationally. [9] Taipei City is Taiwan's political and economic center, with the most human, financial, and market resources. Studying STPs in Taipei City allows us to better understand the characteristics of an urban STP. We used the survey and statistical data of two STPs in Taipei City, NHTP and NKSP. NHTP was planned by the urban government and built by the private sector, while NKSP was planned by the central government and built as a public-private partnership. Studying the development status of these two urban STPs simultaneously, we can compare the similarities and differences in their competitive advantages and development strategies using the 4D analysis framework.

From 2004 to 2020, there were 13 surveys of STP enterprises by the Taipei City Government, a survey every year (2004-2012) and every two years (2014-2020). The questionnaire obtained information on enterprise operation status, R&D status, human resources, industry chain, demand for services, and development strategies. The analysis results serve as the Taipei City Government's basis for formulating industrial development policies and STP services. [13, 67-69]

4 Findings and Discussion

4.1 Economic Aspect

4.1.1 Enterprises Operation Status

While the increase in companies represents the popularity of STP, the land and space might restrict it. With a small land area of only 10 hectares, the number of NKSP companies was limited. NHTP was developed by private investment, with a larger land area of 149 hectares. More buildings were gradually completed to allow new companies to settle in, and the

number of enterprises continued to grow. In 2019, there were 5,299 enterprise units in NHTP, accounting for 26% of the number of businesses and companies registered in the Neihu District, showing the development of an industry cluster (Figure 3). [12-13, 70]

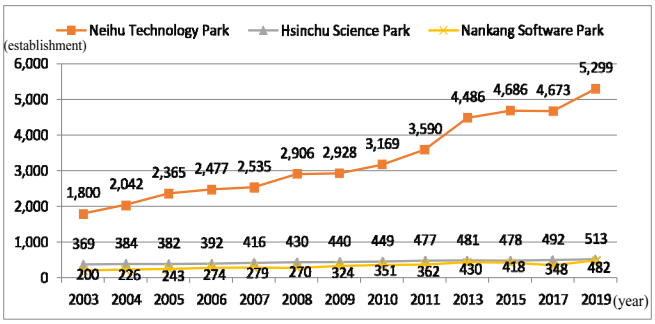


Figure 3. Number of enterprise units in NHTP, NKSP, and Hsinchu Science Park (2003-2019)

According to the 2016 Taiwan Industry and Service Census, the percentage of establishments in the service sector of Taipei City accounted for 91.6%, while that in the industry sector accounted for only 8.4%. [71] However, the percentage of establishments in the industry sector of NHTP accounted for 16.6%, and that of NKSP accounted for 22.8%, both higher than that of Taipei City. By the middle classification of industries, NHTP and NKSP had more manufacturing, information and communication, and professional, scientific, and technical activities companies. There were also more financial and insurance institutions providing capital and financial services, which is helpful for the operation and development of other companies in the STP (Table 3).

Table 3. Number of enterprise units of Taipei City, NHTP, and NKSP by industry group

Industry Group	Taipei City 2016		Neihu Technology Park 2019		Nankang Software Park 2019	
	establishment	%	establishment	%	establishment	%
Grand Toal	202,475	100.0%	5,299	100.0%	482	100.0%
Industry Sector	17,080	8.4%	882	16.6%	110	22.8%
Mining and Quanying	16	0.0%	0	0.0%	0	0.0%
Manufactuning	7,230	3.6%	663	12.5%	95	19.7%
Electrictity and Gas Supply	94	0.0%	21	0.4%	0	0.0%
Water Supply and Remediation Activitites	368	0.2%	10	0.2%	2	0.4%
Construction	9,372	4.6%	188	3.5%	13	2.7%
Service Sector	185,395	91.6%	4,417	83.4%	94	77.2%
Wholesale and Retail Trade	86,650	42.8%	1,771	33.4%	4	19.5%
Transportation and Storage	9,901	4.9%	142	2.7%	15	0.8%
Accommodation and Food Service Activites	19,227	9.5%	102	1.9%	85	3.1%
Information and Communication	7,888	3.9%	721	13.6%	76	17.6%
Finanical and Insurance Activities	11,185	5.5%	658	12.4%	9	15.8%
Real Estate Activities	6,794	3.4%	248	4.7%	77	1.9%
Professional, Scientific and Technical Activities	16,832	8.3%	558	10.5%	8	16.0%
Support Service Activities	4,698	2.3%	108	2.0%	0	1.7%
Eucation	3,459	1.7%	6	0.1%	0	0.0%
Human Health and Social Work Activities	4,220	2.1%	10	0.2%	1	0.0%
Arts, Entertainment and Recreation	3,267	1.6%	39	0.7%	3	0.2%
Other Service Activities	11,274	5.6%	54	1.0%		0.6%

4.1.2 Locations of Suppliers and Customers

From the location of the suppliers and customers of STP companies, we can observe the production and sales networks. In 2010, 41.2% of NHTP companies' main suppliers were in Taipei City and Taipei County, and 30.5% were in foreign countries; 47.1% of NHTP companies' main customers were in Taipei City and Taipei County; and 23.8% were in foreign countries. The NKSP companies showed similar results (Table 4). These results indicate that the suppliers and customers were mainly located in the same urban region based on geographic relationships. The foreign countries were the secondary locations of suppliers and customers because urban internationalization presents a competitive advantage for urban STP companies in terms of linking global industry chains and gaining benefits.

We also found that 5.4% of NHTP companies' main suppliers and 11.5% of NHTP companies' main customers were in the STP. These findings showed that some upstream and downstream firms are located in the same STP, and the companies gain a competitive advantage from industry clusters and supply chain integration.

Table 4. Locations of main suppliers and customers of NHTP and NKSP (2010)

Location of Main Suppliers/Providers and Customers	Neihu Technology Park 2010		Nankang Software Park 2010	
	establishment	%	establishment	%
Suppliers/Providers	2,226	100.0%	239	100.0%
The STP	121	5.4%	7	2.9%
Taipei City & Taipei County	918	41.2%	103	43.1%
Other cities of Taiwan	508	22.8%	57	23.8%
Foreign Countries	679	30.5%	72	30.1%
Customers	2,535	100.0%	288	100.0%
The STP	292	11.5%	44	15.3%
Taipei City & Taipei County	1,195	47.1%	121	42.0%
Other cities of Taiwan	444	17.5%	60	20.8%
Foreign Countries	604	23.8%	63	21.9%

We combine the firms in STP and Taipei City and Taipei County as regional firms, take firms in other cities of Taiwan as domestic firms, group the STP companies by three locations of major suppliers and customers, and observe the industry network spatial characteristics of the STP companies. Of the NHTP companies, 35.3% mainly had regional suppliers and customers (regional companies); 42.8% (35.3%+7.5%) had domestic suppliers and regional customers; 40.2% (35.3%+4.9%) had regional suppliers and domestic customers; and 53.3% (35.3%+7.5%+4.9% +5.6%) had domestic suppliers and domestic customers (domestic companies). Further, 20.9% (13.1%+7.8%) of NHTP companies had mainly foreign suppliers and domestic customers, which were import-oriented companies with the glocalization feature; 16.1% (9.1% +7.0%) had domestic suppliers and foreign customers, which were export-oriented companies with the globalization feature; and 46.7% (13.1%+7.8%+9.1% +7.0%+9.7%) had foreign suppliers or foreign customers (global companies) (Figure 4).

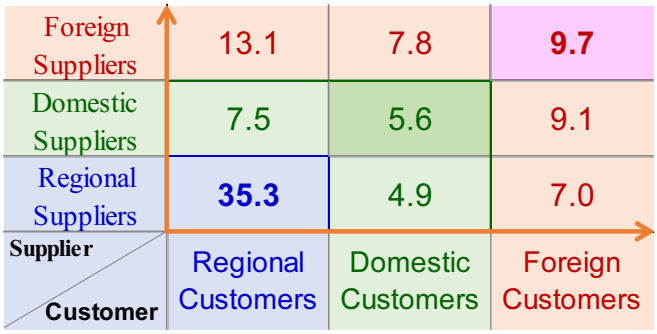


Figure 4. Location groups of NHTP companies by main suppliers and customers (2010)

Using the above grouping method, we calculated the proportions of regional companies, domestic companies, and global companies in an STP. NKSP had 55.2% domestic companies and 44.8% global companies (Figure 5). Compared with the results of the *IASP General Survey 2015*, which showed that 13.5% of companies located in STPs were international, our method showed that the degrees of globalization of NHTP and NKSP companies are much higher than most STP companies in the world. [32]

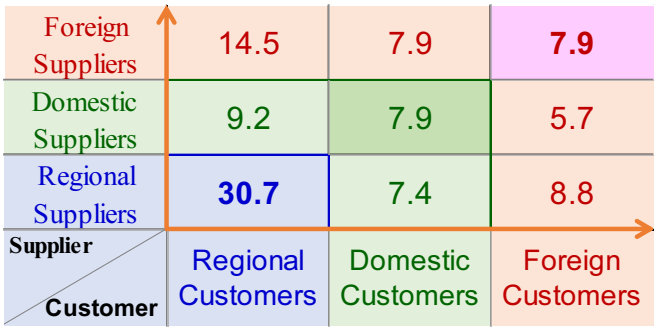


Figure 5. Location groups of NKSP companies by main suppliers and customers (2010)

4.2 Technological Aspect

4.2.1 R&D Status

Promoting the R&D and innovation capabilities of its tenants is the primary function of an STP. In 2008, 21.8% of NHTP companies had R&D personnel, 14.6% had established R&D units, and 4.6% had R&D patents. By contrast, 42.5% of NKSP companies had R&D personnel, 27.6% had established R&D units, and 10.5% had R&D patents. Of NHTP companies, 7.4% purchased technology externally, of which 3.3% were from other countries and 2.6% were from Taipei City & Taipei County. Of NKSP companies, 12.7% purchased technology externally, of which 6.6% were from other countries and 3.9% were from Taipei City and Taipei County (Table 5). In addition to self-R&D, the urban STP companies purchased international-level technology from foreign companies to improve their competitiveness.

4.2.2 Models of R&D Activities

STPs usually encourage companies to conduct R&D activities and provide an environment for interaction between tenants. In 2019, 40.7% of NKSP companies and 20.1% of NHTP companies had innovation R&D expenditures. The high proportion of NKSP companies willing to invest in R&D is related to the characteristics of the ICT, software, and biotechnology

Table 5. Company R&D status of NHTP & NKSP (2008)

R&D Status	Neihu Technology Park 2008		Nankang Software Park 2008	
	establishment	%	establishment	%
Grand Toal	2,383	100.0%	228	100.0%
Self-R&D	575	24.1%	112	49.1%
R&D personnel	519	21.8%	97	42.5%
R&D unit	348	14.6%	63	27.6%
R&D patent	110	4.6%	24	10.5%
External purchase	177	7.4%	29	12.7%
This STP	13	0.5%	0	0.0%
Taipei City & Taipei County	63	2.6%	9	3.9%
Other cities of Taiwan	22	0.9%	5	2.2%
Other countries	79	3.3%	15	6.6%
Joint R&D object	95	4.0%	25	11.0%
Colleges and universities	23	1.0%	5	2.2%
Research institutions	15	0.6%	10	4.4%
Firms inside this STP	7	0.3%	1	0.4%
Firms outside this STP	50	2.1%	9	3.9%

industries that NKSP mainly develops, as well as the arrangement of many research centers and incubation centers in NKSP.

For enterprises, R&D activities may involve important business secrets and adhere to deadlines. Therefore, self-R&D is usually the first choice (26.7% of NKSP companies and 13.3% of NHTP companies), followed by the introduction of technical product authorization and joint R&D with research institutions. Some companies cooperate with suppliers or customers on research, which will improve product quality through the cooperation of suppliers or design products from the perspective of customers to meet market needs (Table 6).

Table 6. R&D Models of NHTP & NKSP (2019)

R&D Models	Neihu Technology Park 2019		Nankang Software Park 2019	
	establishment	%	establishment	%
Grand Toal	3,396	100.0%	300	100.0%
R&D expenditure				
No	2,713	79.9%	178	59.3%
Yes	683	20.1%	122	40.7%
R&D Models				
Self-R&D	453	13.3%	80	26.7%
Technical product authorization	139	4.1%	39	13.0%
Outsourced research	39	1.1%	13	4.3%
Joine R&D with research institutions	83	2.4%	15	5.0%
Joine R&D with colleges and universities	44	1.3%	11	3.7%
Joine R&D suppliers or customers	69	2.0%	8	2.7%
Joine R&D with peers	23	0.7%	3	1.0%
Joine R&D with startups	12	0.4%	2	0.7%

4.2.3 R&D Projects

R&D projects include the materials R&D of the manufacturing industry, the business models of the service industry, and the application of innovative technologies that are useful to various industries. In 2019, the companies in NHTP and NKSP with R&D expenditure paid more attention to the R&D of electronic material, the innovative technology of AI, IoT, big data, cloud computing, and the business model of omnichannel. If the STP can establish a platform for technology cooperation and encourage the companies to conduct joint R&D, it may create a competitive advantage to speed up the research process (Table 7).

4.3 Social Aspect

4.3.1 The Employees and Labor Force

In the 2019 survey, NHTP was the largest STP in Taiwan, with 166,322 persons engaged. The 2003-2019 compound annual growth rate (CAGR) of persons engaged in NHTP was 6.1%, compared to 4.4% in NKSP and 2.8% in Hsinchu Science Park (Figure 6). [12-13]

Table 7. R&D projects of NHTP & NKSP (2019)

R&D Projects	Neihu Technology Park 2019		Nankang Software Park 2019	
	establishment	%	establishment	%
Grand Toal	3,396	100.0%	300	100.0%
R&D expenditure				
No	2,713	79.9%	178	59.3%
Yes	683	20.1%	122	40.7%
Material R&D				
Electronic material	86	2.5%	11	3.7%
Composite material	43	1.3%	6	2.0%
Metallic material	44	1.3%	5	1.7%
Biomaterial	27	0.8%	4	1.3%
Polymer material	30	0.9%	3	1.0%
Ceramic material	3	0.1%	1	0.3%
Innovative Technology				
AI	93	2.7%	12	4.0%
IoT	96	2.8%	10	3.3%
Big Data	71	2.1%	9	3.0%
Cloud computing	88	2.6%	8	2.7%
Smart manufacturing	81	2.4%	6	2.0%
Edge computing	17	0.5%	5	1.7%
5G Applications	59	1.7%	4	1.3%
Blockchain	26	0.8%	2	0.7%
Business Model				
Omni-channel	129	3.8%	8	2.7%
Live stream/Subscription	40	1.2%	6	2.0%
Sharing economy	36	1.1%	5	1.7%
B2B	13	0.4%	4	1.3%
O2O	19	0.6%	3	1.0%
P2P	6	0.2%	2	0.7%

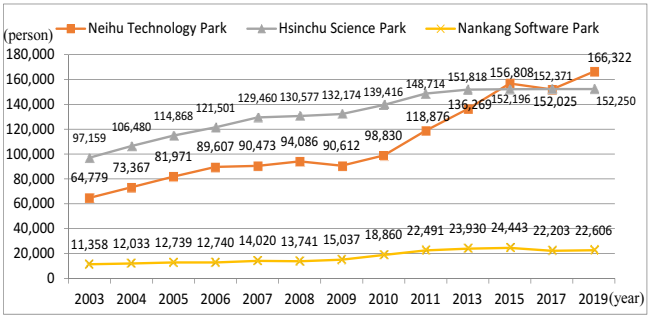


Figure 6. Number of persons engaged in NHTP, NKSP, and Hsinchu Science Park (2003-2019)

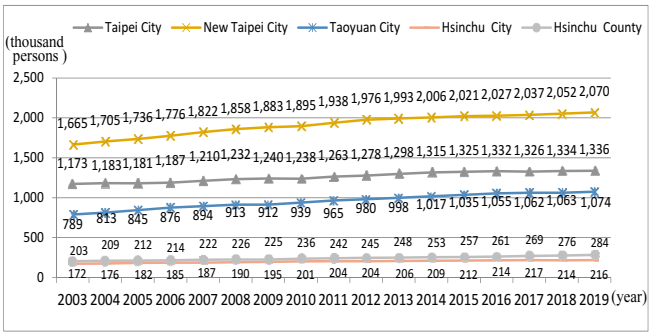


Figure 7. Labor force statistics of five cities in Northern Taiwan (2003-2019)

However, the labor force in Taipei City is limited and cannot support the persons required by STPs. Nevertheless, the labor force in nearby New Taipei City is increasing each year to support the growing needs of STPs in Taipei City (Figure 7). [72] Therefore, in addition to recruiting regional/city labor, it is necessary to recruit domestic talents from other cities and global talents from other countries to satisfy the needs of urban STPs.

4.3.2 Human Resources & Global Talents

High-quality talent is an important factor in competitive advantage to improve the productivity of enterprises. Taipei City has 24 universities and colleges, and about 80% of employees have a college degree or above, which is the highest among all cities in Taiwan (Figure 8). [73]

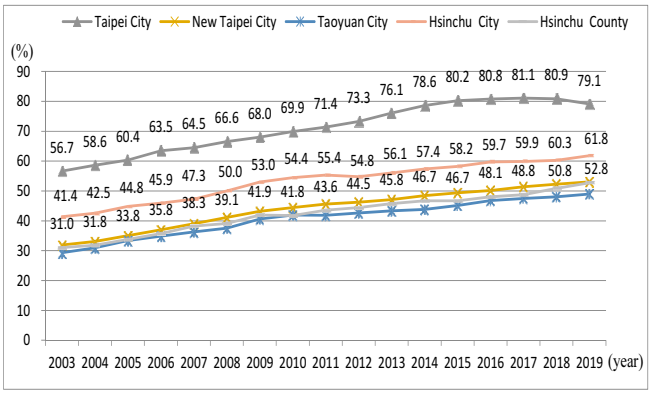


Figure 8. Percentage of employees with a college degree or above in five cities in Northern Taiwan (2003-2019)

According to the 2019 survey results, 72.5% of NHTP companies' supervisors had college/university degrees, 17.6% had graduate school degrees or above, 59.5% of NKSP companies' supervisors had college/university degrees, and 31.3% had graduate school degrees or above. Supervisors with high educational attainment can help develop the high-tech industry in STPs, and those with foreign study experience can connect to global education and research networks. Of NHTP companies, 7.0% of the companies' supervisors had foreign university degrees or above, compared to 7.9% of NKSP companies (Table 8).

Table 8. Employee educational attainment of NHTP & NKSP (2019)

Employee Educational Attainment	Neihu Technology Park 2019		Nankang Software Park 2019	
	establishment	%	establishment	%
Grand Toal	3,519	100.0%	345	100.0%
Junior statt				
Senior high/vocational school and lower	431	12.2%	66	19.1%
Domestic college/university	2,500	71.0%	213	61.7%
Foreign college/university	63	1.8%	11	3.2%
Domestic graduate school	135	3.8%	28	8.1%
Foreign graduate school	12	0.3%	3	0.9%
Unconditional/Others	378	10.7%	24	7.0%
Superivisor				
Senior high/vocational school and lower	102	2.9%	10	2.9%
Domestic college/university	2,414	68.6%	191	55.4%
Foreign college/university	138	3.9%	14	4.1%
Domestic graduate school	510	14.5%	95	27.5%
Foreign graduate school	110	3.1%	13	3.8%
Unconditional/Others	245	7.0%	22	6.4%

In terms of employees' nationalities, 25.8% of NKSP companies employ foreign staff from China, Hong Kong, Macau, Japan, South Korea, and North America, and 11.5% of NHTP companies employ foreign staff from China, Japan and South Korea, Southeast Asia, and Europe (Table 9). NKSP has more companies hiring foreign staff because its primary industries, such as IC design and biotechnology, need to introduce foreign technology. The survey results showed that urban STP companies employ talent mostly from neighboring countries, meeting the characteristics of international talent flow.

Table 9. Global talent employment status of NHTP & NKSP (2019)

Employee Status of Global Tradents	Neihu Technology Park 2019		Nankang Software Park 2019	
	establishment	%	establishment	%
Grand Toal	3,519	100.0%	345	100.0%
Foreign staff				
No	3,114	88.5%	256	74.2%
Yes	405	11.5%	89	25.8%
Region of nationality				
China	116	3.3%	33	9.6%
Hong Kong and Macau	52	1.5%	25	7.2%
Japan and South Korea	112	3.2%	26	7.5%
Southeast Asia	118	3.4%	16	4.6%
Central and South Asia	36	1.0%	11	3.6%
Europe	10	3.1%	9	2.6%
North America	85	2.4%	19	5.5%
Central and South America	15	0.4%	5	1.4%
New Zealand and South America	8	0.2%	1	0.3%
Others	4	0.1%	1	0.3%

4.4 Environmental Aspect

4.4.1 Impacts of Rising Land Prices

Taipei City, the capital of Taiwan, has the highest land price among all cities. At the growth stage of STPs, the land prices of industrial zones in the Neihu District and Nangang District were less than half that of the Xinyi District of Taipei City, attracting many companies. However, with the development of cities and STPs, land prices continued to rise. In 2019, the average land price of industrial zones in the Neihu District almost tripled from 2003, and that in the Nangang District doubled (Figure 9). At the mature

stage of the STPs, the competitive advantage of cheap land prices and rent no longer exists. [74]

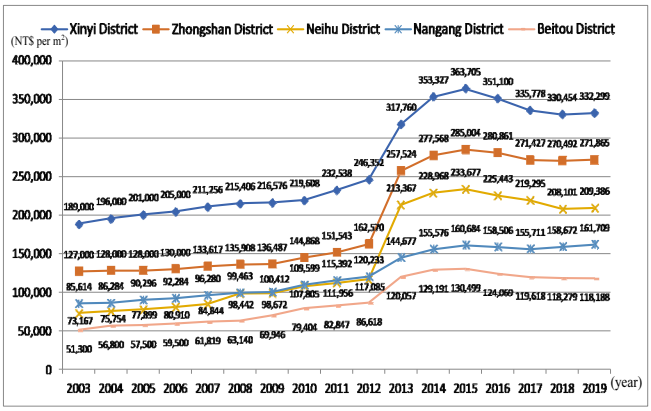


Figure 9. District comparison of industrial land prices in Taipei City (2003-2019)

Although rising land prices reduce the willingness of new companies to settle in the STPs, for those companies that purchased land and buildings in the early stage of urban STPs, high land prices represent an increase in the company's assets. Taking NHSP's index company Lite-On Technology and the first building of NKSP as examples, the CAGR of land price (2003-2019) is 7.4% and 7.1%. The third building of NKSP near the MRT station and the Taipei Nangang Exhibition Center has a higher CAGR of land price as 10% (2007-2019). Early STP companies using real estate profits to invest in R&D and innovation will be more competitive (Figure 10). [75]

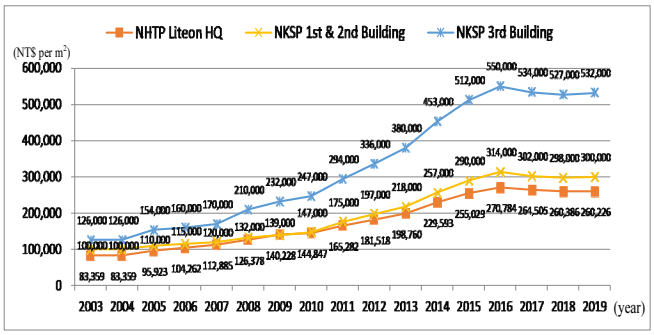


Figure 10. Comparison of land prices of NHTP & NKSP (2003-2019)

4.4.2 Reasons for Enterprises to Enter the STPs

The different stages of STPs attract enterprises for various reasons. According to the survey results, the initial stage attracts enterprises looking for future scalability and to benefit from the effects of industry clusters. As an urban STP gradually develops, environmental factors, such as infrastructure and public facilities, transportation environment, and geographic relationships, become important. When the STP matures, the infrastructure is more complete, thus attracting more enterprises (Table 10, 11). The main reasons for enterprises to move to an STP have gradually shifted from the economic aspect to the environmental and social aspects, such as convenient transportation, living consumption functions, and good human resources.

Table 10. Reasons for enterprises to enter NKSP (2003-2015)

Reasons \ Year	2003	2004	2005	2006	2007	2009	2011	2015	Trend
Future scalability	51.2	45.7	35.3	37.9	36.7	38.2	23.2	24.3	-
Effect on industry cluster	39.6	46.2	29.0	26.8	24.9	31.5	31.2	25.5	
Good infrastructure & transportation	38.6	36.3	40.5	46.0	37.6	43.0	50.7	63.8	+
Low cost of land & buildings	39.6	20.6	10.5	12.1	10.2	10.9	10.1	10.9	-
Reasonable rent			50.5	35.3	30.6	18.2	22.8		-
Good living functions	10.7	8.5	14.7	8.5	8.2	13.3	17.8	37.1	+
Geographic relationships		7.6	13.2	14.3	9.0	21.8	18.5	30.4	+
Good human resources						6.7	5.1	26.8	+
Good e-environment	9.6	9.9	15.8	7.6	7.4	6.7	10.9		
Service of city govemment	13.2	11.7	9.5	7.1	6.5	0.0	6.2		-
Entry permit of enterprise HQ	4.1	7.6	5.3	0.9	1.2	1.2			
Entry regulations loosening	2.5	1.8	2.1	4.0	3.7	4.9	1.1	4.3	

Table 11. Reasons for enterprises to enter NHTP (2003-2015)

Reasons \ Year	2003	2004	2005	2006	2007	2009	2011	2015	Trend
Future scalabity	64.5	45.8	50.1	48.2	58.7	45.8	20.7	226	-
Effect on industry cluster	35.8	42.3	28.9	32.0	36.2	30.4	26.9	24.1	-
Good infrastructure & transportation	39.6	25.1	20.5	34.7	42.8	37.2	51.1	55.7	+
Low cost of land & buildings	37.5	19.6	24.6	21.6	25.5	20.3	7.4	110	-
Reasonable rent			5.2	2.9	7.0		12.8		
Good living functions	17.2	14.0	15.1	16.9	18.9	18.1	25.3	36.3	+

Table 11. Reasons for enterprises to enter NHTP (2003-2015)

Reasons \ Year	2003	2004	2005	2006	2007	2009	2011	2015	Trend
Geographic relationships	1.5	14.9	32.5	24.7	28.0	24.8	25.1	28.9	
Good human resources						5.7	7.8	27.5	+
Good e-environment	6.2	6.2	6.5	5.9	6.8	5.3	6.9		
Service of city govemment	12.2	9.4	6.5	7.5	8.3	7.4	3.7		-
Entry permit of enterprise HQ	9.9	7.8	10.5	7.3	8.3	8.3			
Entry regulations loosening	7.7	5.6	6.4	6.5	7.4	7.2	5.3	5.3	

4.5 Political & Multifaceted Aspect

4.5.1 The Demand for Services of STP Companies

The demand for services of companies at different stages of STPs is quite different. At the initial stage of STPs, companies require environmental services, such as improved public facilities and transportation, increased STP shuttle bus services, more parking spaces, and better living functions. In addition to offering preferential measures, services inside the STP, such as network and wireless broadband services, talent matching, and a single window for business registration, were also required (Figure 11).

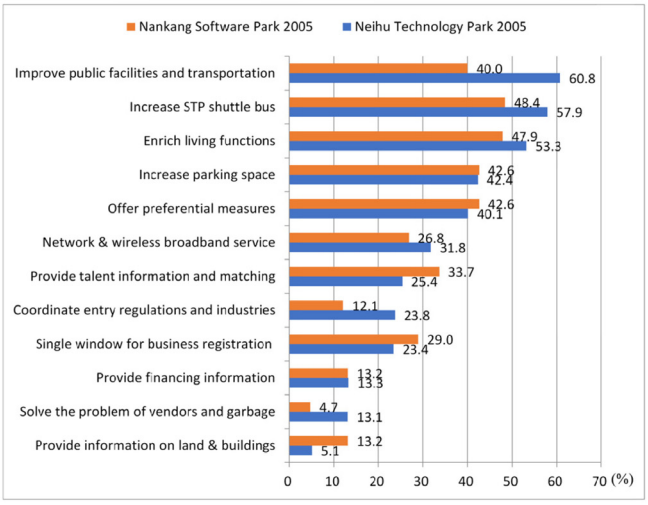


Figure 11. Demand for services of NHTP and NKSP companies (2005)

After strengthening the exchange between STP companies, cooperating with universities and research institutions outside the STP obtains further growth energy. In the 2009 survey, an investment incentive or R&D subsidy was the most required service of NKSP companies, while both NHTP and NKSP companies required international industrial cooperation, industry-university-research exchange activities and cooperation projects, international industrial cooperation, and industry incubation services (Figure 12).

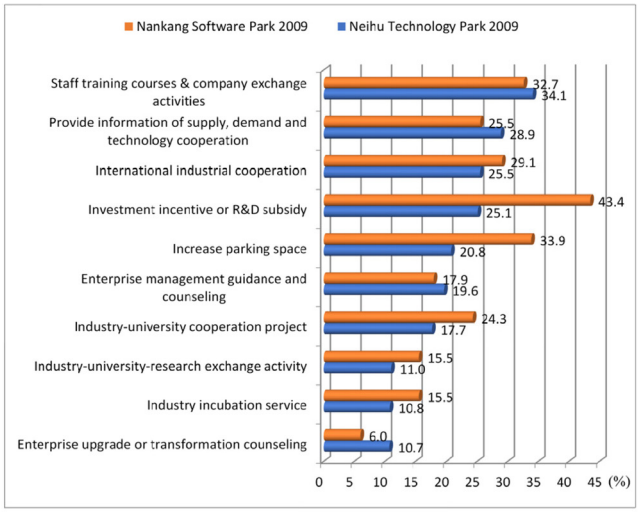


Figure 12. Demand for services of NHTP and NKSP Companies (2009)

4.5.2 The Support of Regional/Urban Government

According to the IASP survey, a lack of financial resources is the biggest constraint on the growth and competitiveness of STPs, followed by a lack of public sector support, government regulations, and bureaucracy. [32] To promote local prosperity, the Taipei City Government gradually relaxed the entry industries, following the opinions of the NHTP Development Association. The entry permit of the operational headquarters of the enterprise promoted the flow of international talents and knowledge exchange, and formed an innovation ecosystem connecting domestic and foreign enterprises.

When an STP enters the mature stage, the increased number of enterprises and employees cause traffic congestion. During rush hour, the roads around the STPs become crowded with vehicles. Thus, in 2015, traffic congestion was the problem STP companies most hoped to solve. To improve the regional environment, the government must adopt a long-term urban plan so that STPs can grow sustainably. In addition to public facilities and investment incentives or R&D subsidies, talent-matching platforms, matchmaking services for startups, and innovation exchanges are also needed (Figure 13).

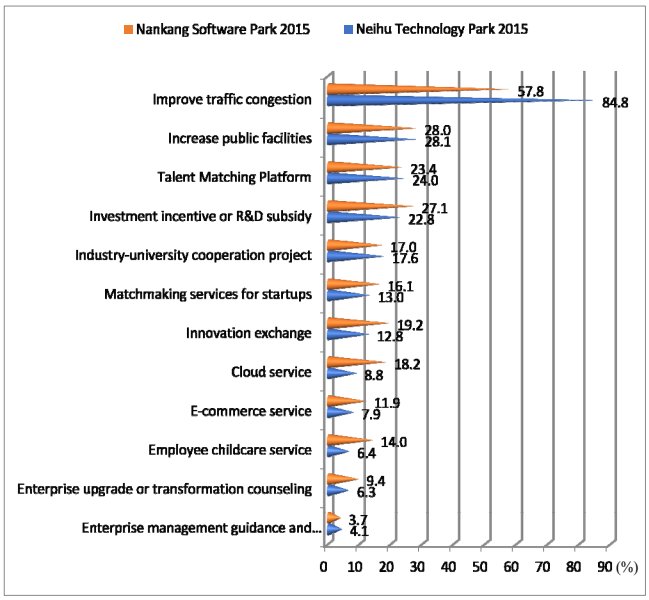


Figure 13. Demand for government services of NHTP and NKSP Companies (2015)

To promote the development of regional industries, the Taipei City Government formulated many specific industry counseling plans for the companies established in Taipei City to apply. [76] In 2017, 50.9% of NHTP companies and 48.7% of NKSP companies needed the industrial services of the Taipei City Government. The Taipei City Industrial Development Incentive Subsidy Program, Taipei Industrial and Commercial Organization Participating in Overseas Exhibition Subsidy Program, Taipei SME Financing Loan, and Taipei Innovation were the plans that best met the needs of the STP companies. The development of STPs would also benefit from subsidies or loans and assistance in the incubation and fundraising of startups by regional governments (Figure 14).

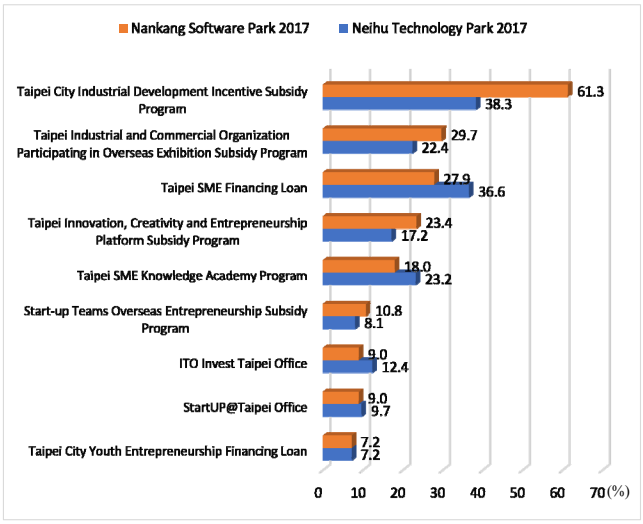


Figure 14. Industrial plans and services of the Taipei City Government that meet the needs of NHTP and NKSP companies (2017)

4.5.3 Shock of Covid-19 Pandemic

The COVID-19 pandemic broke out in early 2020, affecting 54.2% of NHTP companies and 41.7% of NKSP companies because of a decrease in market demand and enterprise revenue, a lack of materials from upstream suppliers, a lack of labor in production, and an increase in personnel costs (Table 12).

Table 12. Impacts of Covid-19 pandemic on NHTP and NKSP (2019)

Impacts of Covid-19 Pandemic	Neihu Technology Park 2019		Nankang Software Park 2019	
	establishment	%	establishment	%
Grand Toal	3,519	100.0%	345	100.0%
Not affected	1,612	45.8%	201	58.3%
affected	1,907	54.2%	144	41.7%
Affected situation				
Decrease in market demand	1,347	38.3%	69	20.0%
Decrease in enterprise revenue	779	22.1%	70	20.3%
Lack of materials from upstream suppliers	310	8.8%	33	9.6%
Increased costs of human resources	287	8.2%	13	3.8%
Factory shutdown	255	7.2%	13	3.8%
Lack of labor in production	125	3.6%	21	6.1%

In response to the pandemic, the government planned some relief measures, such as a business shock subsidy, labor relief, a discount on utility bills, and financing assistance, to assist enterprises; 23.9% of NHTP companies and 19.7% of NKSP companies applied for these relief resources. [77] These measures allowed companies to temporarily overcome the difficulties of reduced demand, hindered global logistics, and reduced labor (Table 13).

Compared with the COVID-19 pandemic's impact in the United States and Europe, which caused numerous fatalities, its impact in Taiwan was relatively mild. In 2020, Taiwan was one of the few countries with positive economic growth of 3.11%. [78] In the *2021 World Competitiveness Yearbook*, Taiwan ranked 8th among 64 economies, up three places from 2020. [79] The COVID-19 pandemic in Taiwan was well controlled, and thus had minimal impact on industrial activities. Facing the threat of the epidemic, the cooperation and self-discipline of Taiwan's government,

Table 13. Application for relief resources by NHTP and NKSP (2019)

Application for the Relief Resources	Neihu Technology Park 2019		Nankang Software Park 2019	
	establishment	%	establishment	%
Grand Toal	3,519	100.0%	345	100.0%
No	2,678	76.1%	277	80.3%
Yes	841	23.9%	68	19.7%
Relief options				
Business shock subsidy	434	12.3%	41	11.9%
Labor relief	250	7.1%	26	7.5%
Discount on utility bills	224	6.4%	28	8.1%
Fiancing assistance	213	6.1%	24	7.0%
Tax assistance	103	2.9%	14	4.0%
Rental assistance	61	1.7%	17	4.9%

society, and enterprises have formed an outstanding competitive advantage, and STP companies have also benefited from this advantage.

4.6 Development Strategies of Urban STPs

4.6.1 Planning the Future Scalability of the STP

Among the reasons for entering the STP, companies attach the most importance to future scalability. Therefore, the development stage of an STP should reserve space in the surrounding area for future development. For example, the NKSP was planned in accordance with the surrounding Nangang Economic and Trade Park. Later, the Nangang National Biotechnology Research Park was established, and a biotechnology industry corridor was connected to the Academia Sinica. The Taipei City Government also proposed the Eastern District Gateway Project to increase software, convention and exhibition, and innovation industries. Considering the surrounding society and environment as a whole, and promoting technology exchange, industry cooperation with other parks under government policies will promote the sustainable development of an urban STP.

When expanding an STP, it can connect with more distant industrial and commercial areas to plan from the perspective of urban development. For example, since its development, NHTP has connected with the logistics, storage, and media industries in the southern section of Dawan and integrated with the commercial area of the northern section of Dawan. The surrounding residential areas have been developed to incorporate emerging industrial and commercial industries in the Neihu District. In the future, it will extend to Beitou Shilin STP, combined with nearby hospitals and universities, to develop smart health, digital technology, and other industries. [80]

4.6.2 Applying ICTs to Construct a Smart STP

To develop high-tech industries, STPs often apply the most advanced ICTs in different aspects. Chang claimed that the use of information technology could change the industrial structure, enterprise management, and production process. [81] Under the promotion of the STP service center, importing e-commerce and customer relationship management offer competitive advantages. [82]

As a critical link for further intelligent and real-time smart city applications, human behavior recognition can help in the management of STP personnel. [83] To improve traffic around the STP, an analysis of road density, traffic events, and rainfall volume can be used to implement a real-time traffic prediction model. [84] However, as the use of ICT services requires the consumption of a large amount of energy, the STP can apply energy-efficient technologies, such as the service-oriented virtual machine placement algorithm, to build a green data center with fewer physical servers and reduce the impact on the environment. [85-86]

Overall, if an STP can apply ICTs to upgrade the infrastructure and services and introduce advanced ICTs into companies' R&D, production, and sales activities, it can effectively enhance the competitiveness of companies and become a smart STP with competitive advantages. The development experience of the smart STP can extend into the region, making STP a critical hub for smart cities and smart countries.

4.6.3 Creating an STP Ecosystem with Sustainable Development

To promote the sustainable development of STPs, we can examine how to cooperate with stakeholders. They include members inside the STP, enterprises, R&D institutions, and incubation centers, and actors outside the park, such as universities, governments, and communities. Enterprises must give back to stakeholders through substantive funds or honors to maintain positive feedback. The STP enterprises must compensate for damage to the interests of the surrounding communities or the environment. [87-88]

An STP ecosystem should be established so that the STP and all stakeholders have a positive relationship to promote sustainable development. When universities or R&D institutions assist in forming start-up companies, the government should give subsidies to the R&D activities, and start-up companies must give back to academic and research units after making

profits. The government will also benefit from taxation, increased employment, and economic growth, and continue to support the development of STPs.

5 Conclusions

The establishment of STPs is a common policy used by most countries to promote R&D and innovation, develop high-tech industries, increase economic growth, and create employment. This paper proposes a four-dimensional analysis framework for the competitive advantages and development strategies of urban STPs, which can also be used for other economic/industrial zones or industry clusters. We can use this analysis framework to take stock of the competitive advantages of an STP, list the differences with other STPs, and propose appropriate development strategies from dynamic time and space contexts.

According to the surveys of NHTP and NKSP enterprises in Taipei City, NHTP's enterprise revenue and number of employees are higher than those of Hsinchu Science Park. The growth rates of NHTP and NKSP are also higher than those of Hsinchu Science Park. The urban STPs have competitive advantages, such as many universities, skilled labor, talents with foreign experience, and a large market connecting to the world. Based on geographic relationships, the suppliers and customers of urban STP companies were mainly located in the same urban region.

A government-led STP should arrange for research centers and incubation centers to move to the STP and offer some R&D subsidies to mirror the R&D activities of a private STP such as NHTP. In addition, urban STP companies mainly purchase technology from foreign companies, which means introducing international-level technology to improve their competitiveness. To promote joint R&D among the STP tenants, the STP service center should hold more social activities and educational training courses to increase communication opportunities and subsequent technical and business cooperation.

In the different stages of the life cycle of STPs, the reasons for attracting enterprises move from that of future scalability to economic factors and to environmental and social aspects. The low cost of land and buildings and future scalability are important reasons for enterprises to enter urban STPs. However, as urban STPs develop, land prices rise, and space and scalability decrease. If early STP companies use the profits of rising real estate to invest in R&D and innovation, they will have more competitive advantages.

Governments are helping to promote the development of urban STPs. The national government provides subsidies and preferential measures for specific industries, while local governments increase the regional infrastructure, relax the regulations, and carry out overall planning for the surrounding area of STPs to increase future scalability.

The COVID-19 pandemic has seriously affected people's social lives and the global economy, but it has also created new opportunities for industry development. In addition to the original competitive advantages of urban STPs, it is necessary to find new strategies to promote further development. Finally, we propose three suggested strategies: planning the future scalability of the STP, applying ICTs to construct a smart STP, and creating an STP ecosystem with sustainable development.

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