LESSONS FROM SCIENCE CITY PROJECTS AND THEIR SUCCESS FACTORS

by

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ABSTRACT

Globalization has drastically improved latecomer countries' access to advanced technologies. To the extent that technology upgrading is important for development, it provides a unique opportunity for latecomer countries to raise per capita income. One such way of upgrading the technological capabilities of a latecomer country/region is through the development of "technopoles" or Science Cities. These technopoles, if successfully developed, can help regions to achieve several objectives: (a) transfer of technology, (b) create local spin-off companies, and (c) gain competitive edge by embracing better technology and (d) increase productivity. Thus, in the last half-century, many governments invested heavily on the planning and development of such technopoles with the aim of making them the "innovation center" of science and technology for the region/country. However, the success rates of these planned technopoles differ. Some technopoles emerged as new "growth engines" but some became a burden to the government and a waste of scarce resources. If governments understood the critical ingredients for successful technopole development, they could better plan for them at the outset before they embark on such major economic and urban projects.

This paper shows a framework of success factors that drove the transformation of Boston's Route 128 area from an industrial ruin into a world-class high-tech industrial cluster (or technopole) driven by knowledge-based asset (Chapter 2). When tested against three planned technopoles, namely Akademgorodok (Russia), Taedok Science Town (South Korea) and Tsukuba Science City (Japan), it showed that as more factors in the framework exist in these planned areas, the more vibrant the technopole e.g. more private companies within the community, more interaction and public-private partnerships, spin-off companies, etc (Chapter 3). Lessons are drawn from the planned technopoles case studies, which could serve as policy considerations for regional land use and economic planners. The framework is then applied to Singapore and recommendations are made on how Singapore can improve their economic policies to better realize its vision of a world-class science and technology hub (Chapter 4). Lastly, the entrepreneurial culture factor is discussed in greater detail in the Singapore context (Chapter 5). It examines the state of entrepreneurial culture in Singapore and whether she is truly lack of entrepreneurs.

Thesis Supervisor: Tunney LEE
Title: Professor Emeritus

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Writing and researching on this thesis topic has been and exciting an rewarding experience for me. I have heard so much about building a knowledge-based economy and the importance of innovation for sustainable economic development. This thesis allowed me to truly understand why cities embrace "high-tech" and how governments try to achieve technological advancement through planned science cities.

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CHAPTER 1: INTRODUCTION

1.1: The worldwide "technopole" phenomena

Economies operate increasingly in markets that demand innovation and flexibility to meet the new challenges. In order to do so, nations are desperately seeking technological improvements to gain competitive advantage in the global economy. Technology contributes to the development of the society, education, and economy of a nation through the discovery, transfer, diffusion, and application of new knowledge. Thus, those areas that have failed to make the necessary investments on high value-adding knowledge-based industries have remained rooted in declining activities or non-competitive businesses whereas areas that did have emerged as successful locales of innovation.

Two internationally successful regional economies that have succeeded in becoming growth poles of the nation through the use of cutting edge technology are Massachusetts's Route 128 and California's Silicon Valley. They have been a source of inspiration for cities around the world as the model for a knowledge-based economy. Many regions have tried to copy these two areas when trying to develop their own technopoles. The idea of developing high-tech industries through technopoles is firmly based upon the assumption that technological innovation leads to economic growth.

1.2: What is a planned "technopole"?

Ideally, technopoles are planned centers that generate the basic materials of the informational economy for the promotion of high-tech industries. Technopoles are often developed by a special type of public-private alliance[1], in association with universities, quasi-public or nonprofit type of developments e.g. research institutes. These organizations are specifically implanted in order to help in the generation of new knowledge, together with the private companies that occupy the resulting spaces.

The area works on a basis of a cluster concept and is often an important innovation center for technological development and new products. The technopole plays an important role in facilitating technology transfer and the commercialization of new technology and products. It also provides a supportive environment for ventures and small businesses.

In order for governments to realize the vision of planned technopoles, it is paramount that the land use and economic planners understand the economic, social and institutional conditions that enable knowledge-based economies to thrive. Often in a planned technopole, the government typically plays multiple roles as a planner, coordinator, initiator, operator and financial provider.

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[1] Defined as a cooperative relationship between two or more independent organization entities agreeing to work together to achieve specific, predefined objectives (Tae Kyung Sung, 1999).

1.3 Literature Research: Concept of Clustering and Economic Development

The competitive advantage of regions can be linked to the theory of industrial clustering as a growth system for economic development. A successful high-tech cluster can "drive" economic development based on specialization, improving technological capabilities, innovativeness, facilitate tacit knowledge flows and learning through interaction (Castells and Hall, 1994, Porter, 1998, Saxenian, 2000, Amsden and Chu, Forthcoming).

a) *Advantages of industrial clustering*

Porter popularized the theory that industrial clustering provides a competitive edge for a region's economic development because:

> "The enduring competitive advantages in a global economy are often heavily local, arising from concentrations of highly specialized skills and knowledge, institutions, rivals, related businesses, and sophisticated customers. Geographic, cultural, and institutional proximity leads to special access, closer relationships, better information, power incentives and other advantages in productivity and innovation that re difficult to tap from a distance. The more the world economy becomes complex, knowledge based, and dynamic, the more this is true".

Thus, companies that are part of a cluster network can operate more productively in sourcing inputs, information, technology, and institutions; coordinating with related companies; and measuring and motivating improvement. In addition, clusters enhance a company's ability to innovate. Peer pressure, pride, and the desire to look good in the community spur executives to outdo one another. Through the interactions within the cluster, insights and skills from various fields merge, sparking new businesses. While such benefits can be reaped in regions with established agglomeration economies, the formation of that initial cluster is often difficult in a latecomer country since they are not at the technological frontier and they have much skill deficits.

b) *Technopoles, the 21st Century Industrial Complexes*

Thus, Castells and Hall emphasized that a latecomer country must accumulate knowledge and improve its own technological capabilities in order to move from industrial economy to a knowledge-based one. With increased knowledge, the technological potential of countries and regions and their ability to produce the most advanced technological products is enhanced. This constitutes having technological inputs that will condition the improvement of products and processes in downstream industries.

Castells and Hall advocated that countries should develop clear development strategies to bring its current development level to the next. To build local competency in technology, nations have to import technology while encouraging inward investment to train its labor force. It is crucial to have sustainable source of innovation, synergy and networks between different players in the technopole and a long-term vision to guide development to ensure that the pre-conditions for "natural" growth of the technopole is present. In selecting an appropriate location for a technopole, it must be sensitive to the established research-industrial networks and synergy must be developed at the new location on the outset.

c) *Need for networking or synergy amongst players in the cluster*

A key feature of cluster development is the formation of networks between different entities of the clusters. Amsden and Chu had defined "network" as a locus of transactions among firms that are mediated *personally* rather than *anonymously*, as they supposedly are in market theory. There are two forms of networks:

i) Formal Networks e.g. subcontracting of parts of components, customization of inputs that require close inter-firm cooperation, "in-processing" or local procurement of peripherals from known suppliers, and

ii) Informal Networks e.g. interactions between businesses to exchange ideas, etc.

The stronger the networks, the more interactions there will be between firms within the cluster, the more synergy will exist. It is advantages for a firm to locate in the technopole because they can have access to latest knowledge and ideas, which help them to develop proprietary knowledge-based asset and thus, higher profit margins for their product.

1.4: Research Interest: Sustainable high-tech cluster development

There is a general consensus in literatures that economic clustering can provide an environment that allows companies to increase their technological capabilities and innovativeness through better knowledge flow. The emergence of planned technopoles is government's reaction to jump-start the high-tech cluster formation process.

Many governments have used a "one size fits all" formula to develop their technopoles, which consists of "a small dose of venture capital, a university, fiscal and institutional incentives to attract high-technology firms, and a degree of support for small business" (Castells and Hall, 1994). Such technopoles often fail, as it could not create any innovation milieu, resulting in a waste of economic resources. Thus, I believe that building a science city is much more complicated and requires a deeper understanding of how high-tech clusters work before undertaking such projects. I am also interested in studying technopole developments because Singapore is also in the process of developing a US$9b Science Hub as part of its efforts to transform its economy into a knowledge-based one.

In view of Singapore's efforts and the difficulties in developing successful technopoles, the primary objective of my research is to establish and understand the critical success factors underlying a successful high-tech cluster development. With this knowledge, I can better make policy improvements to develop Singapore into a science city.

1.5: Methodology

This thesis uses Massachusetts's Route 128 high-tech corridor as an exemplary case study to establish the set of success factors that allowed the economy to remain competitive over the years. The hypothesis is that planned technopoles that have the success factors are also more likely to become successful growth poles for its region and vice versa. To test the hypothesis, the success factors identified will be tested against 3 planned science city developments as follows:

a)	Akademgorodok	(Siberia)
b)	Taedok Science Town	(S. Korea)
c)	Tsukuba Science City	(Tokyo)

The central government was instrumental in deciding the "ingredients when developing these science cities. Studying their development process allows a careful analysis of the government's role, how different factors interact with each other and their outcome. Specifically, each case study is chosen for the following reasons:

a) Akademgorodok Science City of Siberia

The planning for Akademgorodok Science City started in 1957 under the conditions of total state control over research, industry, and spatial location. Although it was developed before Route 128 or Silicon Valley became successful, I believe that the same success factors would have to be present if this Science City is to be successful.

b) Taedok Science Town of South Korea

Taedok Science Town was developed (in the mid-1970s) from a direct presidential decision to foster science and regional decentralization from Seoul. Taedok is located 100 miles (160km) south of Seoul in the middle of the Korean countryside of Taejon city. Some literature had indicated that this research-based city was unable to facilitate regional economic development. However, Taedok seems to play an increasingly important role in South Korea in the 1990s. This case provides insight to the outcomes of the science city when some factors are missing and whether the location of science city matters in determining its success.

c) Tsukuba Science City of Japan

Tsukuba Science City, which was conceived in 1961, was Japan's first attempt to build a science city. Tsukuba is located just outside Tokyo and is to be the national research center of Japan. It had little private enterprise within the Science City. This case shows whether a concentration of national research institutes alone was a sufficient "pull" factor for a technopole to develop

CHAPTER 2: MASSACHUSETTS ROUTE 128

2.1 Introduction

Although Route 128 only shot to fame in the 1960s, the foundation for its success was laid long before WWII. In the 1800s, New England pioneered technologically innovative production methods and equipment for textile, machine tools industries. Despite losing its traditional industries to other lower-wage regions in the early 1900s, it managed to re-industrialize repeatedly in different industries thereafter to maintain its position as one of the most innovative industrial hub in the world.

In particular, the establishment of MIT in 1861 signified the region's long industrial tradition. MIT was to be "an industrial institution designed for the advancement of the industrial arts and sciences and practical education in the Commonwealth" (Pg 46, Rosegrant and Lampe, 1992). MIT had taken pro-active steps to work with the industries[1] and had been more open to accepting research contract from private industrialist. By the 1930s, MIT was an elite academic institution and had the oldest and most distinguished electrical engineering department in America.

2. 2 Key events between 1940s and 1980s

In the 40s – start of intensive military research

The revolutionary occurrence in the industrialization history of Massachusetts in the last few decades could be traced back to World War II. This international event spurred unparalleled economic growth in the Greater Boston region.

Government-funded research and economic activities

Because of MIT's capability as a top engineering school in America and its close relationship with Washington DC[2], it became the nation's leading research center during the war, performing more military research than other US universities. MIT's laboratories received one-third of the $330m in contracts that was awarded by the Office of Scientific Research and Development (OSRD) during the 1940s and 1950s to research in the emerging fields of radar, missile guidance and navigational systems, etc. (Saxenian, 1994). Other universities in the Boston area received substantially lesser research funds. It was during this time that the relationship between science and government was revolutionized; government funds universities to do research instead of internalizing research work within government labs.

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[1] For example, in 1910, Donald Jackson, the chair of electrical engineering department, appointed an advisory committee made up of top executives from major corporations such as GE and Westinghouse. The university also set up a Division of Industrial Cooperation and Research in the 1920s (later renamed to Office of Sponsored Projects) to solicit corporate research contracts and keep companies apprised of MIT research findings (Saxenian, 1996, pg 13).

[2] Vannevar Bush, who served President Roosevelt as the Director of the newly formed Office of Scientific Research and Development (OSRD), was an EE professor at MIT before he went to Washington. Subsequent MIT professors who became science advisers to the President include James Killian (1940, Truman), Jerome Wiesner (1960, Kennedy), Lee Du Bridge (Nixon), Guyford Stever (Ford), Frank Carter (Carter).

Because of government funding, MIT was able to engage in high-risk, high-cost basic research[3] i.e. scientific investigation that seeks to expand our fundamental knowledge and understanding of human beings and the world around us. A consequence – and often a motivation – of this understanding was the ability to alter or control some process or phenomenon. Ultimately, when this ability was applied toward some useful end, a technology was born. Basic scientific research was often, therefore, at the very root of technology innovation (Rosegrant and Lampe, 1992). The findings from basic research were critical for the advancement of military technology and the commercial market. The independence and freedom to explore the frontiers of knowledge without a guaranteed payoff led to many unanticipated benefits, as seen from the number of spin-off companies founded by MIT researchers.

A typical example of this "multiplier effect" arising from a government-funded research was from the research on radar and navigation system. MIT used government research finds to set up Radiation Lab. Together with Harvard's labs which studied submarine warfare and anti-radar systems, these research units created jobs and drew top physicists and electronics engineers from across the country. Many of these skilled labor remained as university researches and faculty, or as employees in local companies, after the war.

The local industry benefited from this research. Raytheon, a small company then, was awarded government contracts to produce tubes and magnetrons for radar services. Within a short period of 5 years, its sales grew from $3m to $173m and its employment grew from 1,400 to 16,000 (Saxenian 1994). By the 1950s, Raytheon could diversify into other areas such as developing missile guidance system. By the end of the war, the Boston area, together with its numerous research labs, renowned universities like MIT, Harvard and other local universities, offered an intellectual and technological labor pool unsurpassed in the world.

Rise of Venture Capitalists

The setting up of company is contingent on the availability of funding. In 1925, when Raytheon went into the manufacturing of vacuum tube for radios, it was funded with investments from J P Morgan and an informal group of wealthy Bostonians. Other technology start-ups during this period such as Polaroid and National Research Corporation also relied on local individuals for financing (Saxenian, 1994).

In the 1940s, formal venture capital markets started to form. In 1946, a group of New England financiers and academics, including MIT President Karl T. Compton, organized the American Research and Development Corporation (ARD) to supply capital to research-based enterprises seeking to exploit the new technologies developed during the war. ARD became the first publicly held venture capital company in the nation. The company actively pursued investment opportunities at MIT and its labs[4]. The early successes of ARD-funded enterprises encouraged the region's banks and insurance companies to invest in high-tech firms (Saxennian 1994, pg 15). Private investment also

[3] Basic research is a scientific investigation that seeks to expand our fundamental knowledge and understanding of human beings and the world around us.

[4] ARD's funded companies included High Voltage Engineering Co., Tracerlab, and DEC.

increased significantly after that, with the First National Bank of Boston[5] serving as an intermediary between aspiring entrepreneurs and wealthy families such as Rockefellers, Whitneys and Mellons.

The First National Bank of Boston also formed its own investment company in 1957 and became the nation's first Small Business Investment Corporation (SBIC). The Small Business Investment Act provided tax benefits for companies that invested in small business. Former employees of ARD and the First National Bank of Boston subsequently set up more venture capital firms. As observed by Dorfman, "it appears that in the postwar era, new firms were in a better position to find venture capital in Boston than in many other parts of the country" (Lampe, 1988).

<u>In the 1950s & 60s – the boom period</u>

Although the war had ended, military research grew at the onset of Cold War, Korean War and the space race. These two decades saw a growth in the number of spin-off firms, and the development of computer technology at MIT.

On-going basic research

In 1951, MIT established Lincoln Lab at the request of the Air Force to develop long-range radar, air defense warning systems and high-speed digital data processors (Saxenian 1994). MIT's Instrumentation Lab (now Charles Stark Draper Lab), which developed aircraft and missile navigational equipment, began devising missile guidance systems for air defense for the space race. The MITRE Corporation, a spin-off of MIT's Lincoln Lab, worked on air defense and missile warning systems. The Air Force Cambridge Research Laboratories, which grew out of the breakup of the Radiation Lab, focused on radar and air defense. By mid 1960s, these labs jointly employed some 5,000 scientists and engineers.

Premises and infrastructure

In general, the state provided excellent building space at relatively low cost e.g. abandoned mills, good surface and air transportation (reducing transportation cost and providing certainty to production of goods) and attractive residential neighborhoods with easy access to work sites. However, it was the completion of the first 27-mile (43.5km) stretch of Route 128 in 1951 that opened up land resources for this growing research and industrial activity.

> "Route 128 was the foundation stone for the development of high technology as we know it today. You couldn't possibly have put the number of high-tech firms that located along (Route) 128 into existing communities." (Pg 109, Rosegrant and Lampe, 1992)

Although Route 128 was never built with an objective to be a new high-tech corridor, it opened up a vast amount of land in the Greater Boston Area for new start-up companies to locate within a short drive of MIT. Within a few years, Route 128 attracted a diverse mix of research labs, branches of established corporations and start-ups. "By 1961, there were 169 establishments employing 24,000 people located directly on the highway, and at least as many again nearby that considered themselves Route 128

[5] First National Bank of Boston was renamed BankBoston. Subsequently, BankBoston merged with Fleet Bank and is now operating under the registered mark of FleetBoston Financial Corporation.

firms. In 1965, MIT researchers counted 574 companies in the region, and the number more than doubled in the following eight years" (Pg 16, Saxenian, 1994).

Entrepreneurial culture – spin-offs

The universities generated the ideas for new businesses; the federal government concentrated personnel and money on specific projects; and investors put their faith and dollars behind hundreds of risky start-ups. The high-tech network and its coherent pattern of innovation began with the entrepreneurs who had the guts, the vision and the perseverance to try an idea out on the marketplace and sometimes, to make it work. The innovative ideas – sparked by the interactions of people and organizations – bring spin-offs into new products and enterprises.

Start-ups came from spin-offs from research labs and established companies. The joint efforts of the federal government and MIT during WWII spawned hundreds of new products and companies. MIT engineering department and research labs spawned at least 175 new enterprises during the 1960s, including 50 from Lincoln Lab and another 30 from the Instrumental Lab. Raytheon had close to 150 start-ups. The electronics division of Sylvania (a national corporation) spawned another 39 (Saxenian, 1994). These start-ups were heavily supported by military and aerospace contracts.

Spin-off from other companies was also a critical growth factor in the Route 128 area from the 1960s up to the 1980s. Often, as soon as a company establishes the viability of the marketplace it was pursuing, its key employees began breaking loose to try to do it better on their own. In most cases, these fledging entrepreneurs stayed in the neighborhood, relying on the same network of customers, suppliers, and friends who had supported them in their previous jobs.

Development of computer technology

One of the most direct connections between MIT-induced wartime programs and the subsequent development of Boston's high-tech industries was the development of a computer science capability at MIT.

Jay W Forrester, a researcher at MIT, started the development of this technology when he tried to find means to solve complex simulation problems for aviation. As he required a fast operating system to do the numerous simulation problems, he started Whirlwind Computer Project. After developing it, he sold it to Pentagon as the core of a system to build "electronic radar fence" (SAGE). Forrester was looking for a commercial manufacturer to build his iron core memory for the SAGE project and chose IBM – by pure chance. From then on, IBM moved to computer manufacturing. On the basis of SAGE contract, IBM hired 8000 engineers and workers, signaling its real head start in computer manufacturing with its Model 650, delivered in Dec 1954 (Pg 34, Castells and Hall, 1994). Ken Olsen, a MIT researcher at the Lincoln Lab who was attached to IBM to manufacture the iron core memory, came out and set up his own computer company, Digital Equipment Corporation, in 1957 which went on to become one of the largest electronic computer companies. Other companies that were set up in the 1950s to capitalize on this new technology include Wang Laboratories, Computer Control Corporation, etc.

As observed by Castells and Hall, "a new industry (computer science) grew out of new knowledge created by Academic. But this knowledge was nurtured by Pentagon financial and institutional support." This new technology was improved in subsequent years to develop the minicomputer (see below).

In the 1970s – the "Massachusetts Miracle" years

By 1970, the Route 128 region had established itself as the nation's leading center of innovation in electronics, which required high levels of skill and constant innovation. However, several events made the 1970s an "unclear" period in terms of economic dynamism of high-tech companies.

Recession and unfavorable business policies

In 1970, US slipped into a recession that jacked up nationwide unemployment into a temporary high of about 6% in 1971. In Massachusetts, unemployment kept climbing until 11.2% in 1975 (Rosegrant and Lampe, 1992). Massachusetts was doubly affected as military spending in the early 1970s also reduced due to the end of Vietnam War and slowdown in the space war. These concurrent events affected both the traditional manufacturing business and high-tech industries that had since grown dependent on the low-risk government military contracts for business. Between 1970 and 1972, Raytheon alone laid off 10,000 workers (40% of its staff) (Saxenian, 1994).

To keep the tax revenue up, the capital gains tax and income tax in Massachusetts were increased substantially in the 1970s[6], making Massachusetts uncompetitive. This taxation policy was a single most unfavorable factor in attracting talented people into Massachusetts. At the same time, the high capital gains tax reduced incentives to take on high-risk high-tech businesses. The recessions of 1970 and 1974 effectively dried up whatever enthusiasm left for Massachusetts's venture capital and new public offering on the stock market. In addition, what little venture capital that was left went to the flashier Silicon Valley area, which was starting to have a higher profile than Route 128.

Economic recovery and increased defense expenditure

By 1975, the nation was climbing out of recession and the government spending on military research increased again under the Reagan administration. With the painful lesson of over-relying on Defense contracts, Route 128 businesses started to shift towards the commercial markets, overshadowing the effects of an increased military spending. While in most literature, the 70s was a lull period for Route 128 companies, small firm formation was actually rife in the late 70s[7]. It was also this time that Massachusetts experienced growth in the more commercially focused high-tech sector (especially in minicomputers) that eventually pulled Route 128 out of its recession. In the period between 1975 and 1988, the unemployment rate dropped from 11.2% to 2.7% - this phenomenal achievement is known as "The Massachusetts Miracle".

The commercialization of minicomputers and firm formation (entrepreneurship)

Minicomputer, like other important postwar technologies, was developed through the combined efforts of military funding and university research. While basic computing research was carried out at MIT in the postwar decades, the task of refining the

[6] In 1969, Capital Gain Tax increased from 25% to 49.2% and a "temporary" 7.5% surcharge on state income taxes was imposed between 1975 and 1986. (Rosegrant and Lampe, 1994).

[7] "Only 351 high-tech companies founded during the "booming" 1960s, but there were 638 surviving companies formed during the "depressed" 1970s.... most were relatively small operations, often privately held, that could rely on their own resources." (Pg 128, Rosegrant and Lampe, 1994)

computer for military application was passed to Lincoln Lab, where they were exploring ways to make computers smaller and more versatile.

By the mid-1970s, the nation emerged from its recession with a new generation of improved minicomputers bursting onto the marketplace. DEC was able to produce low-cost minicomputers in large volumes and was leading the market with more than 40% worldwide sales (Saxenian, 1994). Other leading minicomputer makers in the region include Data General, Prime and Wang. "As a broad range of industries embraced computer technology, the potential for both hardware and software companies seemed limitless" (Rosegrant and Lampe, 1992).

The formation of computer ventures based in Massachusetts accelerated from the 1960s through to the 1970s. Altogether, 48 new computer-related companies were formed within these two decades. As spin-offs from existing high-tech firms increased, successful firms became role models for others hoping to try their hand at entrepreneurship. High-tech employment shot up by more than 47% from 1975 to 1983 and roughly 75% of the state's high-tech manufacturing jobs were in electronics and "office machinery", which included computers. However, the most growth came from the "services" sector, which increased by 46% between 1975 and 1983, and employed more people in the state by 1983 than any other job category (Rosegrant and Lampe, 1992).

Effective Networking

With the growth of minicomputer companies, the local supplier base also expanded. The supplier base expanded to include job shops supplying custom circuit boards, electronic components, precision machinery, metal parts, and subassemblies that were critical for developing prototypes and short product runs. The region also became the home of scores of technical and management consulting firms and other providers of business services. This infrastructure was an important resource that supported both established firms and start-ups (Saxenian, 1994). Firms could get what they want quickly without much traveling. For example, although parts could be ordered out-of-state, having supporting firms near the industry became crucial at design stage and was required out of necessity instead of convenience. The availability of scientists and researchers also augment the supply.

By the late 1970s, members of the high-tech community begun to form trade associations to discuss common interests and to boost their political clout. Bankers, lawyers, public relations firms, and real estate companies were tailoring their services to meet the special demands of this pool of increasingly powerful and prosperous client. In addition, the state initiated a series of programs to recognize and encourage technological growth.

Through the years from 1940s – 1970s, the network of interconnected and interdependent goods and services critical in the high-tech sector became almost self-sustaining. As observed in Rosegrant and Lampe, the university services are not the magnet now. The "Mecca syndrome" is that there are a lot of people, a lot of companies in the Boston area and "the combination of venture capital, great schools and a heritage of successful companies now feeds on itself". Together, they form a particular environment of the Route 128 area, one that drew existing companies from across the countries and even from overseas.

In the 1980s – Personal Computers

The industry-driven miraculous boom experienced in Massachusetts eventually "burst" in the 1980s due to several factors. The changing technologies, aggressive global competition, nationwide economic decline and greed all contributed to the decline in economic activities for the area.

Smaller pool of venture capital funds

By the late 1980s, venture capitalist had started to shift away from small, high-tech start-up and increasingly putting their funds into different kinds of deals (including non-technical companies) or more mature high-tech companies. Thus, it was harder for start-ups to get funds.

"Get rich quick" mentality

During the miracle years, this mentality spread among many would-be entrepreneurs, developers and already well-to-do venture capitalists. They were inspired by the many successful people who had reaped fortunes and jumped onto the bandwagon of investing in high-tech companies. It was thus easy to get money to start a business, despite the weak viability of the business. The high demand also resulted in inflated valuation of the high-tech stocks, which could not be supported. Thus, in the late 80s, when there was no eager public market to snap up start-up shares, many entrepreneurs found the going particularly tough (Rosegrant and Lampe, 1992).

Changing technologies and autarchic business style

As Massachusetts boomed in the late 70s and early 80s, Silicon Valley was also growing as a technological region. However, ·Massachusetts had been looking inwards by concentrating on the development of minicomputers that it "missed out" on the semiconductors and personal computers wave that were so rife in Silicon Valley. There was a fundamental shift in technology: The minicomputer was out and personal computers and workstations were in. In addition, most Massachusetts computer makers had an outdated strategy. Each maker had in-house developed machines and softwares that were not compatible with other manufacturers' products. It made them inflexible and when personal computers emerged, minicomputers were "out of fashion". Between 1989 and 1991, minicomputer makers lost more than 40,000 jobs.

2.3 The secret of Route 128's success -- Success Factors

From 1940 to 1990, the Boston area saw two waves of reindustrialization. The first round took place in the 1950s, and was directly linked to military and space programs that concentrated the research and manufacturing activities in the state. The second round took place between 1975 and 1985 and relied on the computer industry as its new industrial base. The growth of this new industry is linked to the growth of one particular product – minicomputers. During these periods, some of the largest and most innovative companies in the world e.g. DEC, Data General, Wang Laboratories, Prime Computers, Computervision, were founded and remained there.

2.3.1 Strong Science Base, Skilled workforce, Ability to attract key staff, Availability of research funds

The Boston area's extensive research and educational infrastructure was the key to the region's ability to innovate. The extensive network of prestigious private universities, hospitals, federal laboratories and other research institutions drew some of the best and brightest students, faculty, and researchers from all over the world into the Boston area. The region's schools provided students with training in the latest technologies, and the network of research institutions and research-oriented firms gave many of them an opportunity to test their skills. These graduates carried new skills to jobs and transferred technology. The principal output of this infrastructure was people with expertise and ideas. The universities also provided the full range of professionals – including scientists, engineers, medical doctors, lawyers, venture capitalists, and managers - required to sustain a high-tech community.

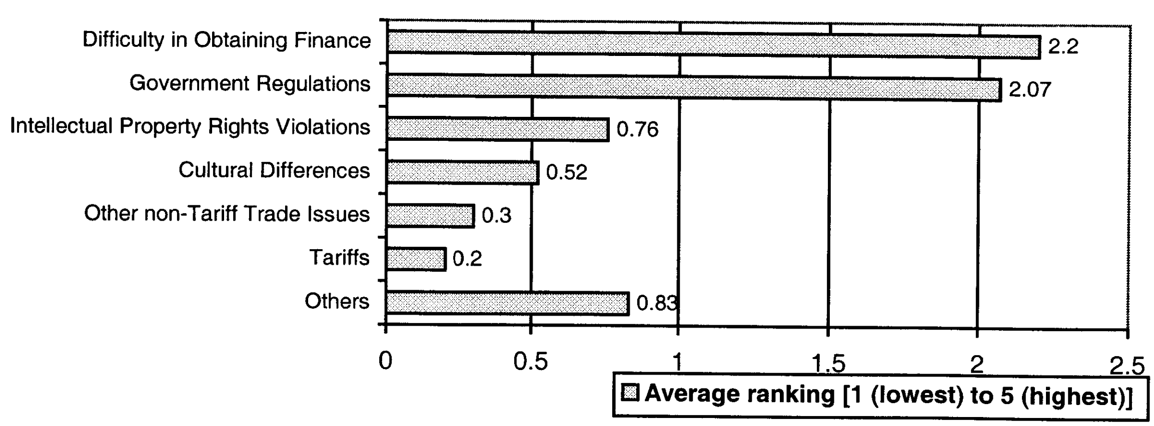
High-tech spin-off was an effect of the congregation of talents in the region, and the diversity of research that were underway. Many spin-off firms were strongly research oriented, taking advantage of the skills found locally, and doing business with the federal government, universities, and the research community. They provided a continuum of research-oriented organizations that helped to ease new technologies into the market.

Above all, there were sufficient federal funds to allow an abundance of continuous basic research to be carried out. To a certain extent, all basic innovation was carried out by military research contract given by the government. Early economic development was then built on these new military research findings. Such research was unlikely to be carried out by the private companies. Thus, the government-backed research fueled the research and knowledge generation process, and facilitated spin-off formation.

2.3.2 Availability of funds for start-ups

Based on BankBoston's (now Fleet Bank) 1993 survey of 883 high-tech companies founded by MIT graduates, it discovered that the greatest obstacles to success in the US domestic market was the difficulty in obtaining funding and government regulations (see Chart 2.1).

Chart 2.1: Obstacles to success in national markets



Source: BankBoston, 1993

For Route 128, the availability of venture capitalists in the 1940s and its growth in the subsequent decades helped spin-offs to form. However, as the venture capitalist market matures and becomes more sophisticated in its investment strategy, it is no longer easy for start-ups to obtain funding and thus retarded its formation.

Venture capitalist follows the "booming" areas. In the 1980s when Massachusetts was experiencing an economic downturn and Silicon Valley was recovering rapidly, the Boston-based venture capitals moved their funds to the Bay Area. During the 1980s, Massachusetts-based companies received $3b in venture capital, while firms in Northern California received $9b (Saxennian, pg 106). Thus, venture capitalist facilitates firm formation, but will never lead such activities.

2.3.3 Supportive Policy Environment

The Route 128 high-tech community was not planned and the government did not actively reduce unfavorable business regulations to stimulate economic development. However, the fact that so many companies were willing and able to set up companies in the Boston region showed that the business environment and the policies affecting businesses in the area must have been sufficiently pro-business. The unfavorable tax policies in the 1970s, which temporarily kept labor and businesses away from Route 128, showed the negative impacts such "un-probusiness" policies could have on the competitiveness of a region.

One other policy that facilitated Route 128's development was MIT's charge to encourage strong interactions with the industry. This allowed industries to tap the Institute's expertise and to carry out research and development, which would otherwise not be done. This made it advantages for firms to locate in the Boston area. Similarly, the government commitment to the various research programs resulted in the numerous discoveries and innovations, spin-offs and job creation.

2.3.4 Availability of premises and infrastructure

The completion of the first section of Route 128 was on cue with the area's first high technology explosion after WWII. "The opening of Route 128 seemed like tossing candy to a pack of hungry kids" (Pg 109, Rosegrant and Lampe, 1992). The expanding high-tech community was in need of cheap premises with good transportation network to set up their businesses in. Especially for start-ups, the availability of cheap premises is critical to its success. Thus, this highway, which suddenly exposed acres and acres of land a mere 15 to 20-minute commute to MIT and Harvard definitely facilitated the growth of the community. As Route 128 became more congested, many companies started to move to locate along Route 495, which is approximately 25 miles from Boston. Other moved even further to Worcester, New Hampshire or back into Cambridge, like Kendall Square area. The entire Greater Boston region thus formed a physical concentration of high-tech companies.

2.3.5 Entrepreneurial Culture

Singapore's Senior Minister Lee Kuan Yew observed the following entrepreneurial culture in the US:

> "The US has been the most dynamic society in innovating, in starting up companies to commercialize new discoveries or inventions, thus creating new wealth. American society is always on the move and changing. They

> have led the world in patents, striving to produce something new or do something better, faster and cheaper, increasing productivity. Having created a product that sold well in America, they would then market it worldwide." (Straits Times Interactive, Feb 6 2002)

The innovative environment is evident in Massachusetts. Particularly in MIT, the seed of entrepreneurship was planted in its students through its curriculum structure and the students' access to cutting-edge technology encouraged them to become risk-takers. The 1993 BankBoston study showed that MIT-related companies had more than 8,500 plants and offices in the US[8]. If these companies formed an independent nation, the revenues produced would make that nation the 24th largest economy in the world. The types of companies MIT graduates created tended to be knowledge-based companies in software, manufacturing (electronics, biotech, instruments, machinery) or choosing (architects, business consultants, engineers) and highly dependent on a workforce of skilled professionals. These companies had a disproportionate importance to their local economies because they usually sold to out-of-state and world markets.

The usual mindset of MIT students was to "take the risk of failure than the risk of becoming a nobody" (BankBoston, 1993). The learning process at MIT was a "hands-on" process. Because of the research-industrial ties, MIT students could work on "real stuff." Students were "right in the middle of something big" i.e. topics being argued about and worked on at that moment in the industrial world. The ties forged at MIT with fellow students were also crucial in forming future networks i.e. customer or cofounders. As described in the BankBoston report,

> "MIT offers great mentors (professors) and more opportunities (professors' consulting/research activities) for students to test the water in establishing their own businesses. MIT exposes students to cutting edge technologies and new ideas. It probably is easier to explore business potential of these new ideas and technologies as entrepreneurs. It seems to be quite natural that MIT becomes a cradle of entrepreneurs." (BankBoston, 1993)

The university researchers were also trained to be entrepreneurs. To compete for federal research funds, they must submit their ideas and propose research plans to appropriate agencies for peer evaluation and approval. This compelled researchers to articulate the importance of their work and forced them to be entrepreneurs. The labs became springboard / breeding ground for entrepreneurship.

Massachusetts was also "importing" company founders as a result of MIT. While only 9% of MIT undergraduates were from Massachusetts, more than 42% of the software, biotech and electronics founded by MIT graduates are located in the state. The 1,065 MIT-related firms headquartered in Massachusetts, which accounts for 10% of the state's economic base, employ 353,000 people worldwide and 125,000 people in the state (BankBoston, 1993).

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[8] The main locations of companies founded by MIT graduates are as follows: California (162,000), Massachusetts (125,000), Texas (84,000), New Jersey (34,000) and Pennsylvania (21,000). (BankBoston, 1993).

2.3.6 Extensive business support services and networks

A key feature within cluster development is the formation of networks between different entities of the clusters. It took effort, focus, and infusion of federal funds during the war years to ignite Boston's high-tech community, but a network had begun to evolve. As the high-tech cluster developed, supporting services such as patent agents, lawyers, recruitment and property advisors etc formed, reinforcing the high-tech community's presence there. The opportunities for researchers, companies and others to meet and exchange views and information, as well as undertake a range of activities to promote the industry facilitated "ideas generation" and ultimately, the rate of growth of the area.

2.4 Lessons from Route 128

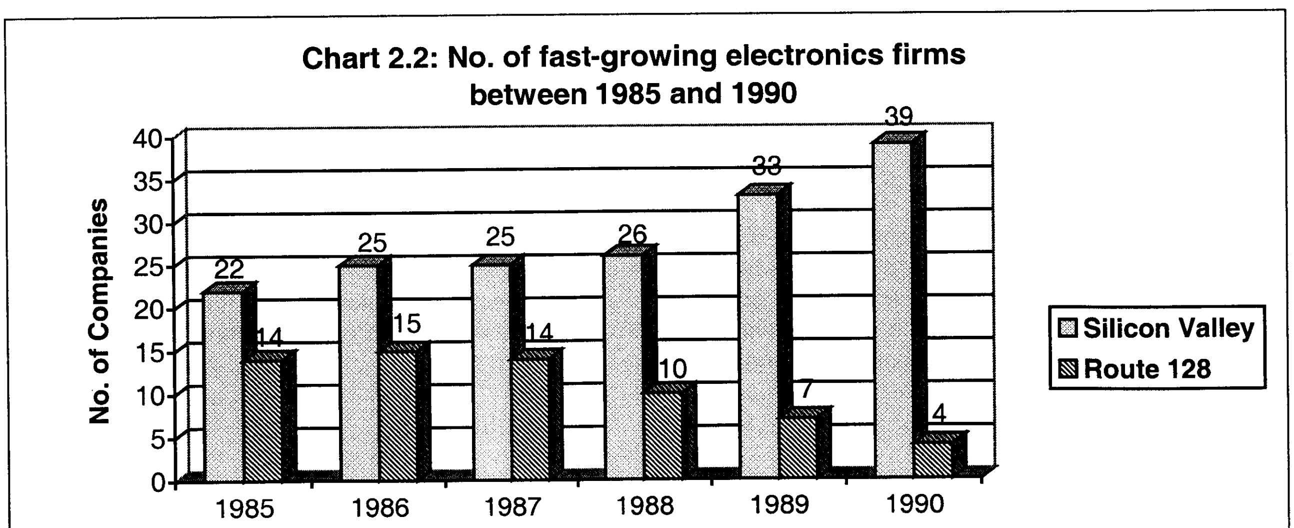
Despite the economic success of Route 128, its development was not without fault. From the temporal economic downturn in the 70s and 80s, several weaknesses could be found.

2.4.1 Over-reliance on federal contracts

The high-tech community of Massachusetts grew primarily with the influx of military contracts, making the companies rely more on federal contracts for business. In fact, many companies were formed primarily to serve the government sector's demand for electronic and military goods. This caused Massachusetts companies to become uncompetitive and vulnerable to changes in government spending. Therefore, once the government spending declined, companies that did no commercial work suffered, as can be seen, from the many company close-downs as a consequence from the dwindling of war activities in the 70s.

2.4.2 Inability to adapt quickly to changing technologies

During the 1980s, Silicon Valley caught up with its Route 128 counterpart. By 1990, 39 of the top 100 fastest-growing electronics companies in the nation were based in Silicon Valley and only 4 were based in Route 128 (See Chart 2.2). Silicon Valley also generated much start-up in the 1980s e.g. Sun Microsystems, etc.



Source: Pg 108, Saxenian, 1994

Route 128 experienced economic downtown then because it failed to shift from minicomputers to personal computers and workstations, missing the entire Silicon Valley's personal computer technology. The cause of the divergence in economic performance in Massachusetts and Silicon Valley was neither due to an absence of a local semiconductor industry[9] in Massachusetts nor regional differences in real estate costs, wages, or tax levels. In fact, Silicon Valley had a relatively high-cost location. It was also not due to changes in defense spending since military spending in Route 128 in the 1980s was increasing.

According to Saxenian, Route 128's failure was primarily due to the region's industrial system. Many of Route 128's technological capabilities were "locked-up" within large firms and thus not available to start-ups or local producers. Silicon Valley's network-based economy was more fluid socially. Its industrial structure was characterized by a network of specialized small firms, resulting in a variety of companies and a high level of formal and informal networking among companies in technical fields. Silicon Valley's venture capital community also promoted this horizontal integration by encouraging companies in their portfolios to work together.

Route 128, on the other hand, was characterized by independent, large scaled firms, which could not adapt quickly to changing environment, although it had economic scale and organization stability (Saxennian, 1994). The hierarchies within the Boston companies were also extremely rigid. The manager created firms with complex and sophisticated organizational patterns that employed individuals who were loyal to the company. Employees expected that hard work would enable them to stay employed in the firm and rise through the ranks, culminating in retirement with a large pension. Employers are generally wary of hiring an engineer or programmer who has left another firm after only a few years. Significant status differences also exist. The hierarchy of positions and the means of formal communication within the firm, along with the structure of salaries and benefits, resulted in strong delineations within the firm[10]. Thus, while Route 128's skill base and supplier infrastructure were more superior to most regions, they were neither as technologically sophisticated nor as diversified as Silicon Valley's by mid 1980s. This ultimately made start-ups and small firms in Route 128 less competitive as they were unable to learn about or acquire state-of-the-art components or services as rapidly as their West Coast counterparts.

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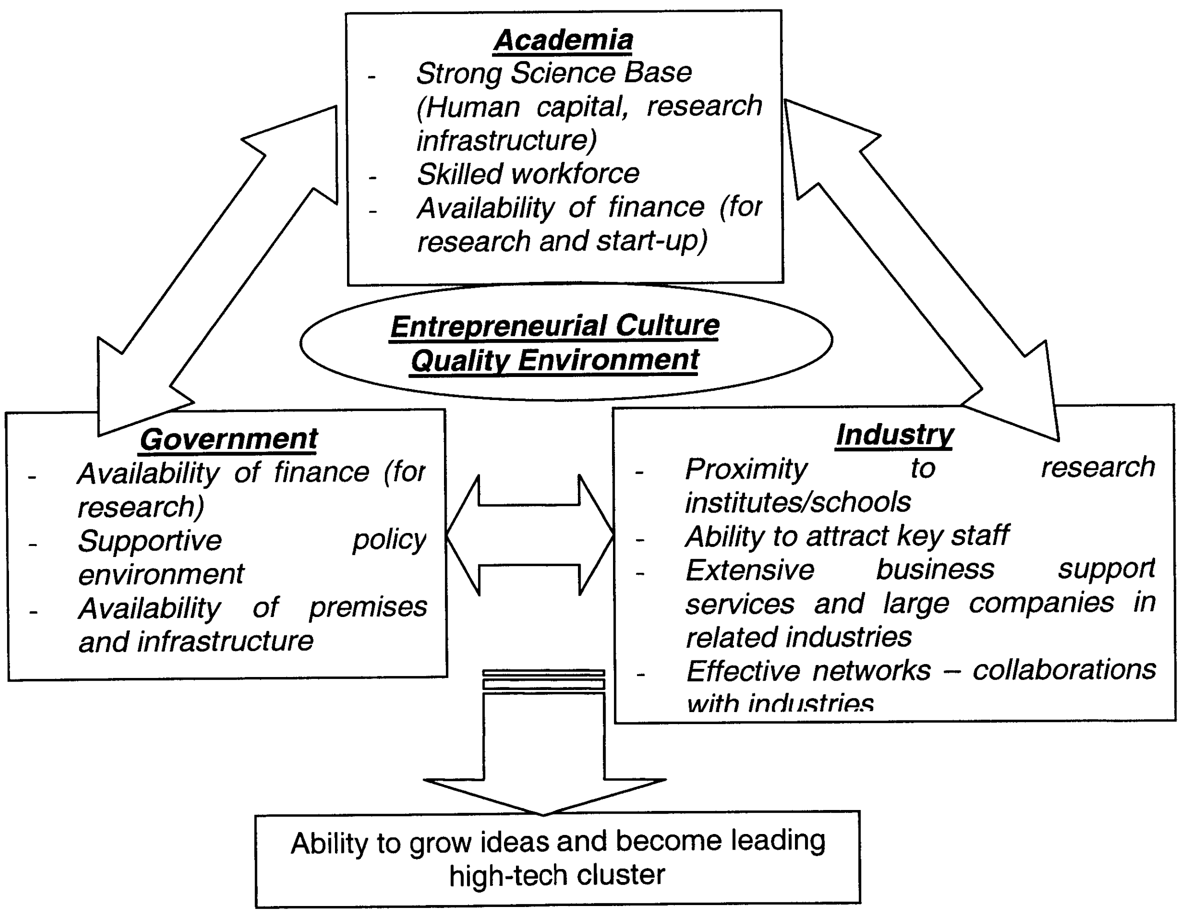
[9] DEC, Raytheon and Data General all had in-house chip facilities.

[10] At DEC, for example, the company centralized many of its prominent functions and a small group of individuals made the decisions, namely Ken Olson (the CEO). The companies attempt to internalize many of their procedures. This vertical integration often includes: software design, component, peripheral, and subsystems production, and final assembly. Similarly, Apollo (minicomputer company at Route 128) was committed to developing a proprietary operating system and hardware for its minicomputers, making its products incompatible with other machines. As compared to Sun Microsystems (a PC firm in Silicon Valley), who pioneered open systems, they used standard, readily available components, and relied on outside suppliers even for design and manufacture of their reduced instruction set computing microprocessor and encouraged them to market the chip to Sun competitors. As a result, Sun workstations, while vulnerable to imitation by competitors, were also significantly cheaper to produce and lower priced than the proprietary Apollo systems (Saxenian, 1994).

2.5 Evaluation Framework

The success factors of Route 128 are captured in Figure 2.1 Each player has particular "contributions" i.e. success factors that made it a developmental force. The professors, students and researchers in the universities and research institutes devote their energies towards research and development and make new discoveries. The government provided the required support for the research. The firms would then produce the physical manifestations of these discoveries for the marketplace. However, no matter how strong each isolated organization was, what was much more important was the strength of the connection between them. In fact, the triangle exists at all only if the connections were there.

Figure 2.1: Relationship between Academia, Industry and Government in Route 128 and its success factors



CHAPTER 3: CASE STUDIES OF PLANNED SCIENCE CITIES

"Who will first make the future happen, and who will lead the world?
The one who innovates in science and technology will."
KAIST

3.1: Introduction

All three technopole case studies, Akademgorodok, Taedok and Tsukuba Science Cities, have an emphasis on achieving scientific excellence by generating synergistic research activities and housed many research organizations and scientists within a high-quality urban space. In all the case studies, the government aims to build a community of researchers and scholars in an area isolated from the rest of the society, or at least from its vibrant urban centers.

In evaluating the case studies, the framework in Figure 2.1 will be used as a "checklist" to assess whether these factors were similarly critical in determining the success of a planned high-tech cluster.

3.2: Case Study 1: Akademgorok Science City (Siberia) – *"academic little village"*

3.2.1 Vision for Akademgorodok and its planning

One of the problems facing the Soviet Union in the 1950s was how to achieve rapid development in Siberia to transform it into a productive force in the eastern part of the country. When Khrushchev visited United States in 1957, he was impressed by the quality of American research universities, and the role of campus life in creating a research environment. Lavrentiev, a prominent Russian physicist and mathematician, advised him to build a new scientific city in Siberia. This science city would concentrate some of the best talent in the Soviet Union to undertake scientific research. They would link research with industrial enterprises to modernize the Soviet industry (Castells and Hall, 1994).

A site in the middle of the birch forest, approximately 15 miles (25 km) from Novosibirsk (the main industrial center of Siberia), was chosen for Akademgorodok Science City (see Appendix 1). It was the first time when a big center of science was created far from Moscow or Leningrad. With a new area and new research institutes with greater autonomy and considerable resources, Khrushchev hoped to provide opportunity for the new generation of scientists whose creativity was hampered by established senior academicians in the main science centers of Moscow and Leningrad (Castells and Hall, 1994).

To provide impetus to decentralize Soviet science to Akademgorodok, the Siberian Branch of Russian Academy of Sciences (SBRAS) was created to be located in this new science city. The goal of the SBRAS is to "intensify development of theoretical and experimental studies in physical, engineering and natural sciences, and economics to solve the major scientific problems and to promote build up of productive forces of Siberia and the Far East" (SBRAS, 1998). Novosibirsk State University, which is now one of Russia's top universities, was also set up as a research university to train and provide the researchers, engineers and technical personnel that the research institutes needed.

When Akademgorodok was completed in 1958, it had an elite university, and about 20 large research institutes of the SBRAC (see Appendix 1). These institutions formed the work place for about 7,500 scientists, 3,500 students, 1,500 university staff members and several thousand workers and technicians employed by the research institutes. By 1990, about 70,000 residents of the 1,500,000 people in the Novobirsk region live in Akademgorodok (Pg 41, Castells and Hall, 1994). The city was self-contained, equipped with residential cottages/apartments, community facilities such as sports hall, stadium, swimming pool, hotel, musical school, etc

3.2.2 Development of Akademgorodok Science City

An important factor during Akademgorodok's initial years was its enthusiastic and talented labor force. Lavrentiev and a group of prominent scientists convinced gifted researchers to move from the country's western regions to Akademgorodok; the elderly scientists moved to Siberia to start a completely new enterprise while the young, bright scientists wanted to work in a more favorable environment, away from Moscow's bureaucracy. For a period of time, Akademgorodok had a science base that was infused with unusual vitality and creativity. The numerous seminars, talks and social functions facilitated social interaction and passionate discussions amongst scientists.

Apart from being a critical research center, Akademgorodok was to be the intermediary between fundamental research and production. Unfortunately, the economic development agency objected, deciding that industries should rely on their own research facilities. The initial plan to locate industrial areas within this Science City was rejected and consequently no industrial zone was planned (Castells and Hall, 1994). This lack of industrial presence was "reinforced" by the lack of infrastructure connection with the surrounding towns e.g. Novosibirsk. There was no train service, and only one road with a public bus connection. The purpose was to preserve the social integrity of Akademgorodok as a scientific community, separated from the industrial working-class city of Novosibirsk (Castells and Hall, 1994).

Akademgorodok played a key role in rejuvenating the Soviet science. The state increased its support for research that are important to national security (especially nuclear physics and space research), international prestige, and economic growth. Scientists increased their control over fundamental research. Khrushchev also encouraged Soviet scientists to participate more regularly in international forums e.g. Geneva conferences on atomic energy. Although government's research emphasis in Akademgorodok was on applied research, it also pursued new and promising fundamental projects (Josephson, 1997).

The situation changed in the 1970s under the Brezhnev regime. Brezhnev wanted to reestablish the supremacy of the central party and was unable to accept the academic freedom and free thought that symbolizes Akademgorodok. Thus, a direct effort was made to end Akademgorodok's special status. SBRAS lost its unique scientist-dominated organizational structure. The research institute became increasingly political as communist party formed party organization in every institute. These organizations controlled all research institutes' activities e.g. the conduct of research, hiring and firing of individuals, researchers' personal lives, and any political and philosophical discussions within the institutes. It was also more concerned with the formal aspects of rule i.e. regular meetings, keeping records, attendance, etc than scientific achievements (Josephson, 1997).

The Brezhnev regime also made it more difficult to obtain the research funding. Firstly, all research projects had to be screened and approved by SBRAS. For economies of scale, the government was more inclined to fund big projects e.g. nuclear fusion or space research but not the more innovative, small-scale projects in sunrise fields e.g. computers and biotechnology (Josephson, 1997). Secondly, in exchange for financial support, policy makers expected scientists to be more accountable by conducting research with short-time horizon for application to industry. This science-production desideratum impacted the way scientists worked. As noted by Josephson, "soviet scientists.... had to be discoverers, creators, innovators, entrepreneurs and salesmen all wrapped into one.... only the rare individual had the time, the interest or the ability to go to the factory laboratory or collective farm in order to promote industrial applications from scientific discoveries ... Akademgorodok has grown out of a Russian tradition of excellence in fundamental research.... Researchers lost their enthusiasm for work. Accountability to the state weakened the fundamental basis that had been the strength of Akademgorodok science" (Josephson, 1997).

Akademgorodok became increasingly provincial and isolated, as there was lack of communication between institutes and industries. Between institutes, there was little exchange as each institute was a self-sufficient entity, reporting only to SBRAS. They became so isolated that each research institute had their own separate facilities e.g. computer services, supply systems, libraries, etc instead of sharing facilities and personnel (Castells and Hall, 1994). Even within each institute, there was little interaction between different departments.

The continued lack of contact with industrialist in the Brezhnev regime resulted in one of the main failures of Akademgorodok. After 30 years, there was almost total lack of linkages with industrial enterprises, whether in Novosibirsk, in Siberia, or the Soviet Union (Castells and Hall, 1994). Each research institute had its own industrial shop to produce the machinery it needed for its experiments (Castells and Hall, 1994). In the first five years of the 1960s, the Siberian division produced more than 350 innovations, but many languished or were transferred to industry only on paper (Josephson, 1997).

On the part of the enterprises, there was also a lack of interest to acquire new technology, as there was no need for it to meet their production quotas assigned under Gosplan. Gosplan's calculation of production quotas was based on off-the-shelf technology available in the international market and thus, the industries could copy or buy Western machinery to modernize Soviet factories. This also undercuts any chance for industrial application of Soviet academic research. Soviet industries e.g. electronic machinery progressively became backward, which had huge impact both on the productivity of industry and on the quality of scientific research (Castells and Hall, 1994).

Akademgorodok was also facing an array of housing and social problems, which the SBRAS was not equipped to handle. These caused the scientists to move back to Moscow and Leningrad (since they would be under equal intense control). Approximately 100 to 150 nuclear physicists moved after staying in Akademgorodok for less than 5 years. It was a 'double-blow' for Akademgorodok as it was both losing its top scientists and was unable to recruit first-class young scientists to Siberia (Castells and Hall, 1994).

After *perestroika*, the opportunities of the market mechanism revived enthusiasm and great dreams in Akademgogorodok. The fact that the scientists knew they possessed valuable knowledge that could result in personal rewards drew out their entrepreneurial spirit. They collaborated with industries to sell their invention and the enterprises tried to be more competitive by adapting their production method to new technologies. Researchers established joint ventures with foreign companies to commercialize their scientific discoveries abroad. Within a few years, the hundreds of spin-off companies in Akademgorodok and Novosibirsk ramped up sufficiently to diversify their businesses and start a process of long-term capital accumulation and reinvestment.

Business networks started to form. As noted in Castells and Hall, "cooperatives, self-accounting units and sheer moonlighting enterprises started to proliferate in Akademgorodok, after linking up with similar entrepreneurial ventures in Novosibirsk and other Siberian cities. Start-up cooperatives and entrepreneurial individuals became active hustlers in seeking foreign partners to finance projects to exploit their research in the Academy's institute" (Ph 52, Castells and Hall, 1994).

The research environment also evolved to meet the needs of this new dynamism. Each research institute became increasingly autonomous by setting up cooperatives to sell their research to earn profits. Scientists need not follow any long-term plan or guidelines of the SBRAS. Researchers used the facilities of the institutes to work on consulting jobs outside. Although SBRAS's disapproved of such activities, they could do nothing to control the researchers as "by the prevailing academic standards, they could achieve above-average scientific productivity merely by doing some research in their spare time" (Pg 54, Castells and Hall, 1994). A new sense of vibrancy and excitement seemed to surround the scientific institutions in Akademgorodok.

3.2.3 Lessons from Akademgorodok

Although Akademgorodok had achieved many scientific advances, it was also plagued by years of decline in the 1970s and 1980s. The success and failures of this science city are evaluated for each of the following periods:

a) Initial phase (early 60s)
b) Years of decline (70s and 80s)
c) After Perestrioka (90s)

a) Initial years

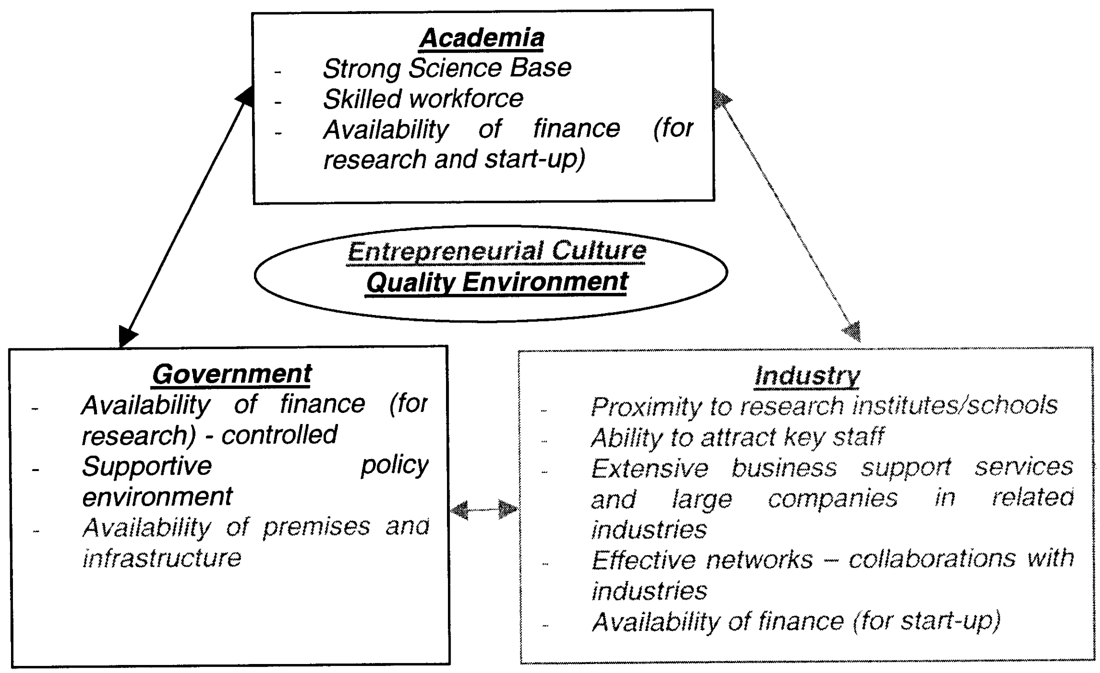
i <u>Strong science base and skilled workforce</u>

The scientific city was an idea by an entrepreneurial government. The young and renowned scientists in Akademgorodok were the foundation for a strong science community. The universities provided the researchers and manpower to build a good research center. The special status granted to Akademgorodok was important to scientific research advancement, as it was facilitated networking and constant contact with national and foreign researchers.

ii Lack of entrepreneurial culture and synergy

The ultimate decision not to actively promote synergy between Academia and Industry proved costly. Although the impact of a lack of industrial presence was not apparent initially, the effect was a technologically backward Soviet economy in later years. The lack of firm formation in the initial years was due to a lack of market mechanism. Despite a strong science base in Akademgorodok, the impact of scientific discoveries on industry and economy was little.

Figure 3.1: Factors affecting development of Akademgorodok in the Initial Years



b) *Years of decline*

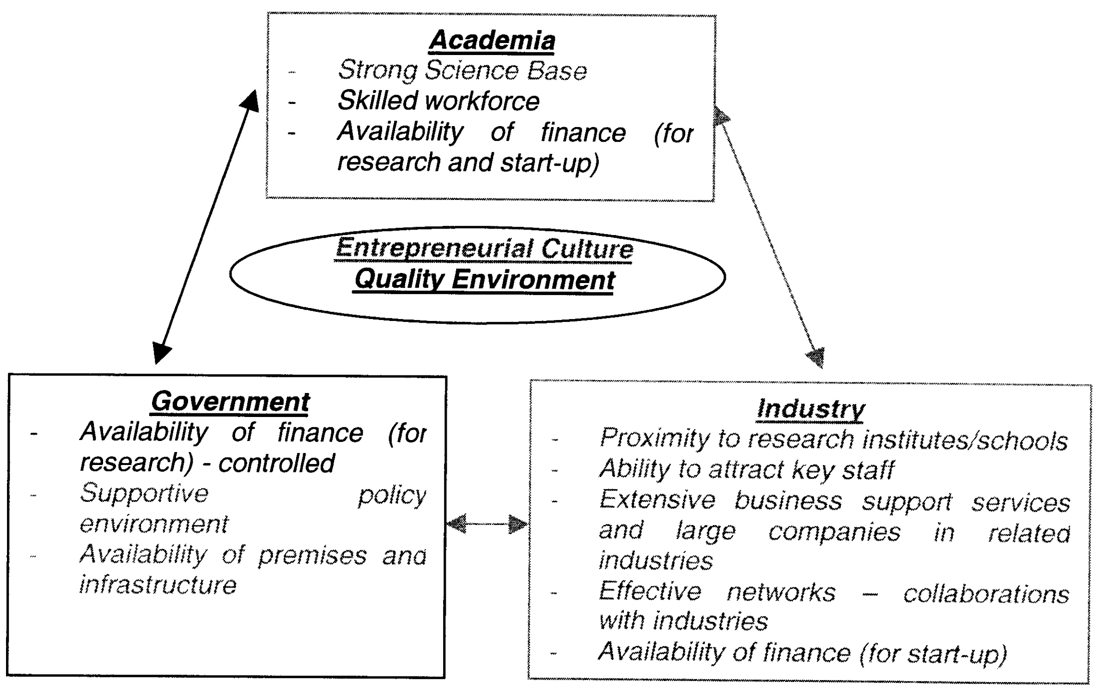
i Unsupportive policy environment

In the 70s and 80s, the government's tight control policy "crippled" Akademgorodok's vitality. The rigidity of the Russian economic and institutional systems made the research institutes increasingly inward looking. The government's inability to solve the housing shortage and social problems adds to Akademgorodok's unattractiveness. The narrow and myopic government policies e.g. short-term research horizon, the government's attempt to politicize and control research institutes directly affected the social fabric of the city (e.g. by restricting foreign researchers, etc) and research activities. Ultimately, these unfavorable policies created an environment that could not encourage synergy or exchange of ideas between participants, which are critical to creating successful high-tech communities (Josephson, 1997).

ii No synergy between Research Institutes and Industries

Paradoxically, despite government's beckoning for scientists to bring their innovations to enterprises for application, there were almost no linkages established between research institutes and industries. "The more the state required that Akademgorodok devote itself to national development programs, the more it resembled that of institutes elsewhere in Soviet Union and the less likely it would have significant impact on the production process" (Pg 304, Josephson, 1997). Furthermore, the lack of basic research compromised the long-term industrial development of the country. The outcome was the isolation of research institutes (from industries and other research institutes) and a striking paradox in Soviet science and technology: a strong scientific base coexisting with increasing technologically backward industrial base.

Figure 3.2: Factors affecting development of Akademgorodok in Years of decline



c) *After perestroika*

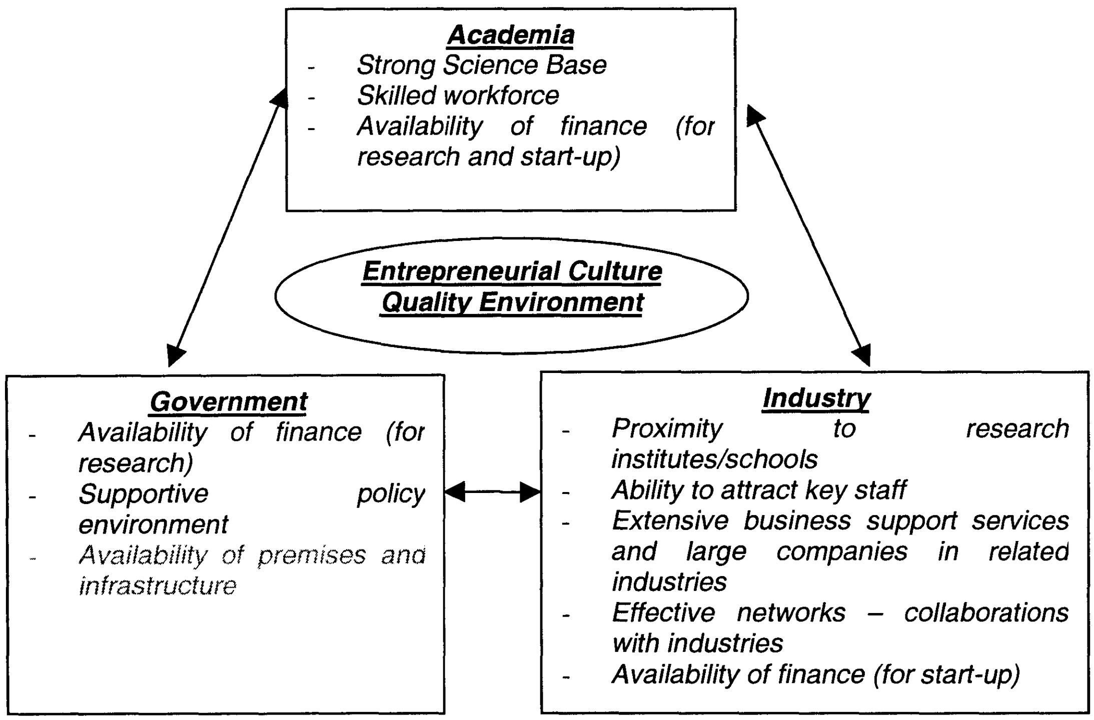
i Introduction of industry and rise of entrepreneurial sprit

The potential for growth and innovation had long been stifled by bureaucracy and reinforced by apathy. The relaxed control of the SBRAS and influences of market forces introduced new vibrancy into Akademgorodok. The prospect of reaping profits from their knowledge was sufficient to turn scientists into entrepreneurs "overnight". Their efforts to looked for enterprises and other research instiutes to "buy" their innovation and creating spin-offs re-introduced industrial participation in science. With the establishment of some commercial activities in Akademgorodok, supporting services developed to partake in this new economy. Thus, networks formed to enable scientists, enterprises and government to realize their own interests.

ii Synergy between academia, government and industry

Through such interactions between academia and industry, technology transfer from research institute to industry and feedback from industry on innovation could occur. Increased business opportunities motivated the link between science and business, thus creating more spin-offs. More horizontal entrepreneurial networks formed and became increasingly important. Although such vibrancy was not due to government efforts, the relatively more relaxed controls were sufficient to create synergy between technology and economy.

Figure 3.3: Factors affecting development of Akademgorodok after *Perestroika*



After perestroika, the success factors of Route 128 "surfaced" and Akademgorodok seemed closer to achieving its objectives to be a successful research science city and an engine of economic growth for Russia.

3.3 Case Study 2: Taedok Science Town (South Korea)

3.3.1 Vision for Taedok Science Town (TST) and its planning

South Korea is a country that has successfully industrialized from a rural agricultural country in the early 1900s to an economy that is increasingly based on high-tech, knowledge-based industries. The roots of its success can be traced to the efforts of a "developmental state (that is) able and willing to increase the competitiveness of Korean companies in the world economy by providing the necessary support in the form of industrial and communications infrastructure, labor training, credit, trade policies and science and technology" (Pg 57, Castells and Hall, 1994).

In the sixties, the South Korean economy was built around light industry, relying on foreign capital and technology for economic growth. In 1970, rapid technology advancement and global competition for newest technology was fierce. Technological advancements made by foreign countries were becoming more difficult to access, and Korea could no longer profit from its light industry. After assessing the situation, the Korean government concluded that Korea should generate its own technology, and a new research center would be the prime generator. The objective for the research center was to develop Korea into one of the best countries in science and technology. This is achieved through increased scientific research, technology development, and cultivation of highly professional experts in science and technology. This meant concentrating Korea's dispersed scientific and technological resources for greater efficiency.

In 1970s, a 2,760 ha of land in the middle of Korean countryside near the existing industrial city of Taejon was selected for the science city development (see Appendix 2). This site is approximately 160 km (100 miles) south of Seoul[1] and 30km away from the nearest city i.e. Taejon. Taedok was to be a highly selective residential area, reserved only for scientists and managers, who would enjoy excellent schools for their children and better services than they had in Seoul. The level of physical infrastructure of Taedok in 1988 is described in Castells and Hall as follows:

a) The town was served by an acceptable level of telecommunications infrastructure;
b) The main land uses for the city was reserved for educational and research facilities and green area (see Appendix 2). The residential and scientific institutions were of good construction and the town was built at very low density;
c) There were only two possible entry points into the town, both guarded by the army at road checkpoints; and
d) The town was served by a Multiservice center, which included hospital, cafeteria, post office, bank, pharmacy, shopping center, bookstore, indoor swimming pool, golf course and a restaurant.

3.3.2 Development of Taedok Science Town

To jumpstart the project, the central government initially used incentives and good working environment to attract potential tenants to TST. However, neither government nor private institutions wanted to move Taedok. Thus, the government had to force

[1] It is also 90 mins by train from Seoul, or 2hr 40 mins by limousine bus directly from Incheon International Airport.

research institutes to relocate. The government first relocated four institutes from Seoul to Taedok in 1978. By 1988, only about 17 research institutes had moved into Taedok (see Table 3.1 below). Of the 17 research institutes, 14 of them are government or government-related establishments and only 3 private industrial research institutes had moved in. These institutes were compelled to relocate from Seoul because "they were part of government or (in the case of the three private institutes) they were established as a *quid pro quo* for government help for their parent corporations" (Castells and Hall, 1994). For the researchers who moved to Taedok, most kept their families in Seoul. The researchers saw little advantage in locating in Taedok as the institutes have little contact with each other.

Table 3.1: Composition of participants in TST

<table>
<tr><th rowspan="2"></th><th colspan="2">Number</th><th colspan="2">Personnel</th></tr>
<tr><th>1988</th><th>2000</th><th>1988</th><th>2000</th></tr>
<tr><td>Government-funded Research Institutes</td><td>9</td><td>20</td><td rowspan="6">7,000 (including 1,000 PhD degree holders)</td><td rowspan="6">14,444 (including 4,014 Ph.D. degree holders)</td></tr>
<tr><td>Private Research Institutes</td><td>3</td><td>29</td></tr>
<tr><td>Government- invested Research Institutes</td><td>2</td><td>9</td></tr>
<tr><td>High Educational Institutions</td><td>3</td><td>4</td></tr>
<tr><td>Public institutions</td><td>NA</td><td>8</td></tr>
<tr><td>Total</td><td>17</td><td>70</td></tr>
</table>

Source: Castells and Hall (1994) and DSTA (2000)

Despite the relatively poorer quality of life in Seoul as compared to TST, the institutes and firms were reluctant to move to Taedok because the real technopole was Seoul, which had both a concentration of high-level engineers and scientists and easy connections to the outside world of science of technology (Castells and Hall, 1994)

A key feature of the plan for TST was the lack of industrial activities (see land use chart in Appendix 2). TST was a distinctive spatial unit, entirely segregated from nearby urbanized areas. There seemed to be no connection between research activity and production activities in the surrounding areas, even the relatively industrialized Taejon (Castells and Hall, 1994). The lack of academic-industry synergy failed to create a "milieu of innovation" in TST or achieve industry feedback on manufacturing or new applications. As concluded by Castells and Hall, Taedok's initial development was created by "force" from the government. "Taedok project appears as a purely political decision, in the early 1970s by the then-President Park, to locate a new center of excellence in his home province (Chungnam), so as to mark his efforts at decentralization... Neither functionally nor industrially was Taedok a viable project" (Pg 63, Castells and Hall, 1994).

In the 1990s, the efforts of the government to recruit scientists and R & D labs (private and public) from all over Korea into TST started to pay off. Since 1988, the number of research institutes in TST increased substantially from 17 to 70 in 2000 to become the largest research center in Korea (Table 3.1 and Appendix 2). The institutes and organizations have also been employing more top scientists and engineers over the years (Table 3.2).

The critical mass of scientists, engineers, students and research activities presented a real opportunity for TST to be a high-tech cluster and a force for economic development. The rate of growth of research institute setting-up in TST increased by five folds as compared to the 1980s and the number of researchers employed in TST almost tripled over the last period (Table 3.2). This signaled a possible change in attitude of the scientists and institutions as they became more willing to locate in TST. The increase in R&D investment over the years showed increasing vitality of R&D in TST.

Table 3.2: Growth of private sector R&D institutes in TST (compared to National)

	Year	1981	1986	1991	1996	Growth Rate (%)		
						81-86	86-91	91-96
No. of private R&D labs	In TST (nation)	3 (122)	3 (290)	5 (1109)	25	0 (237)	166 (382)	500
No. of researchers		1390 (5054)	1390 (12,576)	1666 (28725)	4475	0 (248)	119 (228)	268
Total investment in R&D (bil won)		2783 (3423)	2783 (8521)	3235 (22640)	9594	0 (246)	116 (265)	296

Source: Oh and Kang, 1999

For the universities, one of the most notable entries into TST is Korea Advanced Institute of Science and Technology (KAIST). Formed in 1971, KAIST was the best research university in South Korea and has founded more than 70 modern venture enterprises in Korea (KAIST, 1998). Its entry into TST elevated TST's status as the center of science and technology in South Korea and provided the necessary manpower and source of spin-off companies for the area. In fact, many incoming firms had evaluated the location of KAIST and ease of recruiting graduate as two of their main considerations before settling in TST (Oh and Kang, 1999). Since KAIST relocated to TST, it has raised the level of research activities and built closer linkages with other existing research centers in Korea.

The government has been encouraging local research institutes to collaborate with foreign research institutes to keep abreast of technological advances in the world. For example, the Electronics and Telecommunications Research Institute (ETRI)[2] has a small office in San Jose (California) to support the dozen or more staff that are in the US at any given time and also to act as a base for obtaining information about advanced technology. In 1992, they opened a liaison office in Europe to support information exchange, joint research, etc (David Kahaner, 1992). There are also a growing number of foreign scientists and researchers in Taedok as a result of increased science and research cooperation between TST and other countries, especially the US (TDAGS, 1995).

In recent years, the government (state and local) tried to link the innovative capability of TST with local industrial development. To optimize their proximity to Taedok, the city of Taejon tried to create more synergy between industries and academic by developing two industrial districts next to TST: (a) The Taejon Science and Industrial Complex (TSIC) and (b) Taejon Industrial Complex No 4 (Appendix 2). Taedok would serve as the

[2]ETRI is the R&D arm of Ministry of Science and Technology and focuses on IT, telecommunications, computers, automation and semiconductors.

research base for these developments. TSIC was built as a local government initiated public development plan funded by advanced payment of the companies renting space in the complex. It was completed in 1999 and accommodates about 150 companies and is a manufacturing base for chemistry, microelectronics, electronic controllers and machines. TIC4 will accommodate about 90 companies producing machinery, electronics, automobiles, textiles, food and beverages (TDAGS, 1995).

In 1989, the government unveiled its greater plans to develop four "Technobelts" across South Korea to link up research and industry throughout the country via telecommunications (Appendix 3). The aim was to create synergy between specialized industries and research areas located within the same beltway. Through the epicenters of each Technobelts, technological diffusion will take place to the industries along the four major technobelts (Castells and Hall, 1994). TST thus play an important role in this network of Technobelts as it is located at the crossroad of two belts.

Although Korea had created an extensive program to foster synergy between industry and research centers, only about one-third of the research institutes had regular contact with firms in Taejon i.e. undertaking collaborative research, technical supervision, etc (Oh and Kang, 1999). Given that these improvement programs were implemented only in the 1990s, it is likely that more time is required to realize the full potential. Thus, as TST develops, it could have even greater effect on the economy.

Apart from building up a science case and improving academia-industry interaction, the government also has an "Incubation Policy" to attract entrepreneurs from universities, research institutes, and R & D centers to start their own companies. Incubation institutions (Table 3.3) were formed to facilitate technology transfer to new firms, commercializing new products, mediating between research institutions (universities and research institutes) and private firms and supporting the creation of venture firms.

Table 3.3: Technology Business Incubator (TBI)

Incubating institution	Venture Companies
Korea Advanced Institute of Science and Technology(KAIST)	122
Electronic Telecommunication Research Institute(ETRI)	83
Small & Medium Enterprise Support Center	24
Small & Medium Enterprise Support Center	18
Korea Research Institute of Bioscience and Biotechnology (KRIBB)	17
Korea Standardization and Science Research Institute	12
Korea Nuclear Energy Research Institute & 3 other institutes	24
Total	300

Source: DSTA, 2000

Since late 1980s, spin-off formation has been gaining momentum. There were 3 cases of spin-offs in 1991, but it grew to 9 cases in 1995 and 20 cases in 1996 (Chart 3.1). Up till 1998, 65 high-tech spin-offs were created from 9 organizations in TST, of which 8 were government related research institutes and 1 was private research institute (Oh and Kang, 1999). The spin-offs created 954 new jobs in total (Chart 3.2). As observed by Oh and Kang the spin-offs chose to locate in TST after gaining "independence" because of the image that Taedok had gained as a high-tech cluster and the east of access to technological information (Oh and Kang, 1999).

Chart 3.1: Number of Spin-offs in TST (Cumulative)

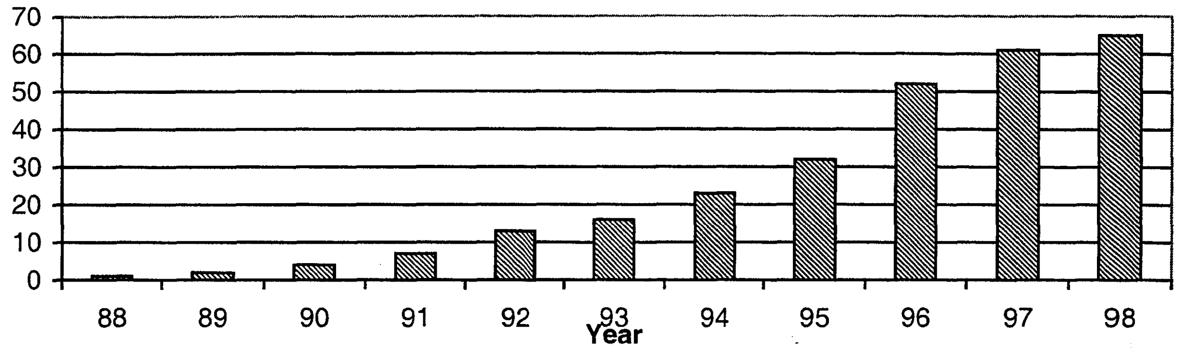
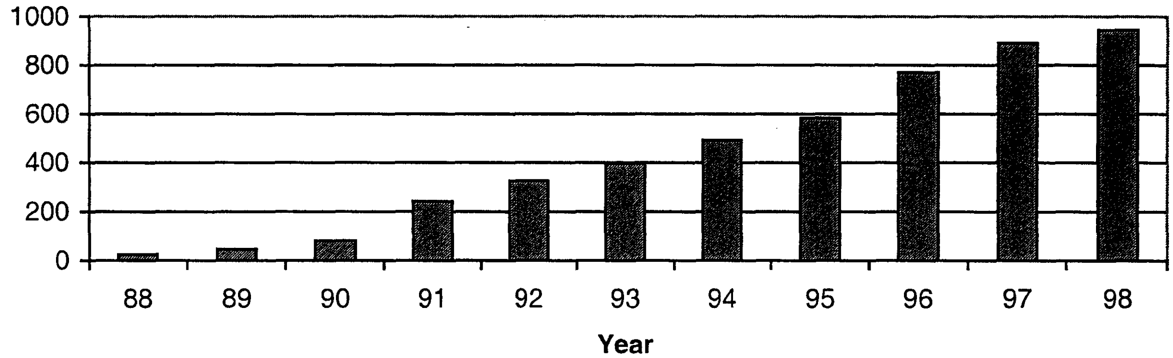


Chart 3.2: Number of jobs created by TST Spin-offs (Cumulative)



Source: Oh and Kang, 1999

The latest idea to facilitate start-up formation is Taedok Venture Techno Valley (TVTV). This Valley is based on a comprehensive development concept of high-tech venture business from the incubation stage to the mature stage. There are four areas to TVTV development:

a) Area for post-incubators where the venture firms just "graduated" from incubators, but are still at the development stage;
b) Area for high tech industries where the large firms could establish their production plant and R&D facilities;
c) Area for supporting facilities where the total service of high-tech venture business, prototype development, consulting firms, etc could be located; and
d) Area for housing estates where highly qualified manpower could have their residence and community facilities (Oh and Kang, 1999).

In addition, TVTV promotes networking via the Network for Venture Community (NVC) scheme. NVC creates a mutual information network that can be shared among research institutes, universities in TST, government, and high-tech venture firms. NVC will have an ideal venture community containing six sectors, namely

(a) Finance Support Sector,
(b) Basic Research Sector,
(c) Facility Support Sector,
(d) Professional Support Sector,

(e) Strategy Support sector, and
(f) Education & Training Sector (Oh and Kang, 1999).
With the development of TVTV, TST will be one of the most attractive place for entrepreneurs to locate their venture business.

TST also became a livable city with choice residential options for the thousands of well-educated, highly qualified people in high-tech industries. As the community facilities are developed and better quality schools provided, the work force in TST became more willing to relocate the entire family into the science city, making it truly a place to work, live and play. In 1995, 49% of the total number of researchers and workers resided within TST (Table 3.4). The percentage of personnel living in nearby Taejon City and Chungchong province had reached 32%. Only 7.4% of workers are living in outer areas of Taejon City and Chungchong Province.

Table 3.4: Residential Location of Workers in TST

	Within TST	Taejon, Chungchong	Dormitory	Other Areas	Total
Public Institutes	41	345	47	14	447
Semi-Public Institutes	3694	2741	538	854	7827
Public Investment Companies	754	561	97	92	150
Education Centers	1687	441	243	3	2374
Private Institutes	1582	1106	792	163	3647
Total	7758 (49%)	5194 (33%)	1721 (11%)	1126 (7%)	15799 (100%)

Source: Taedok Management Office, 1995

TST now has 3 parks, 2 athlete fields, 6 elementary schools, 5 middle schools and 5 high schools and shopping centers. The schools have become well known due to the highly educated parents of these children. These children also have more opportunities to mix with other children of different cultures since the researchers included foreigners. Thus, TST has indeed transformed into a city that can attract highly educated workforce to live and work.

3.3.3 Lessons from Taedok Science Town

The initial years was a time where TST was being developed by sheer governmental force and had very little of the synergy that characterizes an innovative science city. In the 1990s, it seemed that its development has achieved some momentum in being an important research center and was gaining "success" in injecting vitality into the regional economy. The development of TST will be evaluated in two sections:
a) Its initial years, from 1970s to late 1980s
b) Further development, from 1990 to 2000.

a) Initial Period

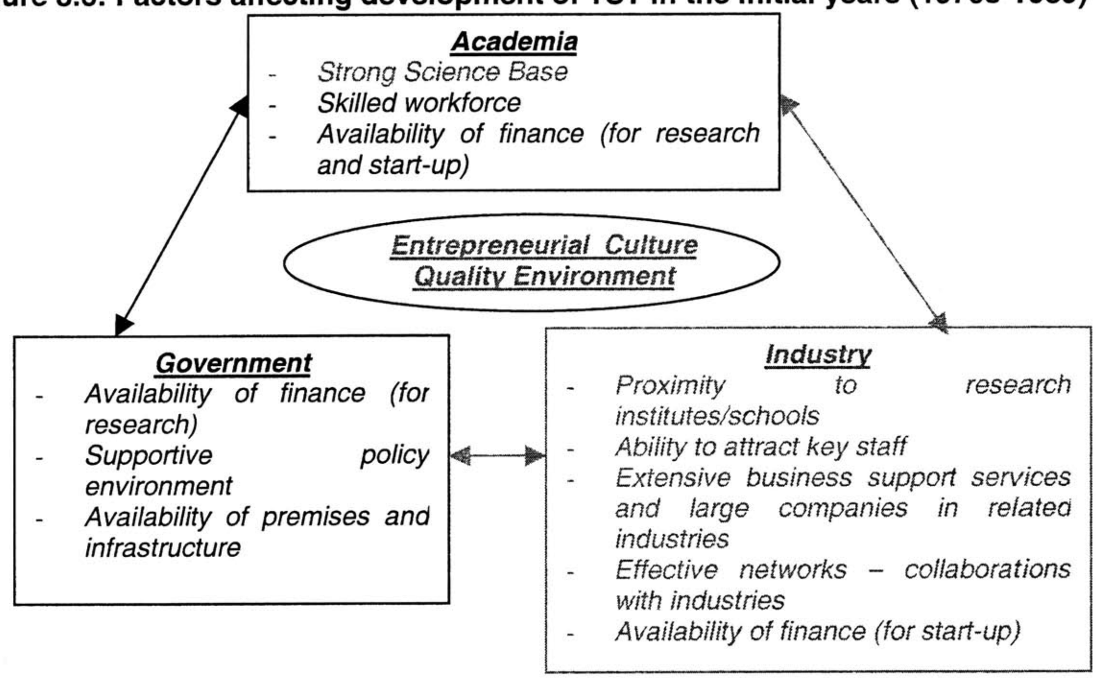
i <u>Unable to build a strong science base</u>
TST was unable to develop a strong science base because research institutes (public and private) did not want to relocate there. Furthermore, the few institutes that relocated did not work with each other to reap the potential benefits presented by being in close

proximity to each other. They refused to move because TST could not match the same location advantage that Seoul offered in terms of economic network and concentration of human capital. It would thus seem that Seoul is the "real" technopole that the Koreans had unknowingly developed. Furthermore, the underdevelopment of social infrastructures e.g. good schools, communal facilities, etc made it difficult for researchers to relocate their families to TST. TST could only be a work place for researchers during the weekdays; it remained far from being a real city where families reside.

ii Lack of industrial presence and synergy with academia

The lack of interactions with industries hampered the "learning by doing" approach to technological development that Korean had been relying on for decades. TST, isolated from industrial establishments and nearby urban areas, was made even more "unreachable" when the master plan provided only two guarded ingress and egress points two and fro the science city. This discouraged any form of interactions with establishments outside TST. Thus, instead of using TST to inject regional economic dynamism, the government achieved the opposite: it helped establish an artificial implant, without the capacity to promote development (Castells and Hall, 1994).

Figure 3.6: Factors affecting development of TST in the initial years (1970s-1989)



iii Strong Government Presence and Short Development Time Frame

After 15 years of development, Taedok was deemed a "failure" by some researchers. However, it seemed too early to conclude that it failed since the science town was still in its "infancy" stage. As the critical mass of research activities slowly developed a strong science base with good quality skilled labor force, TST started to become a true science city with increasing ability to attract research institutions and skilled labor and a high incidence of high-tech spin-offs. The Korean government was proactive in improving its policies and implementation plans to steer TST's development towards being an advanced center of science in Korea.

b) Further development (after 1990)

i Strong Science base, Pro-business environment and Entrepreneurial Culture

After 1990, a strong science base had been developed. The top research institutes and universities in TST were the 'centers' of innovation. The innovations that came out of these labs and universities could be commercialized quickly because of the pro-business policy environment that the government advocated. The ease at which government labs allowed spin-offs to be formed and the encouraging research environment, especially at KAIST, gave researchers and students the freedom to set up start-ups and further their research areas. The fact that the government could foresee the needs of TST e.g. Incubator policy, industrial space, etc and opportunities of TST e.g. "Technobelt provided a "competitive edge" for businesses in TST to grow and to optimize the economic potential of TST.

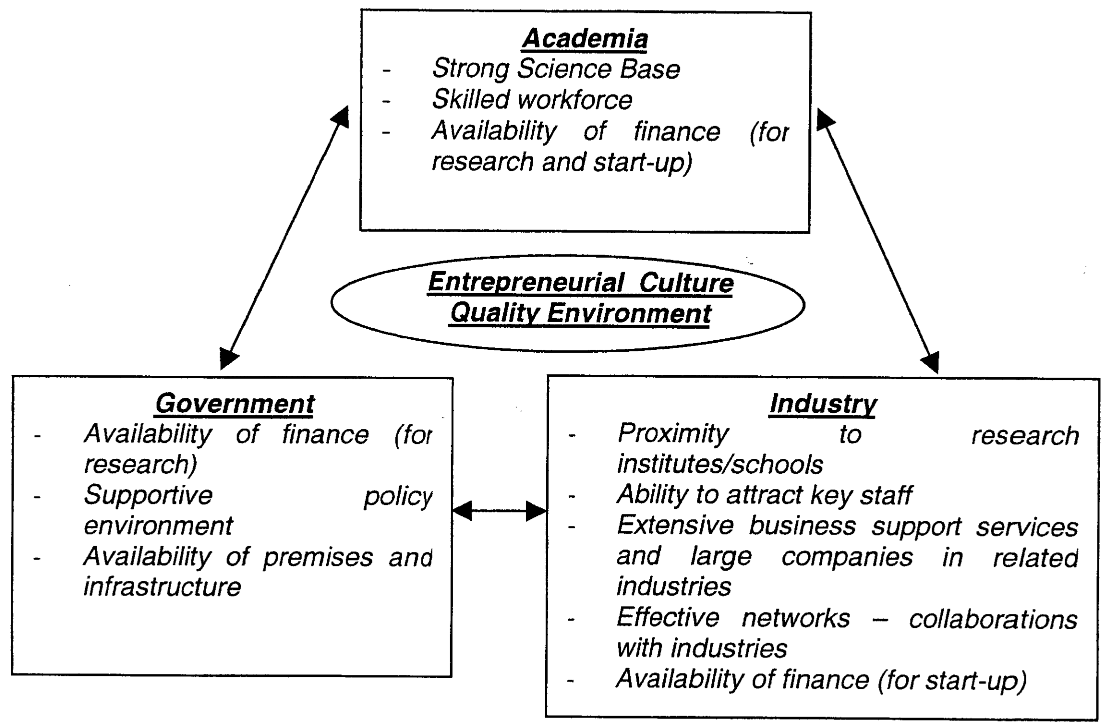
For TST, it is observed that the public institutions are always at the forefront, implementing the latest government policies. For example, despite reluctance to move to Seoul, 11 public institutes proceeded to move to TST as compared to 3 private institutes. In terms of being an innovative force and facilitating spin-offs, public institutions (research and educational) were more instrumental than private research institutes in coming up with new innovations and then facilitating the transformation of that innovation into a new spin-off company and helping it to "grow". Most of the private firms only moved in much later after TST showed some signs of success.

From this case, it can be seen that public institutions play a very important role in planned technopole; first, in developing the required critical mass for a strong science foundation for the new city, and second, in being the implementation arm for government policies.

ii Availability of premises, infrastructure and industrial presence

The massive infrastructure development e.g. TSIC, TIC4, TCTC, etc provided the cheap space needed for industries to locate near Taedok, which was not provided in the initial plan. With increased industrial presence, TST could seek feedback from industries on its research findings and the industries could upgrade their technology base with greater access to new technology. The TVTV project not only facilitated the process of technology transfer, it provided a secured and pro-business environment for companies to grow until they are able to compete on its own in world market.

Figure 3.4: Factors affecting development of TST in the initial years (1970s-1989)



3.4 Case Study 3: Tsukuba Science City (Japan)

3.4.1 Vision for Tsukuba Science City (TSC) and its planning

After World War II, Japan started the process of rebuilding its city and economy. One of its primary objectives was to catch up in its level of science and technology with other advanced countries. At the same time, Tokyo, in the 1950s, was experiencing over-crowding due to rapid population expansion, making it unconducive for living and working. Thus, in 1961, the Japanese government started to relocate government offices *en masse* out of Tokyo.

In 1962, the Science and Technology Council made a report on the necessity of the collective relocation of national experimental and research institutions and to consolidate its presence. The government viewed building a science city as a means to increase the domestic growth in science and technology in their nation, and was willing to invest heavily to fund the development of these projects. In 1963, the Cabinet approved Tsukuba district as the location for Japan's first Science City i.e. TSC.

TSC is located approximately 60 km northeast of the center of Tokyo and about 40 km northwest of Narita International Airport. The site covers an area of approximately 28,400 ha at the southern part of Ibaraki Prefecture, with Mt. Tsukuba to the north and Lake Kasumigaura on the east (see Appendix 4). The goal of TSC was to promote the advancement of science and technology to sustain the urban growth of the capital region and national economy.

The urban planning of the science city started in 1965 and a time frame of 10 years was given for the basic construction and relocation works to be completed[3], ending 1975 (see Appendix 5). TSC consists of two areas:

a) Research and Education District (RED), and
b) Surrounding Suburban District (SSD).

The RED covers about 2,700ha in the center of TSC, where national research and educational institutes, residential area, and parks are located (Appendix 4). The RED also includes an 80ha city center, which is the center of cultural, commercial and administrative activities of TSC. Presently, about 13,000 employees are working in national institutions, of which 8,500 of them are researchers (TSCI). The "Surrounding Suburban District" is designed to accommodate private research facilities and future-oriented industries while preserving agricultural land and the high-quality natural environment (Castells and Hall, 1994). Many private research institutions have branched out into the industrial parks and others in the Surrounding Suburban district. Their research fields are mainly medicine, chemistry, electronics and electricity, mechanical engineering, and construction. About 4,500 researchers are working at the private institutions (TSCI).

In 1997, TSC had a population of about 188,000 and about 300 national and private research institutions and corporations. The projected population of TSC in 2030 is 350,000.

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[3] An extension of deadline was granted for TSC to be completed in 1979 (Tsukuba Science City Information).

Table 3.4: Present and Projected Population Growth in TSC

	Present Population	Planned population	Area
Tsukuba Science City	187,058	350,000	28,400ha
The Research and Education district	64,055	100,000	2,700ha
The Surrounding Suburban district	123,003	250,000	24,700ha

Source: TSCI

The 46 national research and educational institutes in Tsukuba currently report to a great variety of government departments and agencies[4]. TSC has become Japan's largest research and development center, representing approximately 27% of Japan's national research facilities in one single location, and about 40% of the country's research budget and employees.

3.4.2 Development of Tsukuba Science City

In the early days, Tsukuba's growth was slow and somewhat painful. Tsukuba, like Taedok, was developed using "governmental force". Despite protests from local residents and government workers, land acquisition proceeded in 1967 (with some amendments to site boundaries to respond to local protests) and Tsukuba Science City Construction Law was passed in 1970. There was also a lot of opposition to moving out of Tokyo, both from the laboratories and from the Tokyo Teachers' College (Castells and Hall, 1994). Nonetheless, the government proceeded to identify national research institutes to move to TSC (11 institutes were identified in 1967, and increased to 43 national institutes by 1972, Appendix 5). By 1980, some 80% of the government agencies with about 9,000 jobs (and 125,000 people) moved. The response of private industry was slow. There were little take up by private industries in the three major research parks planned for them in SSD.

In the 1980s, there were little interactions between public research and private sector enterprises. Furthermore, the relocated research institutes tend to concentrate on large projects focusing on target technologies and neglecting basic research and applied research relevant to local industry or small and medium firms (Castells and Hall, 1994). Between different disciplines of the research institutes, there was also little communication. The vertical integration of Japanese government agencies prevented research institutes from sharing facilities, which led to excessive duplication of equipment.

TSC was a difficult place to obtain information and research support. Most of the research institutes were institutionally rigid and could not enhance innovation or entrepreneurship. Tsukuba was considered an "isolated island, remote from normal human society" (Pg 72, Castells and Hall, 1994). It took 4 hours to travel to and fro Tokyo. Thus, when the national institutions first moved to TSC, it was difficult to find student help because it was perceived as being far from Tokyo, and there were too few universities to provide research assistants.

[4] 10 to Ministry of Education, Culture, Sports, Science and Technology, 1 to Ministry of Foreign Affair, 6 to Ministry of Land, Infrastructure and Transport, 1 to Ministry of Posts and Telecommunications, 1 to Environmental Agency, 9 to Ministry of International Trade and Industry, 3 to Ministry of Health, Labor and Welfare, and 13 to Ministry of Agriculture and Forestry (TSCI).

Despite the negative feedback on TSC in the 1980s, it did bring about some positive spillovers. Research institutes got new premises and new equipment for its operation. The agglomeration of research institutes has promoted some small meetings among researchers and facilitated the organization of conferences and symposiums in Tsukuba. This gave rise to some exchange and cooperation.

Until the mid 1980s, TSC was failing to attract the private sector to the city. However, the Tsukuba International Science and Technology Exposition 1985 changed this trend. Private firms wanted to be near the Expo site and be within 1 hr's drive from Tokyo. TSC became a good location for the private companies as the government had just constructed a new expressway linking Tokyo and TSC for the Expo (Castells and Hall, 1994). Other infrastructure investment that Tsukuba profited from in terms of improved accessibilities include the Joban Railway expansion to the neighboring city of Tsuchiuria, which allows connection between Tsukuba to Tokyo in 1 hr 10 mins by train, and the Joban Expressway, which extends to TSC, allowing direct access to central Tokyo by car or express bus (Castells and Hall, 1994).

TSC is now into its third phase of development[5] in terms of infrastructure improvements, which concentrates on the improvement of connections to Tokyo via high-speed train (Joban New Line) and Metropolitan Inner City Expressway ("Ken-O Do"), and development of new 2000 ha high quality settlements along the New Joban Line route (Appendix 6). The New Joban Train Line, which will be open in 2005, will link TSC with Akihabara in Tokyo in 45 minutes. The "Ken-o Do" is the ring highway around 40~60 km of the Metropolitan area and it will connect Narita Airport and TSC in 25 minutes.

As of 1989, more than 200 private research facilities have been established in TSC, many of which moved there after 1985. Industrial research parks, built by the government in the SSD, provided suitable, cheap premises for private industries. Currently, there are 7 such industrial/research parks and they house many laboratories and factories of high-technology industries in close proximity to the RED of Tsukuba (see Table 3.5). In addition to increasing the "hardware" of TSC, the government has also improved the "software" in terms of better, shared on-line database throughout Tsukuba Science City and other IT networks.

Table 3.5: Private Research Facilities in Tsukuba

Industrial/Research Parks	No. of companies	Area (ha)
Tokodai Business and Research Park	28	39
Tsukuba Western Business and Research Park	14	102
Tsukuba Northern Business and Research Park	17	128
Tsukuba Research Park Hanare	7	5.4
Tsukuba Techno Park Toyosato	26	69
Tsukuba Techno Park Sakura	5	24.6
Tsukuba Techno Park Oho	10	41

Source: TSCI

[5] The first phase consists of city construction (1963 – 1980) where TSC saw the relocation of government institutions into TSC. The second phase is the city development (1980s to late 1990s), which saw the development of Tsukuba Center Building, international events such as Tsukuba Expo 1985, and the relocation of private institutions into industrial areas located at the Surrounding Suburban Districts (Tsukuba Science City Information, 1997).

To encourage industrial interaction with the public sector, a Research Exchange Promotion Act was passed in Dec 1987. This Law, which allows private enterprises to use the facilities of the national institutes and promotes personal exchange and joint ownership of patents between national institutes and private enterprises, reinforced the trend of increasing private sector presence in TSC. This Law resulted in numerous joint research centers being set up at universities to promote industry-academic-government tripartite cooperation, resulting in substantial increase in collaborations (see Table 3.6). A framework of how universities cooperate with industries is in Appendix 7. The government also encourages manpower movement between industry and academic so that it will promote both the transfer of technology to industries and the communication of industrial needs to the public research institutes.

Table 3.6: Increase in partnership between universities and industry

Type	FY1987	FY1997*	Growth rate
Joint research	396 cases 465 researchers	2,362 cases 2,394 researchers	x6.0 x5.1
Commissioned research	3.93 billion yen	33.26 billion yen	x8.5
Commissioned Researchers	914 people	749 people	x0.8
Grant contributions	29.1 billion yen	26.5 billion yen	x1.6
Contributory Lectures/ Contributory Research Divisions	2 Universities 1 Contributory Lecture 4 Contributory Research Divisions	29 Universities 54 Contributory Lecture 19 Contributory Research Divisions	x14.5
Cooperative Research Centers	3 Universities	53 Universities	x17.7
Research Cooperation Divisions	7 Universities	29 Universities	x4.1

Source: Press Release 2000/04, MEXT

To what extent has Tsukuba been able to generate spin-offs? While TSC is seeing more of joint research between private research companies and universities or public research institutions, very few spin-offs resulted (Castells and Hall, 1994). For example, the Electrotechnical Laboratory, one of the national research institutes in Tsukuba, has developed many links with private companies and universities. They have more than 100 joint research projects with companies. But not many people from this laboratory transfer to private companies, or universities, even after 20 years. Those who left went to the big companies instead of starting their own business. "The USA-style "start-up" breakaways are almost unknown here" (Castells and Hall, 1994).

In the 1990s, the Japanese government faced another challenge: the "hollowing-out" of R&D activities. Investment in R&D by the Japanese government was smaller than that in Western nations, and was unable to rise. Many fields of basic research were inferior to those in Western countries, and application development researches were becoming inferior to those in the United States. Japan's R&D systems were less flexible, competitive and restricted. It was also a matter of great concern that young Japanese were less interested in science and technology.

Thus, in 1996, the Science and Technology Basic Act was enacted to raise the level of Japan's science and technology. In July 1996, a Science and Technology Basic Plan was drawn up based on the provisions of the Act. The Plan aimed to develop Japan into a "country with international economic competitiveness and sustainable growth" by "contributing to the world by generating knowledge and its utilization". Its strategy was to develop new knowledge, produce knowledge-based vitality, and to create a society of knowledge-based affluence.

The Plan adopted a two-prong approach to promote the advancement of science and technology in Japan:

a) To promote systemic reforms for the construction of a new *research and development system* by enhancing human capital, creating a flexible, competitive and open research environment, the development of R&D abilities in industry, universities and government, etc and

b) To *increase investment in research and development*. For a start, the government intends to increase investment in government research and development amount as a percentage of GDP beyond that of Europe and the U.S.

A key feature of this plan is its emphasis that universities, national and public research institutions in Japan must undertake more basic research to generate new knowledge. Another feature is the strengthening of the linkage between acquiring new knowledge and using new knowledge. Thus the process of technological transfer is very important and this is achieved through improvement in the network of the industry-academia-government cooperation and ensuring that there is consistent flow of knowledge from the R&D to the society. Notably, TSC, which was the only city mentioned in the Science and Technology Basic Plan, was tasked to be "a center for exchanges of information and research throughout the world" (Science And Technology Basic Plan, 1996).

Some of the strategies outlined in the plan were as follows:

a) In order to strengthen its scientific base, Japan would focus on (a) improving its human resources through improved education at universities, (b) creating an appealing world-class research environment to enable young researchers to pursue independent researches, (c) increasing the areas of industry-academic-government cooperation and changing school education to cultivate interest in the young toward science and technology. An appealing research environment e.g. well-conditioned facilities, research supporters, intellectual infrastructure, and research information infrastructure is crucial to attracting first-class local and foreign researchers raising the level of research. Japanese researchers were expected to produce research achievements of high quality and export them worldwide.

b) To foster closer working ties between industries and academics, the government allowed researchers and academics to work part-time at the research institute and use the remaining time to carry out R&D with businesses or to provide technical guidance for businesses. They also allowed academics to hold director position in private companies that make use of the new technology derived from the research findings. This established a system for human resource interchange.

c) In terms of funding, the government is committed to continuously increase research expense funds by increasing the pool of competitive funding i.e. funds from which researchers could get from outside their research institutes.

Competitive funding had increased 2.4 times from 5% of total expenditure on science and technology related expenditures in 1995 to 8.9% in 2000 (ARPST, 2001). These funding are allocated selectively on a competitive basis (APRST, 2001).

The objectives of increasing synergy, collaborations and technological transfer between public and private sectors are being achieved as seen from the increase in the number of joint research papers (Table 3.6). A survey[6] in FY 1998 also showed that international exchanges between researchers are also on the rise. The survey showed that there were more foreign researchers in TSC in FY 98, an increase of 5% from previous year and the average duration of stay is also longer (MEXT Press Release, 2000). The purposes of the stay for majority of the people were research (1,728 people or 43% of foreign researchers), training (1,110 people or 27%) and overseas study (1,014 people or 25%).

The comprehensive strategies that the Japanese is implementing and their constant policy review to "stock-take" their progress show their commitment to making science and technological advancement successful in Japan.

3.4.3 Lessons from Tsukuba Science City

The development of TSC has been slow, but improving steadily. Much of its improvement over the last 40 years has been motivated by government policies. An attempt to draw lessons from TSC's development will be made over two periods:

a) Its initial years, from 1963 to 1985 (after major infrastructure improvements and 85 Tsukuba Expo was held) and
b) Developmental Years from 1985 to late 1990s. The Basic Plan approved in 1996 is a big push from the government to augment the situation in TSC then and will be evaluated as part of the Developmental Years.

a) Initial Period (1963 – 1985)

i <u>Inability to build a strong science base and lack of facilities</u>

After TSC was completed in the late 1970s, it had little ability to attract key research institution and key research staff to build a science base strong enough to make it a key R&D city. Similar to TST, it was only through government coercion that the critical mass of the research institutions and universities relocated to TSC. Even after they moved there in the 1980s, researchers and research institutes were unhappy because they had to leave their family behind in Tokyo while they work in TSC (Castells and Hall, 1994). Furthermore, the science city was far away from the main commercial cluster of Tokyo and required long traveling time. Also, the researchers were unable to employ research

[6] A total of 171 organizations in TSC was surveyed. This comprises 40 national research institutes and universities, 6 public-service corporations, 2 incorporated educational institutions and 123 private organizations. The number of organizations that responded was 102. Information was obtained from those foreign researchers who had been staying for more than five days by means of a questionnaire. Chinese were the largest national contingent with 907 people (22%), followed by South Korea with 517 (13%), the USA with 222 (6%), Thailand with 152 (4%), India with 140 (4%) and Indonesia with 138 (3%) (MEXT, 2000).

assistants as the main skilled population base was in Tokyo. There was also little interdisciplinary research between research institutes or exchange of information in TSC.

ii Inability to attract Industries and lack of infrastructure

As the natural "technopole" was Tokyo, industries were unwilling to move to TSC despite having access to purpose-built industrial and research parks. Similar to Taedok, industries lag in moving to the new Science City until they have a good impetus to do so. The unattractiveness of locating in TSC was reinforced by the poor transportation infrastructure, which makes traveling between Tokyo and TSC extremely difficult. It was thus impractical for businesses to relocate to TSC if it still wishes to be close to Tokyo.

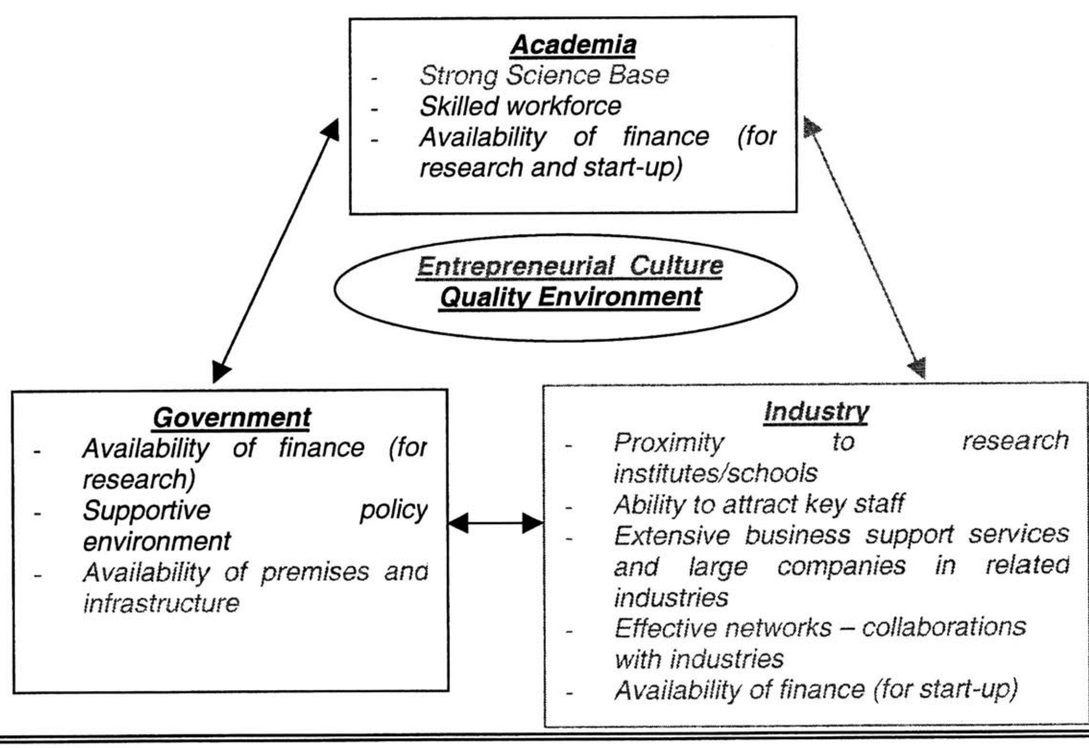
iii Lack of Entrepreneurial Culture

Although there were no data on the number of spin-off firms created in the initial years of TSC (if any), it was unlikely that there was substantial number of spin-offs created as TSC was still trying to establish itself then. Even in the 1980s, TSC did not reap many spin-offs as observed by Castells and Hall.

iv Government Policy

During these initial years, the government tried to build TSC into a credible science town by improving the hardware and software of the new city. The government viewed TSC's development as a long-term process. It was thus too early to decide if TSC had indeed failed before 1985. However, the government was powerful and aggressive enough to designate the relocation of some 43 research institutes and an entire university (University of Tsukuba) into the new city. It thus showed the determination on the government's part to ensure the success of TSC.

Figure 3.5: Factors affecting development of TSC in the Initial Years (1963 – 1985)



b) Developmental Years (1985 to late 1990s)

i Massive Infrastructure Improvement and Increasing Industrial Presence

In subsequent years, the government invested heavily in transportation infrastructure improvement to improve communication linkages with Tokyo, reducing traveling time between Tokyo and TSC by half. The infrastructure improvement included extension of rail service to nearby city of Tsuchiuria and a construction of expressway. The Expo 85 also created some "urgency" for firms to move into TSC to be near the expo site while still being close to Tokyo. More private firms started relocating to TSC. The government is now actively developing a new high-speed railway linking central Tokyo to the central city of TSC. This railway also opens many opportunities along the route near TSC to develop vacant land for approximately 100,000 new population that are expected to relocate here by 2030. The new Metropolitan expressway ring will also link TSC with other existing urban areas around the Metropolitan Tokyo and increase TSC's accessibility as a science and technology hub.

Infrastructure improvements also include the development of the 7 private industrial research parks by the government to provide well-equipped, convenient new premises for the industries to relocate to. The government also made several IT improvements for TSC to increase ease of communication and information sharing e.g. Tsukuba Network.

ii Strong Science Base, Supporting Policy Environment and Greater Academia-Industrial Synergy

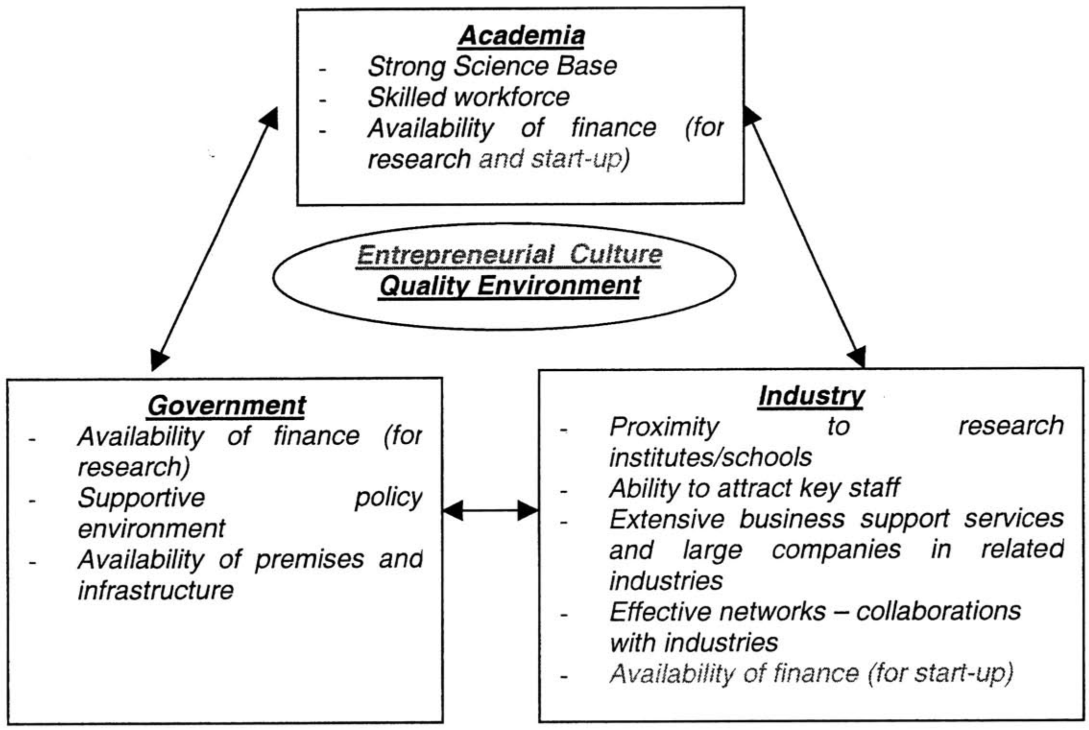
During the 1980s, the city's profound psychological isolation from Tokyo was finally beginning to break down. It could be due to the improved transportation connection or the ever-expanding boundary of Tokyo metropolis beginning to approach close to Tsukuba.

Other barriers those that separated the public institutes, the university and the private companies were also breaking down. The science base of TSC was starting to mature and networks formed between institutions. With the improved infrastructure and the largest congregation of top universities and research centers of Japan in TSC, researchers were more willing to relocate to TSC. These improvements were enhanced when government reviewed its policies to reduce bureaucracy in the system affecting science and technology and to encourage collaboration between industry and academia. The private sector was at last beginning to invest in the city on some scale, resulting in a marked increase in joint research between the public and private sector. It was thus likely that the transfer of technology was successful. As TSC develops, it was able to attract foreign researches to carry out training, research activities or even study in TSC. As described in Castells and Hall, "one could begin to capture ...... the sense that the grand design (of Tsukuba) was taking shape" (Castells and Hall, 1994).

The government's comprehensive approach in the Basic Plan 96 towards advancing science and technology and its focus on enhancing the science base of TSC as its priority for the next few years will have positive influence on TSC. Although it is still too early to conclude the success of the Basic Plan, the important point is the government's forward-looking and pro-active policy measures.

After 40 years of development, TSC is still transforming under the careful guidance of the central Japanese government. TSC has been a very expensive State project, which involves developing an entirely new city with state-of-the-art technological equipment and facilities and good transport infrastructure. With the Basic Plan, more improvements are likely to be seen.

Figure 3.6: Factors affecting development of TSC in the Developmental Years (1985 – late 1990s)



CHAPTER 4: CONCLUSION

4.1 Introduction

In their search of new sources of economic growth and social well-being, many cities and regions made large infrastructure investment to develop technopoles, or science cities. These planned technopoles generate high value-adding knowledge e.g. new technology or innovation, which could be used by industries to gain product competitiveness and/or reap first mover advantage.

The development patterns of "technopoles" are often "copies" of successful market-driven US models of Route 128 or Silicon Valley. They project themselves as "innovation centers' based on research and development. Locales that developed into successful innovation centers had indeed become magnets for other high-tech firms to locate there, forming a cluster of related companies and high-quality human capital.

This thesis studied the development history of Route 128 in detail to understand the success factors of this high-tech cluster. A framework model (Figure 2.1) was developed to show how the success factors interact with each other. When tested against other planned technopoles, it was confirmed that the success factors in the framework were similarly applicable and were key determinants of their ultimate success.

4.2 Boston's Route 128 as a successful case study

Although Route 128 has been a world icon for high-tech business, its economy was not without booms and busts. For example, Boston suffered a bust in its mini-computer industry when it could not compete against Silicon Valley's personal computer industry. It suffered again when the US economy went into recession around 2000, but seemed to be recovering in the last few months, with a resurgence of recession-resistant biotech and bioinformatics firms around MIT. Unemployment in Route 128 had dropped, and local venture capitalists e.g. Polaris and Highland Capital, were raising money again. Nearly 440 software and Internet firms went bust last year, but 400 new ones were created in their stead (The Economist, 9 Feb 02). MIT also retooled to bring business and academia closer together. So what was it that allowed Route 128 to constantly re-invent itself?

Three players were critical in the re-creation of Route 128: The Academia, Industry and Government (see Framework). Although each player had been motivated by fundamentally different goals, they all share interests in many fields of science and engineering. All the players displayed the "entrepreneurial" spirit that propels each individual to challenge its traditional boundary to explore and innovate. The area provided a good living and working environment to retain and attract new talents to build the human capital required for high-tech knowledge-based industries. This continuous interaction between the three players created a special blend of culture, people, institutions, and events that facilitated innovation and produce this hub of high technology environment. The entire system became the "engine" that facilitated the generation of the next wave of high-tech innovation and economic activities and formed many new companies.

4.3 Lessons from testing the Framework

a) Set of success factors must be incorporated in the planning and implementation of the Science City

The framework could be used to analyze the periods of relative success and failures in the technopoles' development trajectories. It was found that as more of the factors became present in the environments of the science cities, their relative success increases.

For example, TST did not have an industrial presence in its initial years, as it was a deliberate government policy to preserve its status as a high-quality environment purely for scientific research. Thus, the universities and research institutes were unable to foster interactions with industries to obtain feedback on their findings. TST was neither able to provide scientific benefits to neighboring cities nor become a true leading science and technology center of South Korea. By sheer will of a government, the coerced mass relocation of government institutions into TST built up a critical mass of scientific activities in the new city. After 1990, this "forced" cluster created new opportunities and made it natural consequence for private research institutes to relocate there. Local government reinforced private industrial presence by building industrial estates next to TSC.

It must be cautioned that the critical mass build-up may not be the only reason for industries to move to TSC. Concurrent to the scientific build-up, the government had also improved public infrastructures e.g. schools, etc, to provide a good quality environment for living. Government policies are also reviewed and improved to make it easier for start-ups and collaborations between public and private organizations. Thus, all the success factors have to be taken into account to make TST attractive and these factors should be taken into account from the outset when planning the science city.

b) Local condition will determine relative emphasis of different factors

Although the framework could be used to understand the critical ingredients that influence a science city project, factors could have different "emphasis" in different science cities. For example, TST and TSC placed lesser emphasis on network formation amongst businesses than to encourage collaborations between public research institutes and private enterprises. However, a less prevalent network of businesses does not mean that these science cities were not successful. It could alternatively be interpreted that "if TSC and TST could also subsequently develop a supporting pool of business networks within these science cities, it would probably enhance the cities' position both as a strong science research cluster and a commerce cluster".

Although the factors could have different emphasis in different science cities, several factors seemed to be strong anchors that consistently played very important roles in each of the science cities. These factors are: <u>Strong Science Base</u>, <u>Skilled Workforce</u>, <u>Supportive Policy Environment</u>, <u>Availability of Funding</u>, and <u>Need for synergy between Academia, Government and Industry</u>. These factors seem to form the basis for which other factors build on to enhance the attractiveness of the science city.

c) Success of Science City depends on how well it achieves its objectives and is measured by many factors e.g. number of spin-offs, extent of technology transfer, new innovations, job creation, etc

Number of spin-off companies is often a positive indicator for economic growth as they contribute to the business base, create jobs and add to economic diversity. Facilitating spin-off formation from a new discovery or innovation is thus often pursued as a government policy. However, if a science city does not create many spin-off companies, it does not mean that the Science City is unsuccessful. For example, in TSC, spin-offs formation was not a prominent policy goal as compared to TST and this outcome could be due to cultural or political peculiarities of each country.

The success of a science city should be studied not only in terms of job creation and level of innovation; it should also take into account whether the science city had achieved the specific objectives assigned to it. The objective of TSC was to facilitate public-private collaboration extensively with the goal of elevating the technological capabilities of industries. The extensive collaborations between public research and educational institutions with existing industries have indeed fulfilled this objective and TSC can thus be considered somewhat a success in this respect.

d) It is more critical that all factors be developed than which party is responsible.

The framework must not be interpreted in its strictest sense. The factors "under" each respective player are derived based on Route 128 case study. Notwithstanding this, it must be highlighted that it is less important "which" is the party "supplying" the respective factor. The critical point is that someone is providing it, thus enabling the factor to contribute to improving the environment so that the potential of the science city could be maximized. Therefore, different players could provide the same factor for different case studies.

For example, the government traditionally provides research funding for high-risk, long-term research activities that may not have immediate commercial value. Thus, private companies do not find it profitable to undertake such research. However, if a big corporation engages in joint research with the university in basic research, the sources of funding would not only be available from government grants, but also industry. If the financial structure changes to allow research institutes to have better autonomy over their finances, research institutes could generate additional income as a source of research funding. Similarly, a strong science base doesn't have to be formed purely by public institutions. In Japan, big corporations have known to invest heavily in corporate research and could similarly add to the development of a strong science base if several large companies concentrate their research branch in the same locale.

4.4 Other Lessons from Case Studies

a) Role of Government changes over time depending on the development stage of the science city

The role of Government featured strongly in all three case studies, especially in their initial years. The governments were able to "force" government institutions into the new science city regardless whether the science city or research institutes were ready to do so. For example, the infrastructure provisions for all three cities were not fully developed when the institutes were relocated. Especially for TST, which is located 160km from Seoul in the countryside, the employees were particularly unwilling to move there because their families had to remain in Seoul due to the lack of community facilities in TST. Similarly, TSC was also still considered "far" by the researchers due to long traveling time. The fact that the governments were powerful enough to effect the institutes' move into the science city made the feat of building a critical mass of scientific activities in the science city more manageable.

As the science city develops, the role of the government changes. A powerful State can become both a positive or negative force in the subsequent years of the city. The changes in the role of the government are manifested in how the government interacts with Academia and Industry through its policies at different stages of development, taking into account the culture prevailing in that country. Changes in government policies can and will directly affect the potential achievements of the Science City.

For example, the environment for innovation and entrepreneurial activities may be undermined if the government imposes unconstructive policies like in the case of Akademgorodok. Under Brezhnev, the potential of Akademgorodok was undermined as the government became more interested in the bureaucratic procedures and imposing extreme controls on research activities. This stifled the scientists' enthusiasm in their work and their ability to pursue their research. On the other hand, the governments in Korea and Japan were more developmental in their policies. The Korean government continued to improve the quality of schools, infrastructure, etc to make the new city more accessible and relaxed guidelines for research to make research environment more attractive to high-quality talents. The Japanese government studied the "ground sentiments" by carrying out regular surveys and reviews of strategic policy directions to ensure that TSC remains relevant in the changing environment. Such proactive action on the part of the government is commendable as it imposes a self-checking element into the science city development.

Overall, building a science city requires a strong political will on the part of the government to constantly "innovate" to attract industries, public organizations and talents from around the world. Its role has to eventually evolve from being a regulator to a facilitator once the science city gains some dynamism.

b) Developing a science city needs a long time

Any critical evaluation of the achievement of Science City can only be made over a long period of time. Governments are in danger of pre-judging whether a science city is successful or not after the science city is in "operation" for a few years. This could be due to high level of public accountability for the substantial public investment in the construction and infrastructure works, or simply pressures to present "results" during election times. However, time is needed for a science city to develop an identity, culture, social and business networks while the communication networks and human capital of the science city is being improved.

In all three case studies, assessments were carried out between the periods of its inception in the 1950s and 60s till the late 1990s. During these periods, all the science cities saw varying degrees of vitality and depression in its ability to be the leading science and technology center for the region. Akademgorodok was successful initially, before going down in the Brezhnev regime and finally, revived again after *perestroika*. Taedok and Tsukuba had little ability to be a milieu of innovation initially, but slowly gained strength in its later years. Castells and Hall noted that the Japanese applies an extraordinarily low discount rate to large public projects, which means that they were not expected to show an effective return for 20 or even 30 years. This showed that they understood that it requires a long time for a science city develop, and any judgment on the science city after only a decade of development would be a "profound mistake" (Pg 76, Castells and Hall, 1994).

c) Flexibility to deal with change i.e. political, technological and economical

The Akademgorodok case study illustrated that even if a science city was successful for a period of time, it did not guarantee success forever. The change in its dynamism and attractiveness could be due to a change in the internal and/or external environments affecting the science city e.g. a shift in technology, as experienced in Route 128 after minicomputers fell out of favor to personal computers. In view of the numerous factors and changes that could affect the science cities, it would not be possible for the government to constantly anticipate and be the "invisible" hand to manage prospective change all the time.

Since no regional economy has the birthright to lead the next wave of innovation, it is thus more important to ensure that the foundation of factors for a successful science city are built and entrenched into the system. This will ensure that the region can have the ability to re-industrialize and build its next boom after it experiences a setback. Ultimately, the real success of a science city or a high-tech cluster is its ability to withstand the test of time with constant innovation, even during different technological eras.

d) Importance of communication i.e. information flow and synergy

Synergy is often seen in terms of networks connecting individuals in many different organizations within a system. These networks encourage information flow and through this, generate new ideas. Such a place enjoys the peak of innovative milieu. As described by Castells and Hall, "synergy operates effectively to generate constant innovation on the basis of a social organization specific to the production complex located in that place" (Pg 225, Castells and Hall, 1994).

In the globalized capital markets where investment is mobile, location decisions of firms are often based on where they can reap the most economic benefits. Thus, science cities, together with its surrounding regions, should try to achieve such synergistic relationship so that it can transfer new knowledge to industries, which would allow industries to gain a competitive advantage in the global economy. As seen from Route 128's experience, the agglomeration of high-tech firms in the Route 128 region was primarily due to easy access to exchanges with other high-tech firms clustering in this area. Ultimately, it would be the access to information, state-of-the-art technology and innovative ideas that would make a location choice comparatively more attractive than other location options around the world. Thus, the system must foster synergistic activities and interaction between academia, government and industry to facilitate knowledge exchange. If not, there would be no reason why company and talents would want to remain in a concentrated area.

4.5 Policy Implications for Singapore

Like Korea and Japan, the Singapore government has been orchestrating her economic development since independence in 1965. In the early years, the government encouraged foreign investment as one of the pillars for economic growth. It was easier to attract foreign investment then because there wwere less competition from other countries. However, with the emergence of China and India, that could provide both cheap labor and a large domestic market, foreign investment has moved into these countries.

Countries around the world have also been enhancing their technological capabilities to produce higher value goods. For example, in terms of goods production, China now has a flying geese formation: cities like Shanghai and Shenzhen are in the lead producing higher value added goods, supported by hinterlands such as Shandong and Guangxi; while further down cities in the western region such as Chengdu and Xi'an produce more labour-intensive products. In India, the consensus was to gradually emerge from the old model of the licence raj and to plug itself into the international grid, in order to prosper with the rest of the world. Specific sectors had taken off dramatically, especially IT, showing India's potential if the whole economy could get moving (Speech by Singapore's Deputy Prime Minister Lee Hsien Loong, 19 Sep 2001).

In this competitive global economic landscape, the need for Singapore to reposition itself to capture the opportunities of globalization is even greater because of its inherently small domestic market. Singapore needs to re-think its economic development philosophy, find new, additional basis for economic growth and job creation. As commented by Singapore's Deputy Prime Minister Dr Tony Tan in the 6th meeting of the International Advisory Council (IAC) on new economic strategies for Singapore, "the new economy engenders a spirit of creativity, innovation and speed, and new rules are needed to embrace this spirit." The IAC advised if Singapore wants to become a global hub for knowledge-driven business and investment, she needs to build on her existing strengths to develop new pillars of competitive advantage that will stimulate innovation and enterprise formation.

4.5.1 Increasing importance in the role of the government

In recent years, many people have criticized that the Singapore government intervened too much in trying to "steer the economy" and that the market should play a bigger role in determining which sector should be developed. The government led Singapore out of the textile industry and into consumer electronics and semiconductors, and is now betting $2 billion on the life sciences. However, the reality is that only the Government has the might to move Singapore quickly into a potential high-growth sector in the current environment where knowledge asset is often proprietary and difficult for private enterprise to access. Thus, for an industry like the life sciences to take off, enormous expenditure is needed to build research centers, assemble world-class scientists, and support long-term research.

Fortunately, Singapore doesn't have to start afresh. The government's successful developmental policy in the last 40 years had enabled Singapore to develop its strength in having a world-class infrastructure, pro-business environment and skilled manpower. In the more recent decade, the government had also been introducing strategies to transform Singapore into a knowledge-based economy. The strategies employed are multi-faceted, ranging from tangible improvements, such as providing investment incentives to favored industries, developing purpose-built science parks for R&D activities, improving its communication infrastructure (transportation and telecommunication), providing source of funds for research and local businesses, to the intangible improvements such as improving the quality of education and urban environment of Singapore as a city to live and work in. Like other cities around the world, Singapore is also developing a miniature "science city" i.e. One North Science Hub next to the National University of Singapore to concentrate research institutions (private and public).

An example of a policy developed on the basis of the "new economy" is Technopreneurship 21. To enable technopreneurship to flourish in Singapore, the Government launched four initiatives centering on education, facilities, regulations and financing. The objective is to build a critical mass of technopreneurial talent, including researchers, innovators, investment bankers, analysts, marketers, venture capitalists, and patent and corporate lawyers. A US$1-billion Technopreneurship Investment Fund was also set up to jump-start the venture-capital industry.

Taking the entire Singapore as a technopole and using Figure 2.1 as a basis of analysis, it seemed that government's past strategies had generally served Singapore well, especially in terms of providing a foundation of developmental policies and strong industrial base. R&D activities, in particular, had been increasingly steadily over the years, from approximately S$756.8mil (US$416mil[1]) in 1991 to S$3009.5mil (US$1672mil) in 2000 (see Figure 1 in Appendix 8). In terms of providing research funding, the government is the 2nd largest source of R&D funding, providing 39% of total R&D funds for 2000. The largest source of fund is internal sources i.e. from the company themselves, etc, which amounts to 54% of total R&D funds in 2000 (NSTB, 2000).

However, despite investing heavily in R&D, Singapore still has a relatively weak science base as compared to other countries. At the same time, Singapore does not have a

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[1] Using an exchange rate of S$1.8 to US$1 for conversion.

strong entrepreneurial culture amongst its people, as compared to other advanced countries, thus making the process of commercializing innovative ideas more difficult (see Chapter 5).

4.5.2 To build a Strong Science Base and skilled workforce

Singapore distinguishes itself from other emerging economies because private sector accounts for a high share of its R&D. In 2000, its share of foreign firm investment in general expenditures in R&D is estimated to be 62%, or approximately US$1.03b (NSTB, 2000). A study done by Asian Development Bank Institute showed that the R&D carried out in Singapore by private research institutes was more "development" rather than "research" (Amsden, Goto and Tschang, 2000). They found that R&D in Singapore was more an adaptation of an existing product or concept and not cutting edge research. For foreign firms, any new research undertaken by the company is always done in their corporate headquarters. The study also found that whatever innovative R&D that does take place in Singapore results from government pressure on MNCs. The study thus shows that little pure science or basic research will be undertaken in emerging economies by MNCs, unless nationally owned enterprises have already taken the lead in investing such activities. Evidence from the survey of private R&D activities reaffirm the study's findings. In fact, no only does the private R&D engage in little basic research, even the government labs and public institutions engage in extremely little basic research activities (see Figure 2 in Appendix 8).

The study explains that the reason why companies did not undertake high-end R&D in Singapore was because of the size of effort required and the qualifications of researchers. The size of research effort in Singapore was smaller primarily because of the limited supply of highly qualified researchers. Thus, technological rents generated by R&D in Singapore could not be expected to equal those generated by R&D in corporate headquarters. Nonetheless, the author opined that Singapore remained distinct because there is a trend for MNCs to carry out more advanced types of R&D in Singapore due to the pervasive use of English and government incentives (Amsden, Goto and Tschang, 2000).

4.5.3 Policy Recommendations

In order to build Singapore into a true science city, it must first strengthen its science base. By virtue of Singapore's small size, developing a 'science city' per se seems secondary since the entire island can be considered a high-tech cluster itself. Furthermore, its good public communication infrastructure (telecommunication and transportation) makes every part of the island easily accessible. In terms of overall R&D expenditure, Singapore still lags behind other countries in terms of Gross Expenditure on Research and Development (GERD) as a percentage of GDP (see Figure 3 in Appendix 8).

In order to strengthen its science base, I recommend that the government improve the quality of its universities and research institutes. It is through the universities and research institutes that new knowledge is generated for the economy. Based on the Asiaweek Magazine's report on Asia's Best Universities in 2000, National University of

Singapore was ranked 6th in the category of "Multi-Disciplinary Schools"[2] and Nanyang Technological University was ranked 8th amongst the Asia's Science and Technology school. Japanese and Korean universities hold the top two positions of both categories (see Table 4.1).

Table 4.1: Asia's Best Universities 2000

Rank	Multi-Disciplinary Schools	Science and Technology
1	Kyoto University (Japan)	Korea Advanced Inst. of Science & Tech (South Korea)
2	Tohoku University (Japan)	Pohang University of Science & Tech. (South Korea)
3	University of Hong Kong	Indian Institute of Technology, Bombay
4	Seoul National University	Indian Institute of Technology, Delhi
5	***National University of Singapore***	Indian Institute of Technology, Madras
6	Chinese University of Hong Kong	Tokyo Institute of Technology
7	Hong Kong University of Science and Technology	Indian Institute of Technology, Kanpur
8	Australian National University	Indian Institute of Technology, Kharagpur
9	University of Melbourne	***Nanyang Technological University (Singapore)***
10	University of New South Wales	Taiwan University of Science & Tech

Source: Asiaweek.com

There must be good quality, innovative manpower behind the research projects. Thus, the government and education system must encourage more top students to take up PhD programs to make research a career option. Singapore's DPM Dr Tony Tan also expressed this need: "we still need to educate and train more scientists and researchers so that they can take the economy up to a higher level" (Straits Times Interactive, 10 Feb 02). Singapore must also attract top foreign researchers to work here to increase the number of high-quality manpower quickly. To be able to attract and retain innovation talent (local and foreign), Singapore needs to enhance the quality of life and to create an attractive work environment. The government research labs and tertiary institutions must carry out more basic research to "fill the research gap" that currently exists.

Concurrently, Singapore government could continue to provide the conditions that can entice private corporate R&D labs to engage in higher value research. However, as seen from the previous case studies, private investment will only increase their investment in a new place when they are assured that the environment is good. Thus, it is only when Singapore's national research institutions and research environment become world-class themselves, will it present a sustainable incentive for the private corporations to carry out higher-level cutting edge R&D in Singapore. When that is achieved, Singapore can then truly be considered a science city with a self-sustaining level of creative energy.

[2] Multi-disciplinary universities offer a broad spectrum of courses from arts to business to engineering. Science and technology schools have a more specialized focus.

4.6 Limitations of study

The research for the thesis was done using case study methodology. Lessons drawn for technopole development were based on the cases chosen for research. It would be ideal if the success factors could be tested through several more case studies.

Due to time limitation, I was unable to do surveys with industrialists to have first-hand information to reaffirm the success factors identified. Also, legal issues with regards to the sufficiency of patents and intellectual property protection were not explored in this thesis.

4.7 Future Research

A possible area for future research is to apply the success factors to Singapore and study in greater details how its policies could be improved to facilitate the advancement of Singapore's science and technology.

CHAPTER 5: ENTREPRENEURIAL CULTURE IN SINGAPORE

5.1 Introduction

Entrepreneurship has been described by the Center for Entrepreneurship at Babson College in Massachusetts as a way of thinking and acting that is opportunity obsessed, holistic approach and leadership. To have a culture of entrepreneurship in the society means that people must think differently, striving to be less conformist and more creative, able and willing to see and take advantage of an opportunity to improve things.

Many people have criticized that Singapore lacks an entrepreneurial culture. One such report is the Global Entrepreneurship Monitor (GEM) 2001 Executive Report[1], which systematically examined cross-national comparisons of the level of entrepreneurship. The GEM 2001 report indicated that Singapore had the third lowest rates of entrepreneurial activity among the GEM 2001 countries[2] (5.2 Persons per 100 Adults between 18 and 64 yrs old), only slightly above Belgium (about 4.5 persons) Japan (about 5.1 persons).[3]

Singapore's entrepreneurial culture is also often compared to that of Hong Kong's. With the communist liberation of the Mainland, Hong Kong received an influx of ready-made entrepreneurs, manufacturers, bankers, shipping operators and traders from the coastal cities such as Shanghai, Xiamen, Shantou and Guangzhou. They built the manufacturing industry in Hong Kong, starting with textiles, plastics, toys and business like shipping and banking. They were experienced entrepreneurs and spawned an entrepreneurial culture among other displaced people who flooded into Hong Kong. The bulk of immigrants that came to Singapore, however, were workers looking for wage employment. Those who did turn to business were mostly traders and shopkeepers with no experience in investing in factories that required long gestation periods and large capital expenditure before they could break even and eventually become profitable. Singapore banks were not keen to advance money to traders to start factories as the bankers did not have the experience or the expertise to make such risk assessments and to manage the risks. Although some Chinese immigrants did build enterprises that became large local enterprises today e.g. the banks, trading companies, family retail and

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[1] Leading scholars of Babson College and London Business School initiated GEM program in 1997, with strong support from Kauffman Center for Entrepreneurial Leadership at the Ewing Marion Kauffman foundation in Kansas City, Missouri. IBM became a global sponsor for GEN 2001.

[2] The countries in the GEM report includes Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, the Netherlandsm Norway, Poland, Portugal, Russia, Spain, Sweden and U.K from the European Region; India, Japan, Korea and Singapore from the Asian Region; Argentina, Brazil and Mexico from the Latin American Region; Canada and USA from the North American Regions; and Australia, Israel, New Zealand and South Africa. Data were assembled for each participating country from four basic sources: 1) surveys of at least 2000 adults in each country; 2) in-depth interviews with more than 950 national experts on entrepreneurship; 3) standardized questionnaires completed by the national experts; and 4) a wide selection of standardized national data.

[3] The report also noted that the small size of Singapore's domestic market and the general weakness in the economies of the region has made it more difficult for start-ups to grow without exporting. Those seeking funding therefore have to demonstrate an ability to penetrate global markets.

real estate empires, Singapore, in general, is belief not to have "inherited" a strong entrepreneurial tradition.

However, if entrepreneurship is about a way of thinking, opportunity seizing for improvement and leadership in implementation, then, entrepreneurship is not only about new venture creation by private individuals. Entrepreneurs could be either public or private entrepreneurs i.e. entrepreneurs in state-owned enterprises and privately owned enterprises. If this were so, Singapore should have more entrepreneurs than perceived due to the strong presence of successful state-owned enterprises.

5.2 Paradox of Income Distribution

The rise of state owned enterprises in Singapore could be explained using the theory of the Paradox of Income Distribution (Amsden, 2001). The theory states that:

a) The more equal the income distribution, the more the government will concentrate its resources through the use of industrial policies to build up "national firms" and establish their core competencies inside or outside manufacturing.

b) The greater the inequality, the more diffusionist the policies and hence, the greater the difficulty of creating national leaders with proprietary, cutting-edge skills.

Why is this so? The reasons are as follows:

a) An unequal distribution of natural resources (thus affecting income distribution) tends to create Ricardian quasi-rents. Thus, if the flow of resources from agriculture to manufacturing depend on relative rates of return, these rents make it more difficult for manufacturing to compete for resources, especially in the absence of knowledge-based assets that create offsetting entrepreneurial manufacturing rents. With quasi-rents, intermediate assets have to be higher than otherwise to make manufacturing relatively profitable and to entice the rich entrepreneurs to invest in manufacturing.

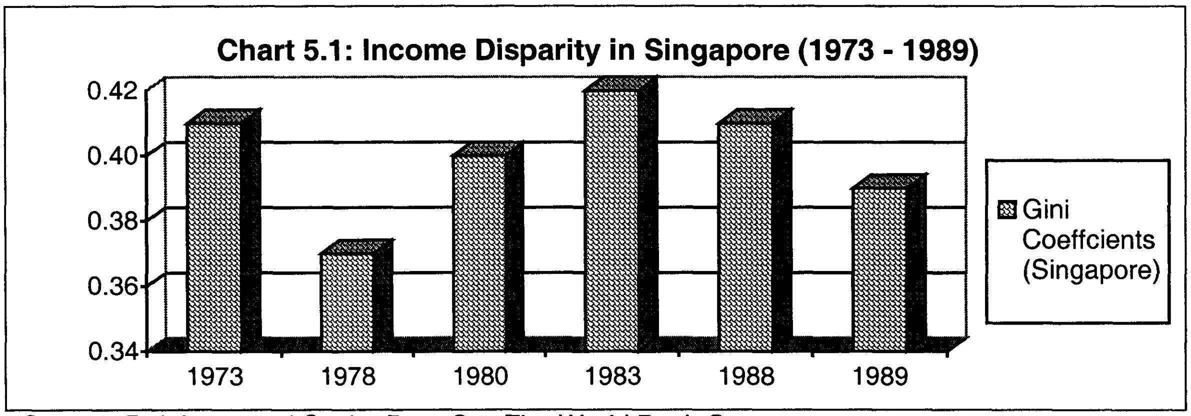
b) Government may allocate intermediate assets to either a relatively large number of firms (diffusion) or to a relatively small number of "national leaders" (concentration). The association between income inequality and diffusionist policies is paradoxical because, if governments (especially authoritarian governments) are regarded as a handmaiden of the rich and powerful, then a concentration of subsidies is expected when existing income distribution is highly skewed. However, if the government skews subsidies to favor existing rich people (because they are experienced businessmen with project execution skills), it will further increase the income inequality gap, making it politically undesirable. Thus, it is the countries with equal income distributions that tend to have developed highly capable national firm leaders and build core competencies.

Using a sample of late industrialized countries as case studies, Amsden showed that that countries with the most equal land distributions i.e. Korea Taiwan and Thailand (Gini coefficients below 0.5) invested heavily in national firms to build national skills whereas countries with the most unequal land distributions i.e. Argentina, Brazil, and Malaysia (Gini coefficients of 0.7 or above) relied on broad diffusionist approach and could not develop core competency in knowledge-based assets.

5.3 Rise of State-owned Enterprises in Singapore

After gaining independence in 1965, the government invested heavily in *physical infrastructure* e.g. port, airport, roads, utilities, industrial estates, health and education. The government concurrently embarked on an industrial strategy of labor-intensive export manufacturing led by *multinationals*, especially in the electronics industry (Texas Instruments, Fairchild, etc.) for mass employment creation and global market access.

In the late 1960s and early 1970s, Singapore experienced a relatively equal income distribution (Gini coefficient of less than 0.5 - see Chart 5.1), largely because of the new home ownership scheme. As a new nation little natural resources and a small primary production sector, the government geared its investment towards industrialization in target industries e.g. petrochemical, cement plant, construction, shipbuilding, etc. Without a pool of promising local enterprises that the government could "groom" into big local business groups (unlike Korea), the government set up state owned enterprises in these key industries and started to build core competencies in these industries.



Source: Deininger and Squire Data Set, The World Bank Group

Because Singapore lacked the capital or interest, government ministers undertook the task of starting new ventures (The Straits Times Interactive, 9 Feb 2002). The government invested heavily in *state-owned enterprises* in key sectors. Successful finance ministers undertook the task of starting new enterprises. For example, the late Finance Minister Goh Keng Swee started a shipping line with government officers and a Pakistani shipping expert to guide them. Neptune Orient Lines (NOL) eventually succeeded. When Malaysia-Singapore Airlines was broken up, the government started Singapore Airlines (SIA) headed by some outstanding civil servants. The same story applied to other enterprises such as National Iron & Steel, Chartered Industries, Keppel Group, Sembawang and Jurong shipyards, and several enterprises in food processing. To undertake the risks of lending to new manufacturing ventures, the government started the Development Bank of Singapore (DBS). These businesses grew into conglomerates e.g. SIA, SingTel, SingTech, Keppel and became Government-Linked Companies (GLCs) when partially privatized through the stock market.

How did the government attract so many public entrepreneurs into the public sector? To build a good-quality government, prestigious full government scholarships were offered to about 250 top young students each year with good academic results to pursue tertiary education in world-class universities in the US and UK. The government scholarships are awarded on a meritocracy basis. These young students, known as "scholars", will serve in the government upon graduation and are almost guaranteed good paying, high-ranking public sector jobs or GLCs. Since the 1970s, the expansion of the civil service and state owned sector was complemented by this steady supply of top-notch human capital in the country. These "scholars", who returned to work as salaried managers and technocrats, benefited from expansion of the civil service and state-owned sector. Thus, under this system, the smartest are "pulled" into the government service and act like "public entrepreneurs" in their posts.

The state of GLCs now

There are now approximately 50 GLCs in Singapore in various industrial sectors (see Appendix 9). GLCs play an important in the Singapore economy. Many of the GLCs are successful companies today and ranked amongst the top companies in the world in their industry sector. Their estimated contribution to GDP in 1998 was 12.9 per cent, which was more than a quarter of local-controlled companies' estimated contribution to GDP.

The presence of these GLCs is over-whelming. For the average Singaporean, the government or some government-linked (owned) entity is her landlord/ property developer, banker, savings/mutual fund manager (i.e. Central Provident Fund[4]), utilities provider (telecoms, electricity, water), public transport provider (transit, bus, taxi), media provider (newspaper, radio, TV), educator (kindergarten through university), recreation provider, and may well be her employer, insurer and provider of other services--not through taxes, but through fees charged by profit-making (often monopolistic) government or government-linked entities, in which she herself is likely to own stock. Local business is disproportionately reliant on government and multinationals as customers (Linda Lim, 2002). Thus, Singapore experienced a situation where the GLCs are "crowding out" the local businesses, as they are so competitive and could enjoy economies of scale.

However, to stay ahead of global competition, Singapore cannot rely only on MNCs and GLCs. Entrepreneurship in the private sector is an important factor in introducing economic dynamism into Singapore. To bring Singapore to the next phase of development, the government policies need to encourage the formation and growth of enterprises. Only then, can Singapore into a vibrant business hub for companies big or small.

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[4] Singapore's version of superannuation fund where a total amounting to 40% of monthly salary will be deposited into the CPF funds. These CPF is used only for selected investment or purchase.

5.4 Singapore's Local Private Enterprises - Private Sector Entrepreneurship

As shown in the GEM study, the current state of private entrepreneurship is indeed lower than most countries. Although part of the reasons could be that the best human capital are already absorbed into the public sector, thus reducing the pool of "potential private entrepreneurs" the fact remained that the entrepreneurship is not a prevalent cultural trait in Singapore. This sentiment is often echoed by observers locally and abroad.

- "Singapore's habits are found to stall innovation" *IHT 3/24-25/01*[5]

- "The survey found that among the things hindering Singapore were "fear of failure and an associated preference for stable, corporate employment". Analysts say Singapore's paternalistic government, its conformist political culture and an education system that puts too little emphasis on independent thought and creativity had combined to stifle innovation. "The hard truth is that Singapore has cultivated a generation of followers rather than a generation of innovators..... That's fine for massive, concerted, centrally-directed growth. But at a time of rapid change and the need for multiple and continuous innovation across an entire economy, the supply of entrepreneurs is suddenly, painfully short." *Global Entrepreneurship Monitor Study*

- "We Singaporeans are too careful, too rule-based, and when we have no rules, we are paralysed." *Sim Wong Hoo, chairman of Creative Technology and head of private sector committee that promotes technology-based entrepreneurship.*

- "In Singapore many of those who were most likely to succeed have been inducted into politics, the bureaucracy and the army, navy and air force. Hence too few are in business on their own and even fewer are entrepreneurs." *Senior Minister Lee Kuan Yew, Feb. 5, 2002, speech.*

5.5 Government efforts in entrepreneurship development

A vibrant entrepreneurial culture in a society cannot develop overnight. It has to be a national effort to nurture a pro-enterprise environment. The Government, through its various agencies, has been undertaking the role of a nurturer and facilitator. They are inculcating creative thinking skills in students, providing program to empower existing entrepreneurs with business skills, and recognizing the successful efforts of homegrown entrepreneurs, among others. Some of the efforts in creating a pro-entrepreneurship environment include the following (Mr Tang Guan Seng, 24/3/2001, speech):

5.5.1 Education

Revamping the educational system by Ministry of Education and introduce courses on entrepreneurship in institutes of higher learning. For example, the School of Computing in National University of Singapore now conducts a minor in entrepreneurship for Engineering students. The Entrepreneurship Development Center at NTU conducts a 2-week course called the Enterprise Development Growth and Expansion (EDGE)

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[5] Quote extracted from Prof Linda Lim's speech.

program for the CEOs and managers of Small and Medium Enterprises (SMEs). Polytechnics have also introduced entrepreneurship modules and established centers such as the Technopreneurship and Design Center at Nanyang Polytechnic.

5.5.2 Schemes to assist SMEs

There are now over 60 program offered by statutory boards that provide various forms of assistance to SMEs. For instance, SMEs can make use of the Local Enterprise Technical Assistance Scheme (or LETAS) for human resource development. It defrays up to 50% of the fees paid to consultants who help "professionalize" the human resources management of SMEs. There is also the e-GEN (e-Growing Enterprise Net-enabling) Education jointly offered by PSB and HP, which provide training to SMEs in e-commerce, critical skills in today's knowledge-based economy.

5.5.3 Recognition of homegrown entrepreneurs

For Singapore to become a place where enterprises and innovation thrive, these efforts can only help complete half the journey. The Government can only play a supporting role, and assist where necessary. The people are the ones who would have to complete the other half of the journey, to take advantage of new opportunities, upgrade their skills, and find their niche in the global market.

To encourage more entrepreneurs, the government uses a "role model" approach by giving due recognition to those who are pro-active, who have succeeded despite failures along the way. The various awards given to local entrepreneurs are Phoenix Award, the Enterprise 50 Awards, and the inaugural Netrepreneur of the Year Award.

5.5.4 On-going Efforts

On 3 Dec 2001, the government set up a 7-team Economic Review Committee to fundamentally review Singapore's development strategy and formulate a blueprint to restructure the economy. The Committee is to work out new strategies to develop upgrade, transform and revitalize the Singapore economy for development as a regional hub in Asia to sustain economic growth, create new jobs and increase the wealth of Singaporeans. One sub-committee was designated to study the promotion of entrepreneurship, and the growth and internationalization of Singapore-based companies. The entrepreneurship sub-committee felt more talent needed to be channeled into building businesses. As a preliminary proposal, the committee proposed that 10 per cent of scholarship holders should be allowed to opt, or be selected, to pursue private sector opportunities. They could either be told to defer their bonds or leave upon their completion (The Straits Times Interactive, 8 Apr 2002).

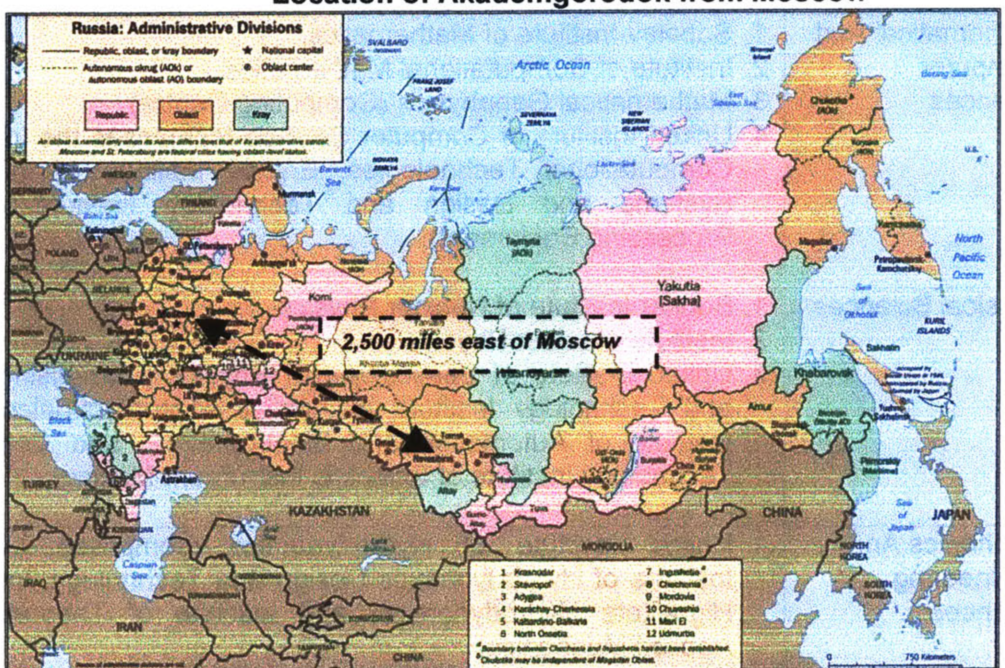
5.6 Conclusion

While it seemed that Singapore did not inherit the entrepreneurial culture from her early immigrants, she is not entirely lack of entrepreneurs. Singapore's entrepreneurs are mainly "public entrepreneurs", implementing change and innovating in the civil service and GLCs.

To develop a dynamic economy, it is no longer sufficient to rely on MNCs and GLCs. The government policy now is to "breed" entrepreneurs. More people must be nurtured to be more independent and self-reliant. They must be prepared to accept failure in entrepreneurial and innovation effort. The environment and policies must facilitate easy firm formation and to allow small business to thrive among the enterprises in the global economy.

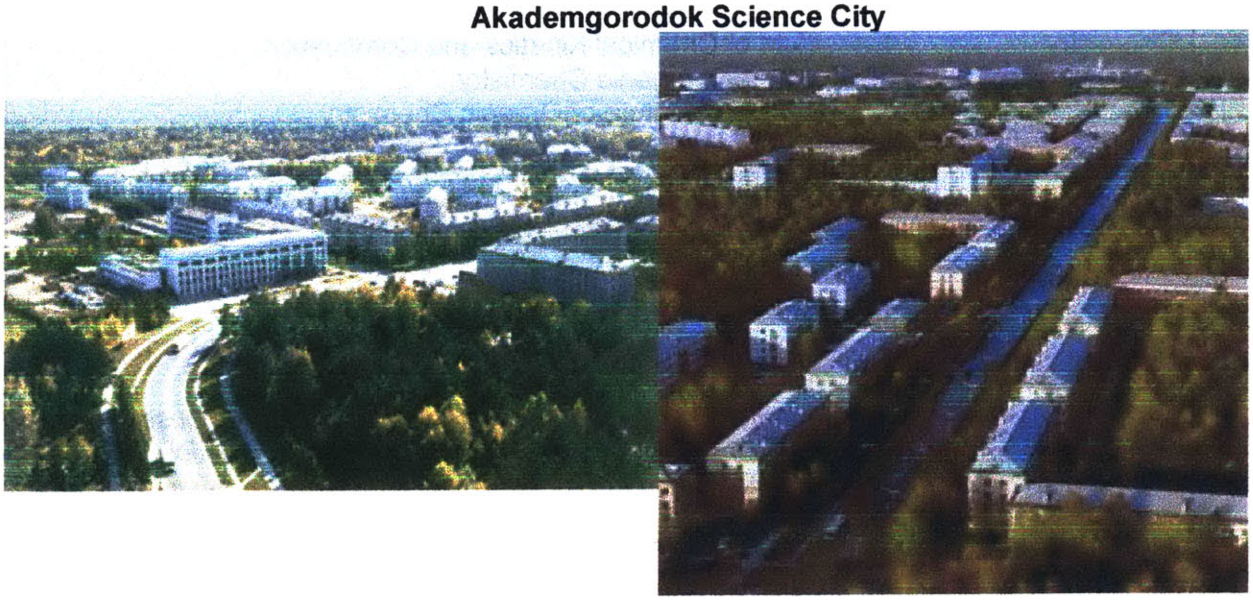
APPENDIX 1

Location of Akademgorodok from Moscow



Source: http://design.lbl.gov/~telnov/htmls/akadem.html

Akademgorodok Science City



Source: http://www-sbras.nsc.ru/sicc/sbras_.htm, http://design.lbl.gov/~telnov/htmls/akadem.html

Examples of Research Areas in Akademgorodok

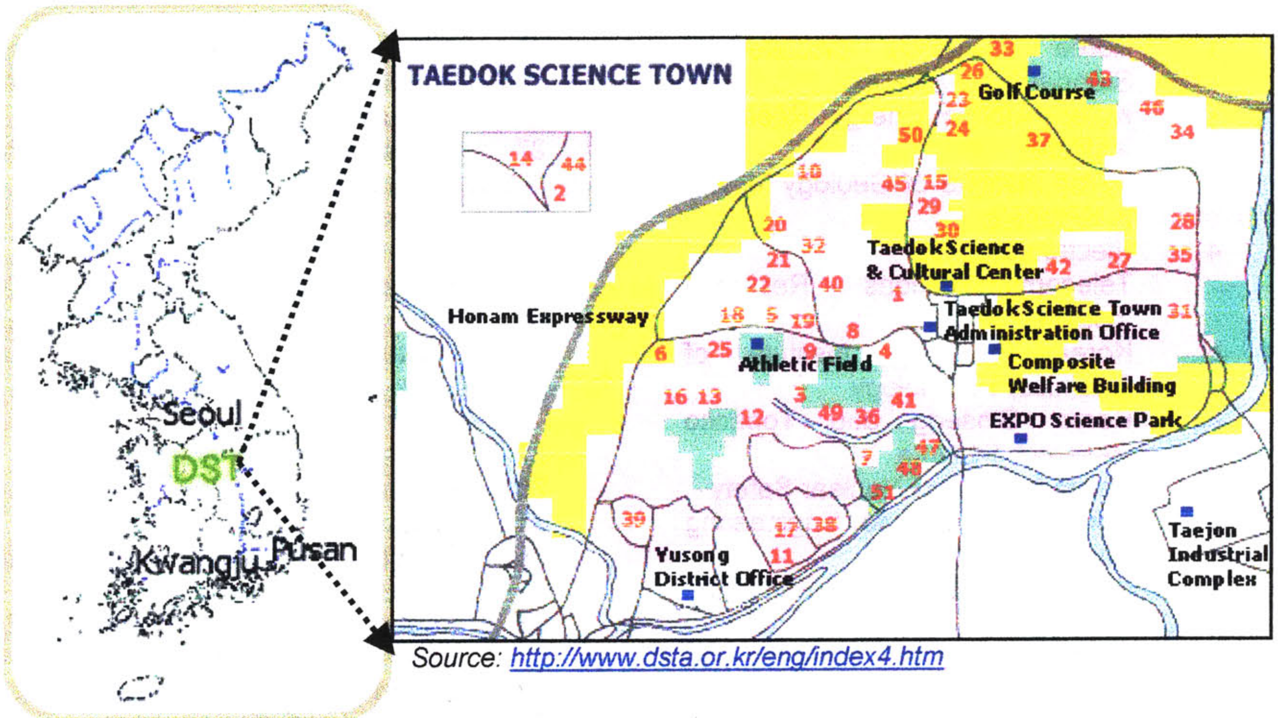
S/no	Research Areas	Research Institutes in Akademgorodok
1	Mathematical And Computer Sciences	1. Sobolev Institute of Mathematics, 2. Institute of Computational Mathematics 3. Mathematical Geophysics (Computing Centre) 4. United Institute of Computer Science (comprises the Institute of Computational Technologies, Ershov Institute of Informatics Systems and Design and Technology Institute of Data Processing Equipment)
2	Physical Sciences	1. Budker Institute of Nuclear Physics 2. Institute of Laser Physics 3. United Institute of Semiconductor Physics (Comprising Design and Technology Institute of Applied Microelectronics, United Institute of Automation and Electrometry , and Design and Technology Institute of Scientific Instrument-Making)
3	Mechanics And Engineering Sciences	1. United Institute of Hydrodynamics (comprises Lavrentiev Institute of Hydrodynamics Design and Technology, Institute of High-Rate Hydrodynamics, and Institute of Theoretical and Applied Mechanics) 2. Kutateladze Institute of Thermal Physics 3. Institute of Mining.
4	Chemistry	1. Institute of Chemical Kinetics and Combustion, 2. Institute of Inorganic Chemistry, 3. Vorozhtsov Institute of Organic Chemistry, 4. Institute of Solid State Chemistry and Mechanochemistry, 5. United Institute of Catalysis
5	Life Sciences	1. Institute of Soil Science and Agrochemistry 2. Central Siberian Botanical Garden 3. Institute of Animal Systematics and Ecology 4. Institute of Cytology and Genetics 5. Institute of Bioorganic Chemistry *The institutes engaged in life sciences have greenhouses, vivaria and experimental farms, including a unique collection of genetic pool of native animals.*
6	Earth Sciences	1. United Institute of Geology, Geophysics and Mineralogy. Sukachev Institute of Forest 2. Novosibirsk Department of the Institute for Water and Ecological Problems *Four associated institutes are engaged in studies of general geology, petroleum and gas geology, geophysics, mineralogy and petrography.*

S/no	Research Areas	Research Institutes in Akademgorodok
7	Social Sciences	1. Institute of Economics and Industrial Engineering, 2. United Institute of History, Philology and Philosophy with its associated institutes of Archaeology and Ethnography, History, Philology, Philosophy and Law.
	The State Public Science and Technology Library of the SBRAS plays an important role in information supply for research and educational institutions of Novosibirsk, as well as of the whole Siberia and the Far East. The library is the largest to the east of the Urals and stands with the largest libraries of the world in importance.	

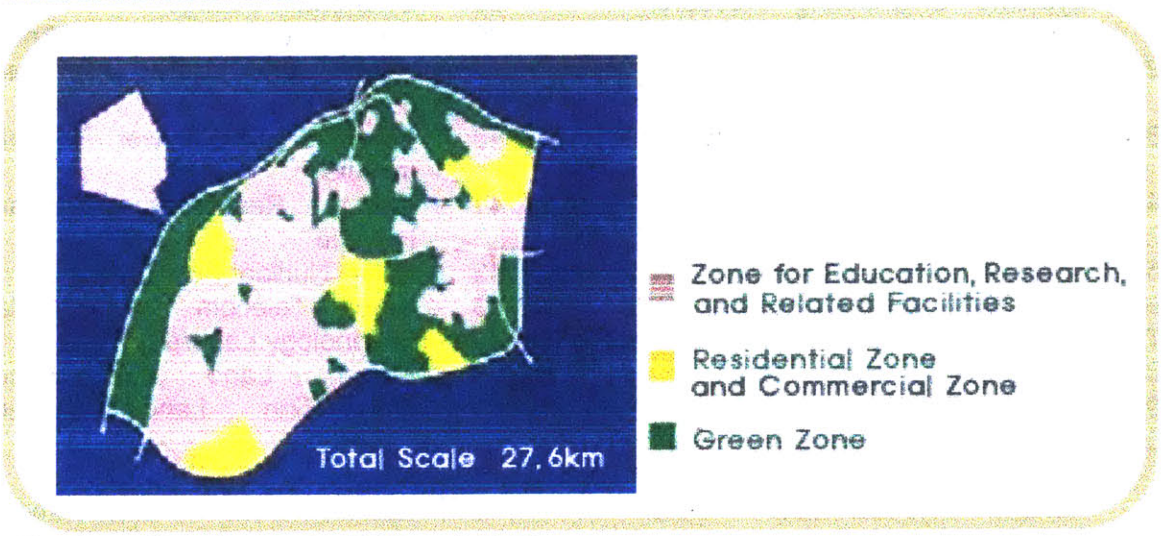
Source: Siberian Branch of the Russian Academy of Sciences, (1998) http://www-sbras.nsc.ru/sicc/welcome.html

APPENDIX 2

Map of Taedok Science Town



Source: http://www.dsta.or.kr/eng/index4.htm



Distribution of land uses in 1988 and 2000

Land Uses in TST		Education and research facilities (sq. m)	Residential & Commercial areas	Green area and others	Total
Percentage of total land area	**1988**	13,157,084 (48%)	2,181,828 (9%)	11,867,822 (43%)	27,600,000 (100%)
	2000	12,696,000 (46%)	1,932,000 (7%)	12,972,000 (47%)	27,600,000 (100%)

Source: DSTA

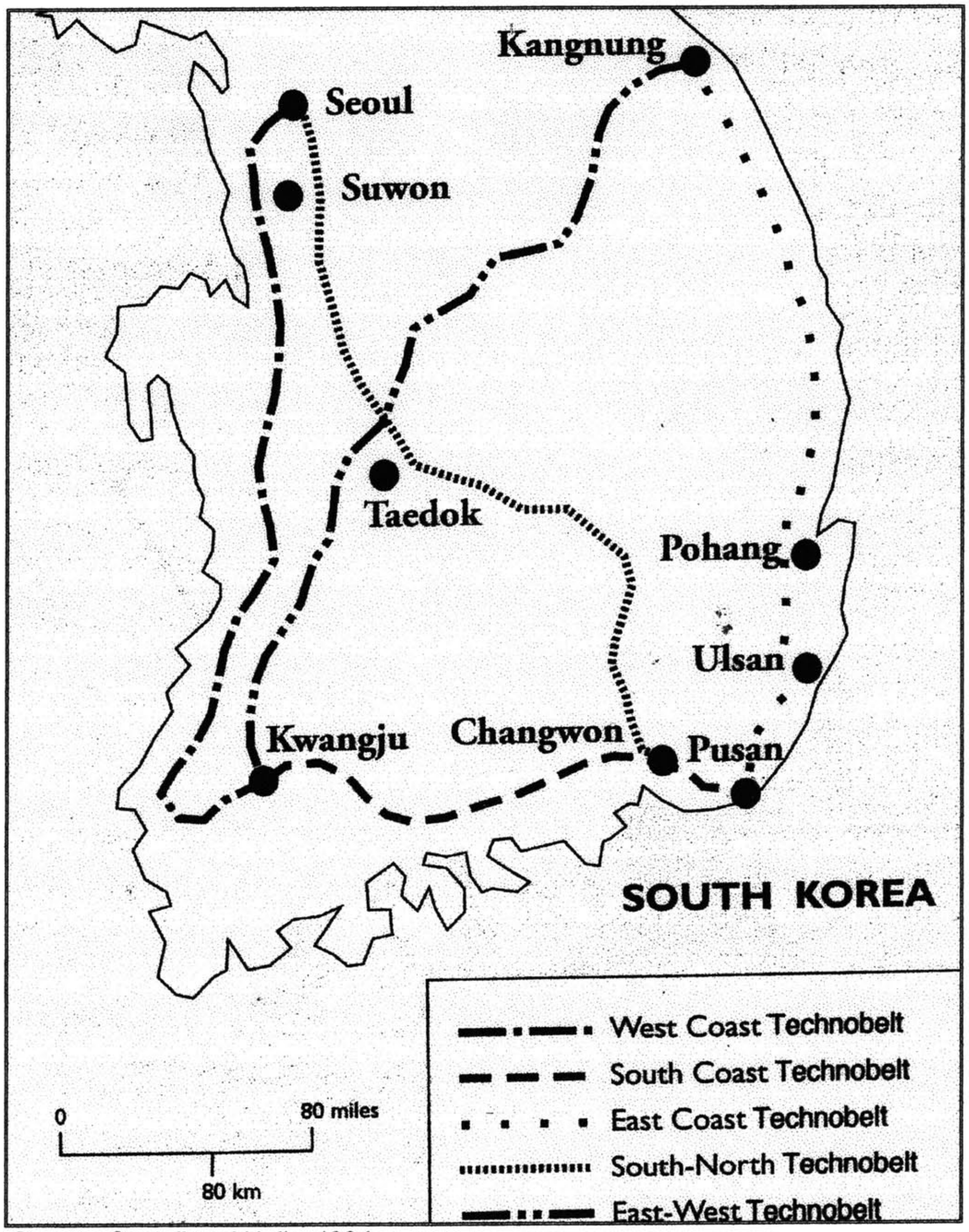
LIST OF RESEARCH INSTITUTES (PUBLIC AND PRIVATE) IN TST

1 Korea Research Institute of Standard and Science
2 Korea Atomic Energy Research Institute
3 Korea Institute of Geology Mining & Materials
4 Electronics and Telecommunications Research Institute
5 Korea Research Institute of Chemical Technology
6 Korea Ginseng and Tobacco Research Institute
7 Korea Institute of Nuclear Safety
8 Korea Science and Engineering Foundation
9 Korea Institute of Energy Research
10 Korea Institute of Machinery and Metals
11 Systems Engineering Research Institute
12 Korea Institute of Bioscience and Biotechnology
13 Korea Aerospace Research Institute
14 Nuclear Environment Technology Institute
15 Korea Astronomy Observatory
16 Korea Basic Science Institute
17 Science Technology Yellow Page
18 Ssangyong Research Center
19 LG Chemical Research Park
20 Hankook Tire Research and Development Center
21 Honam Petrochmical Corp. Taedok Research Institute
22 Daelim Industrial Co. LTD Taedok Research Institute
23 Shinsung Technology Research Institute
24 Hanhwa Group Research and Engineering Center
25 Pah Chun R&D Center
26 Samsung Technology Research Institute
27 Samsung Advanced Institute of Technology
28 Samsung Fine Chemicals Co. LTD R&D Center
29 Kohap Taedok R&D Institute
30 Samyang Genex Research Institute
31 Sunkyang Group Taeduk science Town
32 Korea Register of Shipping
33 Kumho Chemical Laboratories
34 Taekwang Research Center
35 Dongbu Advanced Research Institute
36 Korea Advanced Institute of Science and Technology
37 Chungnam National University
38 Chungnam College
39 Korea Security Printing & Miniting Corporation Technical Research Institute
40 Korea Electric Power Research Insitute
41 Water Resources Research Institute
42 Korea Nuclear Fuel Co. LTD
43 Korea Telecom Outside Plant Technology Laboratory
44 Korea Land Development Corporation. Land Research Institute
45 National Science Museum
46 Keum River Environmental Management Office
47 International Intellectual Property Officials Training Institute
48 Taejon Metropolitan City Officials Training Institute
49 Taejon Regional Meteorological Office

APPENDIX 3

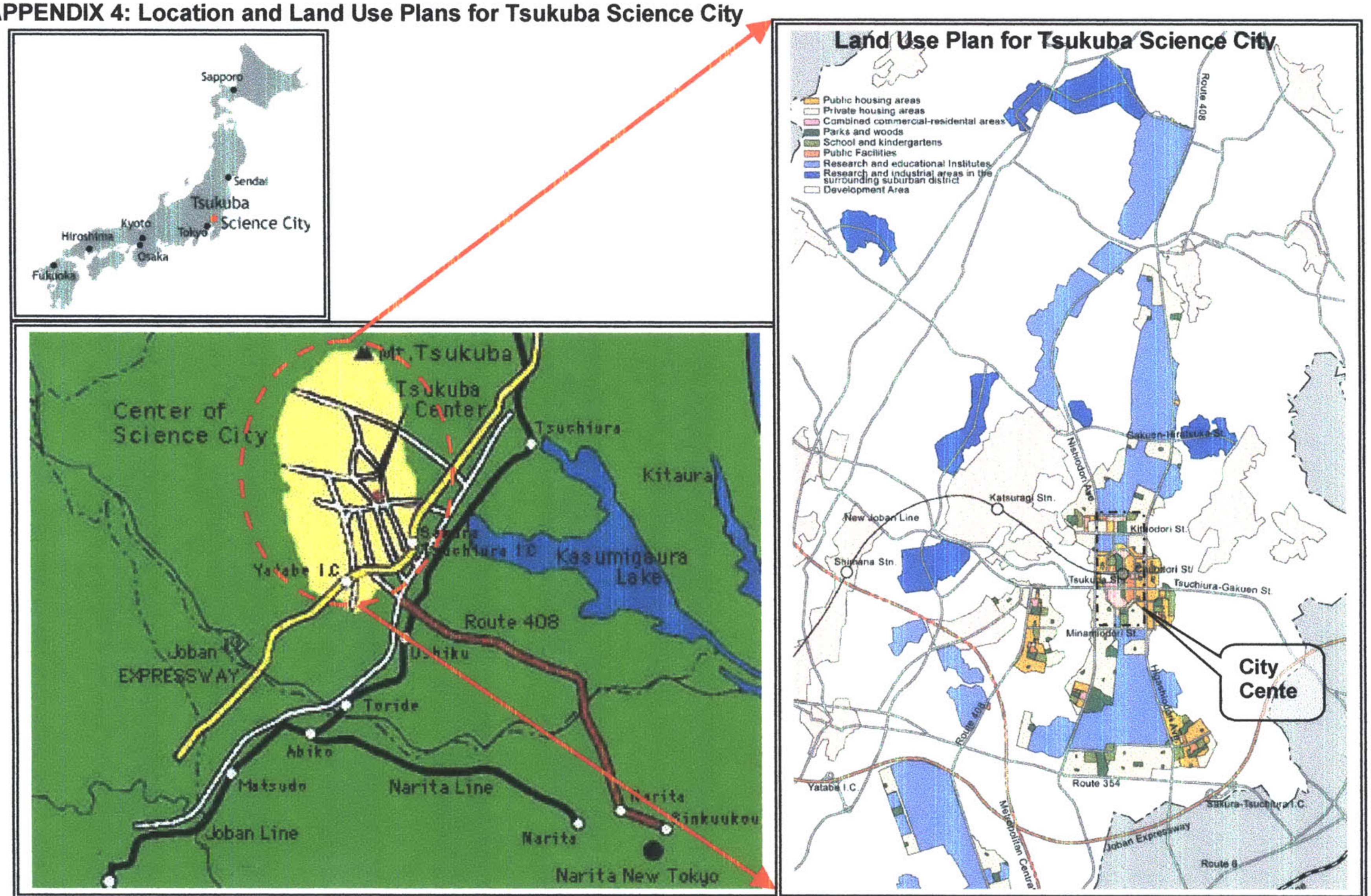
SYSTEM OF 'TECHNOBELTS" ACROSS SOUTH KOREA

1. A West Coast Belt, from Seoul to Kwangju, specializing in energy and food production;
2. A South Coast Belt, from Kwangju to Pusam, centered on heave industry;
3. A North-South Bent, linking Suwon, Taedok and Pusan, organized around electronics, semiconductors and textile industries; and
4. An East-West Bent, connecting Kwanghu, Taedok and Kandnung with new developments in medical and social services research and production.



Source: Castell and Halls, 1994

APPENDIX 4: Location and Land Use Plans for Tsukuba Science City



Source: TSCI

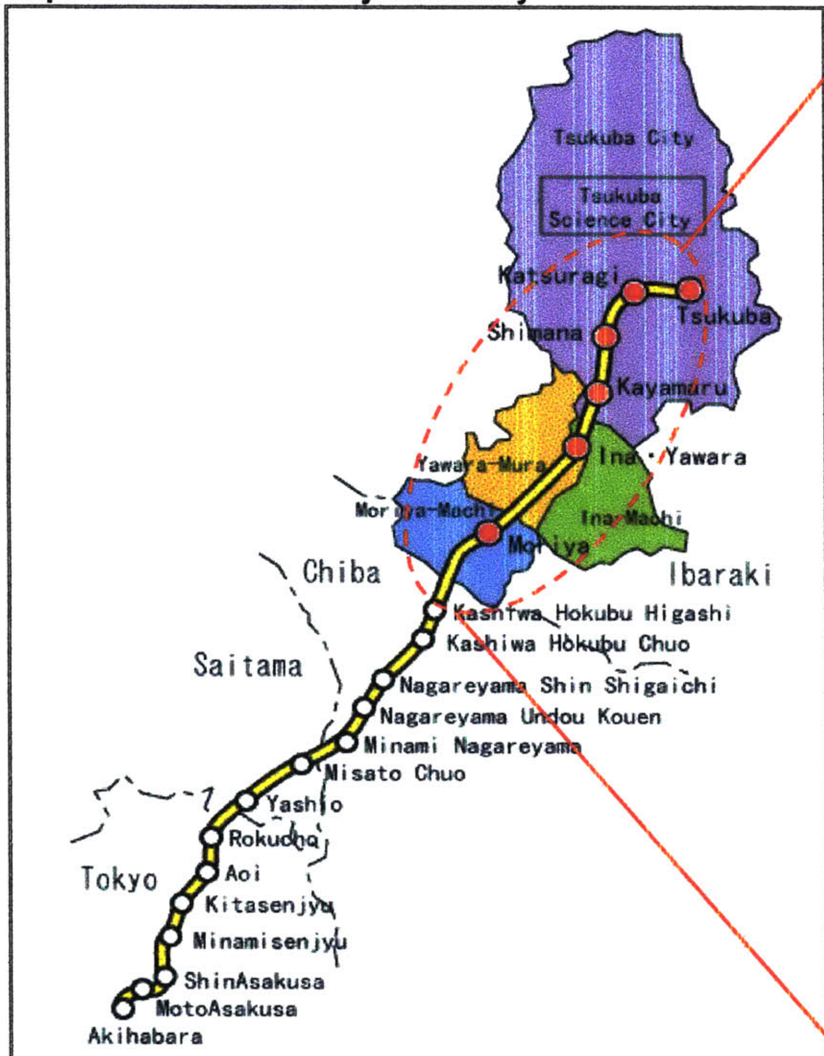
APPENDIX 5

Chronology of Events for Tsukuba Science City

Year	Event
1963	The Cabinet approved the Tsukuba area as the site of a new science city.
1964	The National Region Development Commission completed a blueprint for the Academic New Town. The Cabinet approved a plan to start the construction from 1965 and to complete it within about 10 years. The Cabinet decided to found the Academic New Town Construction Promotion Headquarters.
1966	Land acquisition began.
1967	The Cabinet approved of the basic policies of the development of the New Town, and identified 36 national institutes to be relocated.
1968	Construction work of research/educational facilities started with a large-scale earthquake simulator at the National Research Center for Disaster Prevention of the Science and Technology Agency.
1969	The Cabinet decided to complete transfer of 11 national institutes by 1972.
1970	The "Tsukuba Science City Construction Act" was enacted and implemented.
1971	The head office of promotion of Science City Construction finalized fundamental principles of the development project and outline of the construction program of public and service facilities.
1972	Government employees started to move into official residences. The National Research Institute in Inorganic Material became the first institution transferred to the city. The Cabinet decided to increase the number of national institutes to be relocated or newly established to 43.
1973	The University of Tsukuba was opened.
1975	The Cabinet decided to change the final date for the completion of the transfer of all research/educational institutes from 1975 to the end-fiscal year 1979.
1977	The Tsukuba Academic New Town Council, comprising Ibaraki Prefecture, towns and villages concerned, research and educational institutes in the area and Japan Housing Corporation, was established.
1980	43 research and educational institutions were ready to begin operations. The "Research and Education District Construction Plan" was approved.
1981	The "Surrounding Suburban District Development Plan" was approved.
1983	The Tsukuba Center Building was open.
1985	The International Exposition of Science and Technology (Tsukuba Expo'85) was held, attracting more than 20 million people. Joban highway was directly connected to Tokyo.
1987	The merger of existing towns and villages officially formed Tsukuba City.
1989	The New Tsukuba Plan was drawn up.
1996	The "Science and Technology Basic Plan" was decided.
1998	A change of the "Research and Education District Construction Plan" was decided, and a change of the "Surrounding Suburban District Development Plan" was approved.

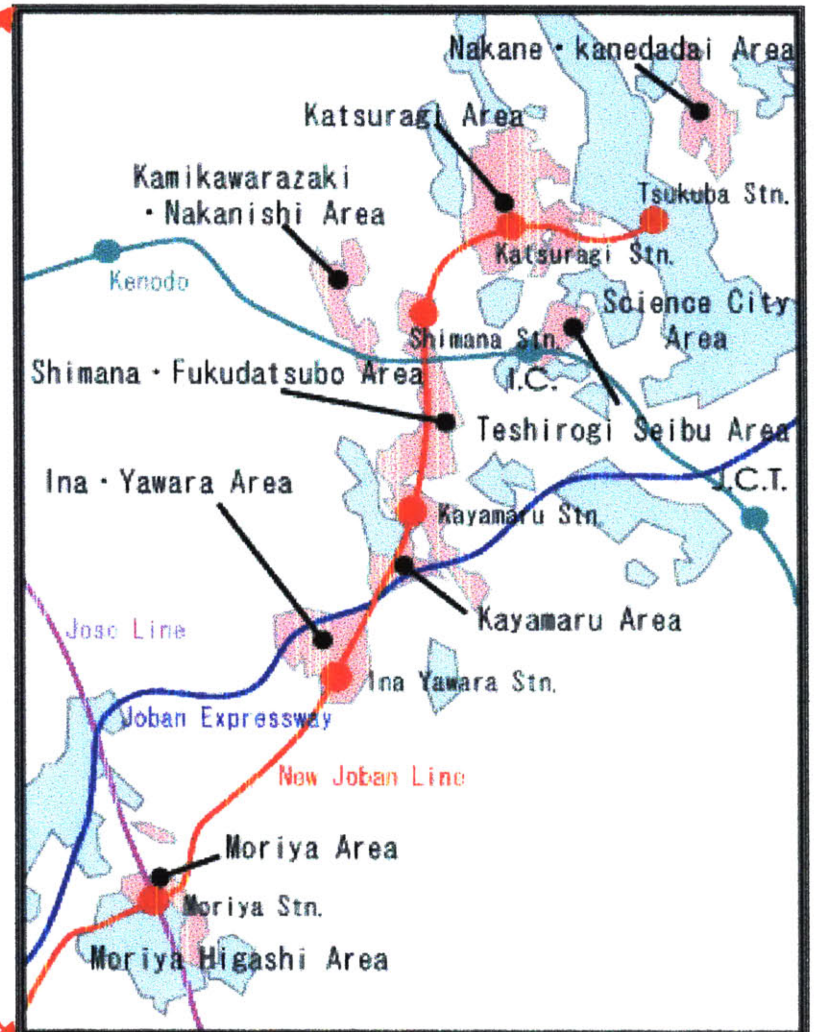
Source: TSCI and Castells and Halls, 1994

Map: New Joban Line Project Railway



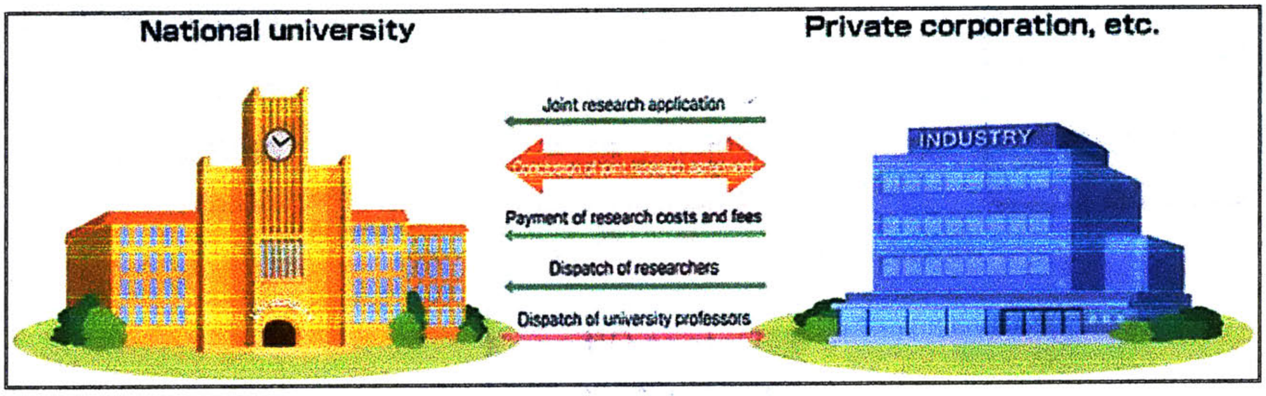
Source: Tsukuba Science City Information

Map: Future settlements along New Joban Line

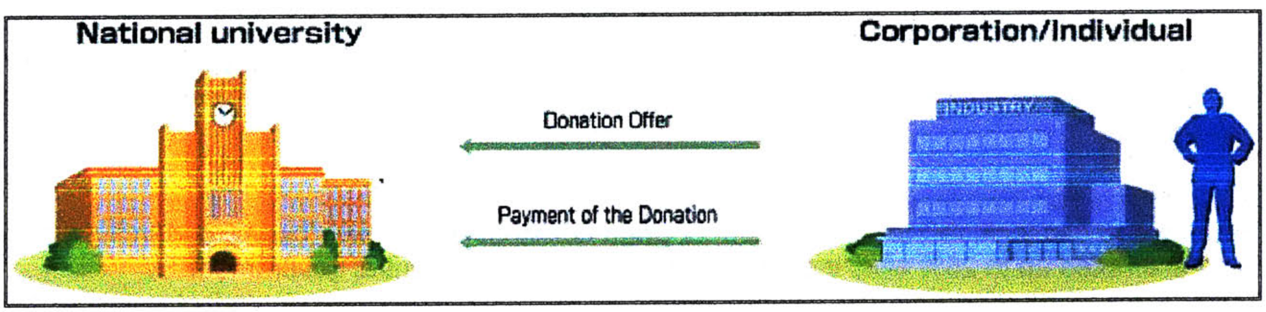


Framework for Partnership Between Universities and Industry

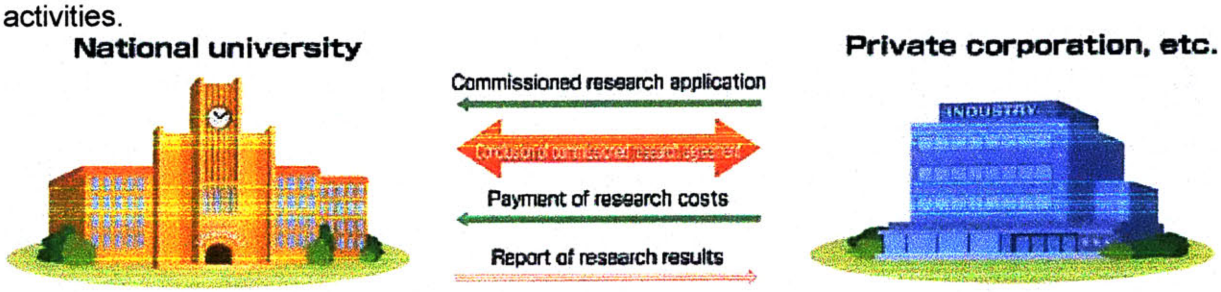
Joint Research
This form of collaborative research started in 1983, where researchers from private corporations, etc., and professors from national universities conduct research on an equal level on issues common to both parties.



Commissioned Research
Commissioned research refers to research conducted publicly under the commission of private corporations by national university professors. The number of Commissioned Research has gone up from 1286 cases to 4499 cases with a much faster rise after 1994.

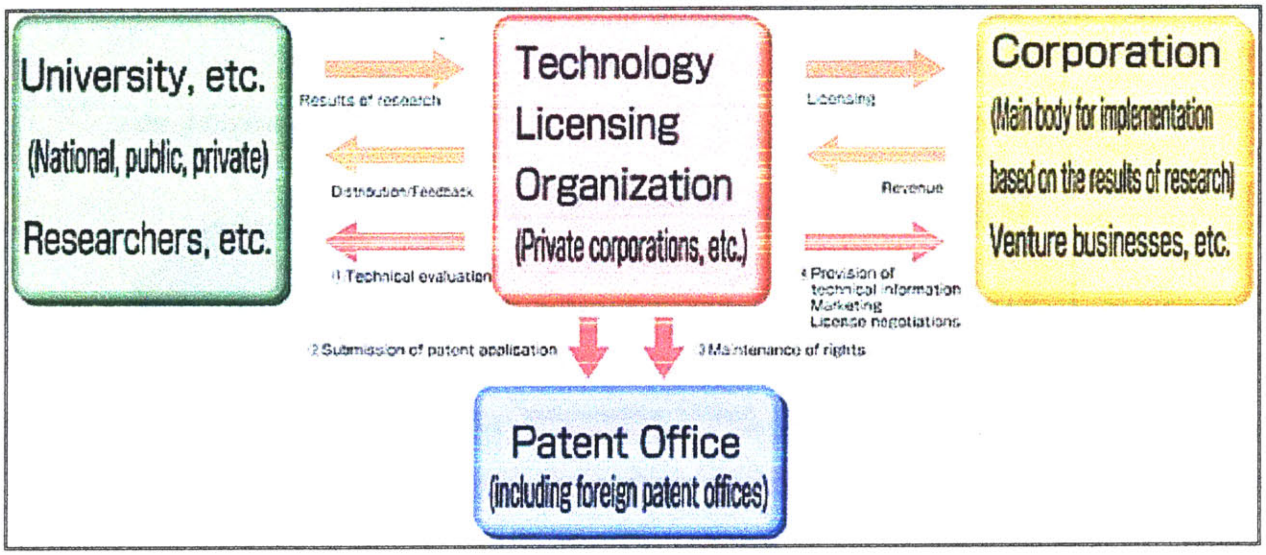


Grants and Endowments
Grants and Endowments refer to the financial donation made to national universities by private corporations, etc., or individuals for the purpose of scientific research or enhancing educational activities.



Making use of universities technologies

The Japan Science and Technology Corporation (under the jurisdiction of the Science and Technology Agency) implements various programs to support licensing and the practical use of the licenses.



Preferential Tax Treatment

Preferential treatment is given in the tax system in order to promote partnership between universities and industry.

1) The joint experiment and research tax system

For corporations that had conducted joint research with national, public or private universities, a fixed percentage of what they pay in trial research costs is exempted from corporate tax and/or Income Tax.

2) Exemption from financial contribution

Corporations can include the total amount of grant contributions in their losses, and individuals ca be exempted up to 25% of its income as contributions to the central government.

In addition, there is a program, which enables national universities to accept researchers and engineers employed in private corporations to give guidance at the graduate level. This is known as Commissioned Researchers.

Source: Press Release 2000/04, Ministry of Education, Culture, Sports, Science and Technology

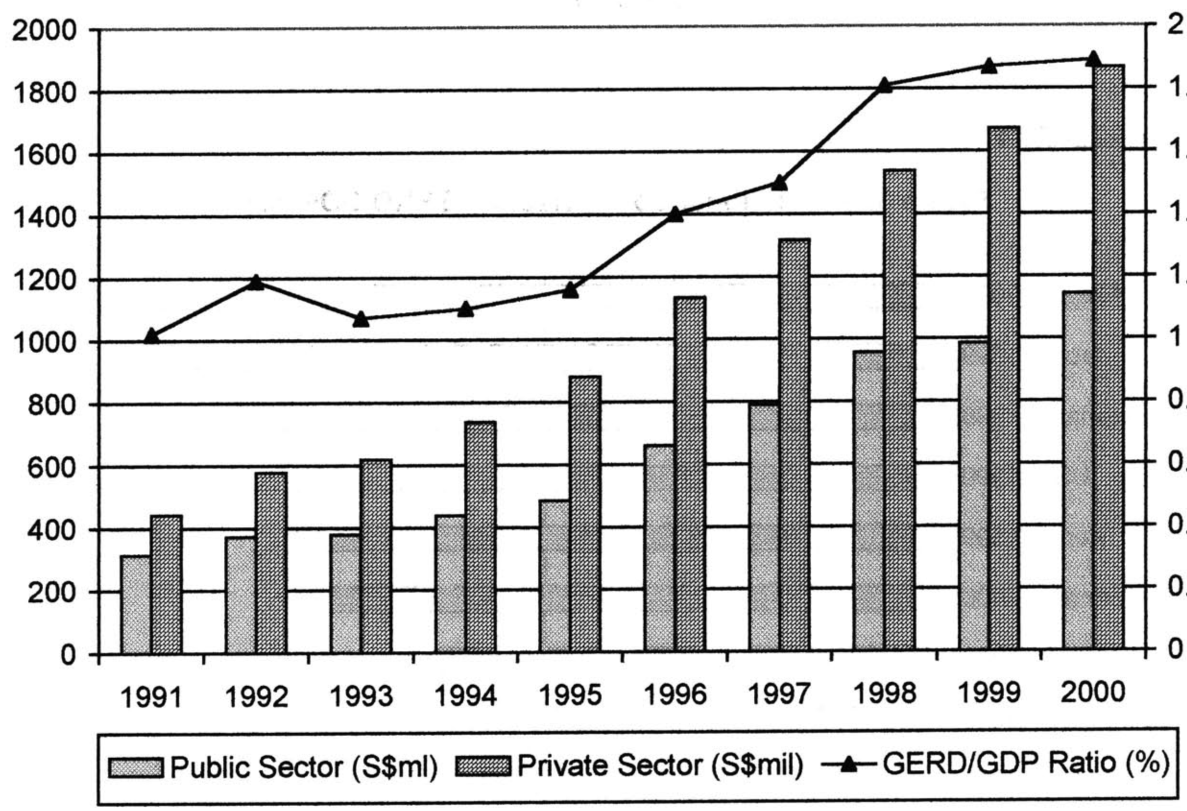
Survey of Research and Development Activities in Singapore

The 2000 National Survey of R&D in Singapore was conducted from April to July 2001. A total of 582 organizations reported that they performed R&D in 2000. This included 539 private sector organizations, 6 higher education institutions, 24 government organizations and 13 public research institutes and centers. 316 or 58.6% of the private sector companies were locally owned, while the remaining 223 (41.4%) were wholly foreign or less than 30% locally owned.

Gross Expenditure on R&D (GERD)

In 2000, Gross Expenditure on R&D (GERD) grew by 13.3%, from $2.66bil to $3.01bil. The private sector accounted for 62% of the total national GERD.

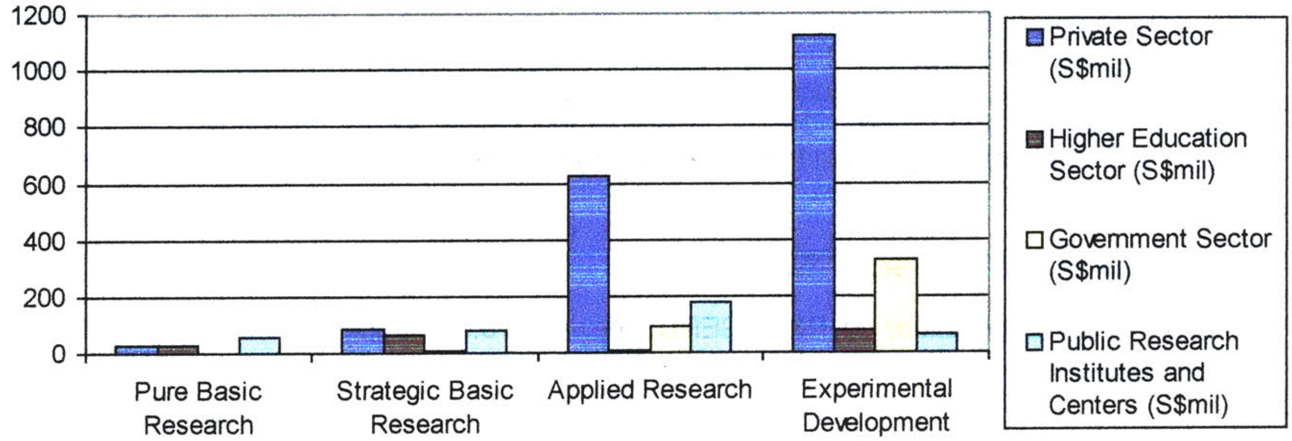
Figure 1: Gross Expenditure on R&D and GERD/GDP (by Year)



Source: National Survey of R&D in Singapore, 2000 (NSTB)

GERD by Strategic Focus

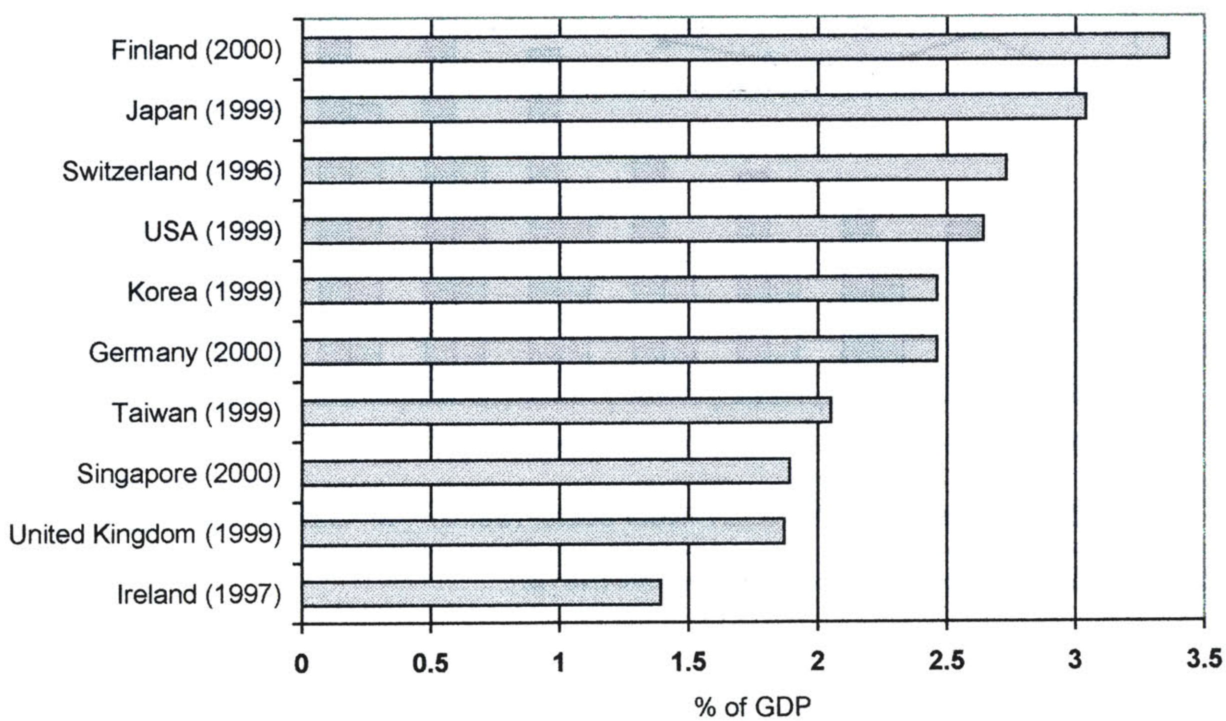
Figure 2: Strategic Focus of R&D Activities (2000)



Source: National Survey of R&D in Singapore, 2000 (NSTB)

GERD by countries

Figure 3: International Comparisons - GERD/GDP (%)



Source: National Survey of R&D in Singapore, 2000 (NSTB)

APPENDIX 9

Examples of Government-Linked Companies in Singapore

State Owned Companies	Industry
1. BIL International Ltd	International investment company
2. Australand Holdings	Real Estate
3. ASA Group Holdings	Manufacturing
4. Vertex Management	Venture capital
5. Premas International	Asset management in the real estate industry
6. The Ascott Group	Serviced residence company
7. SNP Corporation	Media Group
8. SPH AsiaOne Ltd	Media
9. S'pore Airport Terminal Services	Airport services
10. SempCorp Industries	Engineering Services
11. Singapore Computer Systems	IT
12. SembCorp Logistics Ltd	Logistics
13. Singapore Food Industry Ltd	Food processing
14. Singapore Bus Services Transit Ltd	Transportation
15. Singapore Exchange	Financial Services
16. Singapore Airlines Ltd	Airline
17. SIA Engineering Company	Engineering Services
18. Sembawang Kimtrans	Logistics
19. SembCorp Marine Ltd	Ship building
20. SMRT Corporation Ltd	Transportation
21. S'pore Petroleum Company Ltd	Oil
22. Singapore Press Holdings	Media
23. Singapore Technologies Assembly Test Services Ltd	Electronics
24. Singapore Telecoms	Telecommunication
25. Singapore Technologies Engineering Ltd	Engineering
26. Raffles Holdings Ltd	Real Estate
27. Parkway Laboratory Serv	Healthcare
28. Parkway Holdings Ltd	Healthcare
29. Neptune Orient Lines Ltd	Shipping
30. Natsteel Broadway Ltd	Diversified Business Group: Electronics, building products (cement and precast concrete), chemicals, engineering products and services, and property development.
31. Natsteel Ltd	

State Owned Companies	Industry
32. Keppel Integrated Eng Ltd	Diversified Business Group: Rig building, offshore conversion, ship repair & shipbuilding, network & utility engineering services, development & fund management services, other business investments
33. Keppel Hitachi Zosen	
34. Keppel FELS Energy & Infra	
35. Keppel T&T Ltd	
36. Keppel Corporation Ltd	
37. Keppel Land Ltd	
38. Keppel FELS Ltd	
39. Keppel Capital Holdings Ltd	
40. Keppel Tatlee Finance Ltd	
41. Jurong Engineering	Specialists in plant engineering and construction company
42. Jurong Technologies	IT
43. Insurance Corp of S'pore Ltd	Insurance
44. Horizon.Com Ltd	E-business venture
45. Delgro Corporation Ltd	Transportation
46. Delifrance Asia Ltd	Food
47. DBS	Financial
48. Chartered Semiconductor	Electronics
49. Capitaland Ltd	Real Estate
50. Comfort Group Ltd	Transportation

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