Singapore National Information Infrastructure Policy and its Implementation in the Construction Industry

by

Masaru Takeyama

Bachelor of Engineering in Electrical Engineering
Seikei University, 1989

Submitted to the Department of Electrical Engineering and Computer Science and the Technology Policy Program in Partial Fulfillment of the Requirement for the Degree of

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Abstract

IT2000 is a strategic national information technology (IT) policy introduced by the Singaporean government in 1992. The Construction and Real Estate Network (CORENET) is one of such several sectoral applications of IT, expected to be implemented in the construction industry. IT has special significance for Singaporean economic development. Planning practices for the national IT policy in each historic phase have been typical of the Singaporean approach to economic development. The Singaporean construction industry also has a particular role in Singaporean economic development. This thesis analyzes the political, economic, and technical environment surrounding IT and construction and makes some recommendations for successful implementation of the proposed CORENET project.

Thesis Supervisor: Dr. Lee W. McKnight
Title: Principal Research Associate at the Research Program on Communication Policy
Acknowledgment

This thesis would not have been completed without the generous support and advice of my thesis advisor, Dr. Lee W. McKnight. Not only did he give me useful advice on academic and research procedures, he always encouraged me when I lost confidence in continuing the research. He also has been my academic advisor during my stay at MIT. His expertise and knowledge of telecommunication and information technology guided me in constructing an appropriate curriculum and deciding on my research direction.

Most of the data collected for the thesis became available to me thanks to several people in the National Computer Board (NCB) of Singapore. Especially, I owe great thanks to Mr. Loh Yong Chye and Ms. Choy-Peng Shah at the National Information Infrastructure Division (NIID) of the NCB for obligingly responding to my interview during my stay in Singapore, and to Ms. R. Maler Vilee at the Information Department of the NCB and other friendly librarians in the NCB library for specially allowing me to use the NCB library which is not usually available for the public. In this regard, I also owe great thanks to a chief librarian in the Central Library of the National University of Singapore (NUS). She pleasantly gave me a special permission to use the library which is also not open to the public usually. My research would have been totally impossible if they had not presented me with such opportunities.

My academic life in the Technology and Policy Program (TPP) also gave me a problem solving skill in researching science and technology policy fields. The intelligence and personality of my TPP colleagues also greatly excited me. It was a real pleasure that I could study in this exciting academic environment. I have to owe great thanks to all the people who gave me an opportunity to come here.

Finally, I would like to say thanks to my parents and sisters for always supporting and encouraging me during my stay at MIT. I have to say thanks to many other friends both in Japan and the US in this regard, but please excuse me for not expressing them all here. Honestly, I give great thanks to all of them.

August, 1995

Masaru Takeyama
Boston, MA
Biography of the author

The author is a graduate student and a master's candidate at the Massachusetts Institute of Technology as of September, 1995. He received the degree of the Bachelor of Engineering in Electrical Engineering from Seikei University, Tokyo, Japan in 1989. After graduation, he joined Fujitsu Limited in Kawasaki, Japan, and had worked as a hardware electronics engineer in a communication equipment development division. He joined MIT in 1993 as a master's candidate at the Department of Electrical Engineering and Computer Science and the Technology and Policy Program. His research interest at MIT concentrated on telecommunication policy, especially the use of telecommunication as a tool for economic development. This thesis is the principal product of his studies at MIT.
To

Keigo and Machiko, my dear dad and mom
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Key to Abbreviations

ANSI  American National Standards Institute
APD   Application and Promotion Department
AR    Auto Regression
CAD   Computer-Aided Design
CADD  Computer-Aided Design and Drafting
CCS   Centre for Computer Studies
CEO   Chief Executive Officer
CIDB  Construction Industry Development Board
CISD  Computer Information Systems Department
CNC   Committee on National Computerization
CoInNet Construction Industry Network
CORENET Construction and Real Estate Network
CPF   Central Provident Fund
CSCP  Civil Service Computerization Programme
CSD   Computer Services Department
DOS   Department of Statistics
DSC   Design Support Centre
DW    Durbin-Watson statistic
EDB   Economic Development Board
EDI   Electronic Data Interchange
EDIFACT EDI For Administration, Commerce and Trade
EDIMAN EDI for Manufacturing
GDECON Graphical Data Exchange for Construction Industry
GDP   Gross Domestic Products
GINTIC Gruman International/Nanyang Technological Institute CAD/CAM centre
GIS   Geographic Information System
GLCs  Government-linked Corporations
HDB   Housing and Development Board
IES   Institution of Engineers Singapore
IGES  Initial Graphics Exchange Specification
ILIS  Integrated Land Information System
ILUS  Integrated Land Use System
ISS   Institute of Systems Science
IT    Information Technology
ITI   Information Technology Institute
JSIST Japan-Singapore Institute of Software Technology
LandHub Land Data Hub
LSC   Land Systems Committee
LECP  Local Enterprise Computerization Programme
MINDEF Ministry of Defense
MITA  Ministry of Information and The Arts
MNCs  Multi-National Companies
MND   Ministry of National Development
MOC   Ministry of Communication
MOE   Ministry of Education
MOF   Ministry of Finance
MTI   Ministry of Trade and Industry
NCB   National Computer Board
Chapter One

Introduction: IT-led economic development and the Singaporean NII policy

In 1992, the Singaporean government revealed the nation's third national IT (Information Technology) infrastructure policy, called IT2000. IT2000 attracted the attention of many telecommunication and IT people around the world as there was an emerging trend of National Information Infrastructure (NII) policy development in every part of the world such as the US Information Superhighway. However, the IT2000 policy\(^1\) is typically Singaporean in that it emphasizes an NII economic development policy rather than a telecommunication and infrastructure policy. Of course, NII policy in other countries also aims to yield economic value rather than to simply promote telecommunication industry development. What is particularly interesting about the Singapore case is that the government is attempting to integrate all public and private NII applications under a nationally-planned unified framework. Such a strong initiative of the state in the NII policy can be observed in other industrialized economies such as the United States, but the extent and procedures for intervention are typically Singaporean. It is interesting that a developing country employs a non-manufacturing-oriented policy such as the IT policy as an economic development strategy, although Singapore may no longer be regarded as a developing country but one of the newly industrialized economies (NIEs) in terms of real GDP level. This approach is relatively new and referred as IT-led development in some literature (Saito, 1988). Singaporean case is a valuable example to prove this theory.

IT2000 presents various industrial and social applications of the IT, attempting to restructure a current manufacturing-dependent economic structure into more information-oriented one. Among the various industrial applications featured in IT2000, this thesis particularly focuses on the Construction and Real Estates Network (CORENET) as an example of the economic development policy aspect of IT2000. CORENET is a proposed integrated data network for the construction industry (Hu, 1994). Its main

\(^1\) In fact, there are other NII projects called IT2000 in the world such as Vietnamese IT2000 policy. Although I may cite the case in other countries for the purpose of comparison in this thesis, IT2000 denotes Singaporean policy unless otherwise noted.
functional purpose is to facilitate the data flow associated with application and approval processes between the industry and government. In addition, it features design support, information reference, and procurement functions in its integrated system. In so doing, it is intended to help the construction industry raise its internal productivity and as a result the industry's overall economic efficiency.

Even though this project seems quite feasible given the small size of the industry, questions arise when we ask how much effect we can expect from this particular industrial infrastructure development programme. The Singaporean economy, not only in the construction industry, has some very particular characteristics. First, the Singaporean economy is very dependent on foreign capital. The Construction industry is not an exception. Thus, meeting the interests of foreign investors is an essential policy goal. However, assisting local firms may also be important if Singapore aims to reduce this dependency in the future. The second consideration is Singapore's small size. Smallness is an advantage when considering the ease of regulating and coordinating the industry, but turns out to be a constraint when one considers the amount of capital and investment required. Finally, particular Singaporean policy implementation practices also may be either an advantage or a constraint. Considering these factors, this thesis asks the following questions. Can the proposed CORENET project really be a new economic engine as the IT2000 plan expects? Overall, what policy measures should the government take to realize this expectation?

To answer these questions, this thesis analyzes the following issues. In chapter two, Singaporean economic development history is reviewed to clarify the role of IT and telecommunication policy in the Singaporean economic development context. In chapter three, the focus is on the institutional framework for forming a national IT policy to clarify what kind of regime has actually worked for policy formation and implementation. In chapter four, the economic effects of government efforts to promote IT and telecommunication infrastructure development are analyzed by applying historical data to econometric models (Saunders, 1994). In chapter five, specific IT applications in the construction industry are reviewed. It first reviews construction industry professional practices and environmental concerns. Secondly, after investigating technological features and the specifications of the existing and proposed construction industry data network, it clarifies the problems ahead that must be overcome for the successful implementation of the project. Chapter six summarizes the conclusions of the previous
chapters and presents some policy recommendations that would improve the likelihood of successfully implementing the CORENET project.

The question addressed from these analyses from a technology and policy perspective is whether a non-manufacturing technology policy such as IT policy can be a central strategy for economic development. Traditional economic development policies emphasized export-oriented strategies to raise industrial output, but IT typically does not raise output directly. It only raises industrial efficiency. How effective this strategy is in the economic development context depends on the industrial and economic level of the country; therefore, this Singaporean case study should attract the attention of students in the IT-led economic development field. I hope this work contributes to the field by presenting evidence from the Singaporean construction industry.
Chapter Two

IT, telecommunication and economic development in Singapore

2.1. Inherent conditions and government's basic strategies

Singapore is a small city state located at the edge of the Malay Peninsula in Southeast Asia. It became a British colony in 1819, and gained full independence as a republic in 1965. It has almost no natural resources to be exported, little land on which to place large scale manufacturing sites, and a small labor force limiting the growth of manufacturing. On the other hand, located on the Strait of Malacca, it has enjoyed a geographical advantage as an entrepot center in international trade between Asia and Europe. The Singaporean government, recognizing these constraints and advantages, has employed and implemented a unique economic development policy compared with other Asian NIEs. Those inherent conditions are comparable with those of Hong Kong; however, the policy course the government has actually traced is totally different in terms of the degree of intervention in the domestic economy.

There are several characteristics of Singaporean economic development, but two of them will be stressed in this thesis. The first is a very high level of dependency on foreign investment for capital formation. As Singapore had no local industries at the time of independence and almost no ability to establish them by itself, it had to totally rely on foreign capital to establish and promote industrial development. Noticing the importance of maintaining access to foreign capital, the government has always provided various monetary and non-monetary incentives for foreign firms which offer to establish operations in Singapore. An example of monetary incentives is a generous tax deduction for manufacturing sites. An example of a non-monetary one is the provision of excellent social infrastructure such as public utilities and telecommunication infrastructures. Some of these policy measures are elaborated on in the following subchapters.
Table 2.1: Size of public sector in Singapore (1990)

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of Employees</th>
<th>Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOEs and GLCs</td>
<td>83,700</td>
<td>5.5</td>
</tr>
<tr>
<td>Statutory Boards</td>
<td>59,500</td>
<td>3.9</td>
</tr>
<tr>
<td>Total</td>
<td>143,200</td>
<td>9.4</td>
</tr>
<tr>
<td>Total Work Force</td>
<td>1,516,000</td>
<td>100.0</td>
</tr>
</tbody>
</table>


Table 2.2: Percentage distribution of firms, sales, profits and assets of the largest 500 firms in Singapore (1986)

<table>
<thead>
<tr>
<th>Category</th>
<th>Firms</th>
<th>Sales</th>
<th>Profits</th>
<th>Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign</td>
<td>62.8</td>
<td>63.8</td>
<td>70.5</td>
<td>44.2</td>
</tr>
<tr>
<td>Singapore</td>
<td>37.2</td>
<td>36.2</td>
<td>29.5</td>
<td>55.8</td>
</tr>
<tr>
<td>GLC</td>
<td>4.4</td>
<td>12.2</td>
<td>19.5</td>
<td>22.9</td>
</tr>
<tr>
<td>Non-GLC</td>
<td>32.8</td>
<td>24.0</td>
<td>10.0</td>
<td>32.9</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Source: Soon et al. (1993)

The second characteristic is the government’s extensive intervention into economic activities. In almost every economic sector, the government has a statutory board, a kind of government-owned company under a particular ministry. Roles of the statutory boards are sometimes to simply conduct its business as usual, or sometimes to plan a specific industrial policy and lead the development of a particular sector. The Economic Development Board (EDB) is positioned as a special statutory board under the Ministry of Finance (MOF), and is responsible for overall industrialization policy planning. The government also owns a considerable number\(^2\) of state-owned enterprises (SOEs), which later came to be referred to as government-linked companies (GLCs). The discussion of their possible privatization began in recent years. The presence of GLCs and statutory boards in the Singaporean economy is very dominant. According to a study in 1990, they altogether provided about 10% of total employment (Soon et al., 1993, Table 2.1). Another study in 1989 revealed that the GLCs accounted for 12.2% of sales, 19.5% of profits, and 22.5% of the assets of the 500 largest firms in Singapore although their number is relatively low at 4.4% of the total number of the Singaporean firms (Soon

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\(^2\) As of 1993, the number of statutory boards in Singapore is 80, while that of SOEs and GLCs is 450. (EIU, 1994)
et al., 1993, Table 2.2). We can also observe in the same table that foreign firms and GLCs altogether accounted for 90% of profits in the economy. Local non-GLC firms are extremely few either in their number or actual economic importance to the economy.

As we can observe based on these characteristics, contrary to the general laissez faire image, Singaporean economic development policy has been very interventionist. The government intentionally provided generous incentives for foreign firms to attract them and promote rapid industrialization, but at the same time it has fully utilized state power to influence the development of each industry through the statutory boards and GLCs. In sum, Singapore's pro-business environment has been created through extensive government intervention and control, rather than a free market mechanism. This point is often contrasted with Hong Kong's economic development policy, which has not taken any interventionist measures in order to assure growth in international trade. However, recent studies pointed out that Singapore's dependency on foreign investment and government's interventionism have as a result considerably restricted the proper development of local firms (Krause et al., 1987 and Chee, 1994).
2.2. Historical review of policy goals and implementation

Information Technology (IT) and telecommunication policy has played a very
important role in the economic development of Singapore. As discussed in the previous
subchapter, apparently constrained by its physical size, Singapore had to choose a totally
dependent economic development style on foreign investments. Therefore, a policy for
facilitating excellent public utility and communication infrastructure naturally has been
one of the prioritized options for providing an incentive to foreign firms to come to
Table 2.3: Economic development objectives and policy responses in each phase

<table>
<thead>
<tr>
<th>Economic development phase</th>
<th>Primary development objectives</th>
<th>Economic and industrial policy response</th>
<th>Telecommunication and IT policy response</th>
</tr>
</thead>
</table>
| **Phase I:** Labor-intensive export-oriented manufacturing (1965 - 1972) | - Employment creation  
  - Infrastructural development | - Tax incentives for foreign investment (1967)  
  - Improvement of government-union relationship | |
| **Phase II:** Industrial upgrading (1973 - 1978) | - Improvement of labor shortage  
  - Upgrade of industries' technological content | - Tax relief for industrial training expenses (1973)  
  - Minimum wage policy (1973) | - Telecommunication Authority of Singapore (1974) |
| **Phase III:** Economic restructuring (1979-1984) | - Industrial diversification  
  - Designation of target industries for promotion | - Committee on National Computerization (1980)  
  - National Computer Board (1981)  
  - Civil Service Computerization Programme (1981)  
  - The TAS Act (1982) |
| **Phase IV:** Retrenchment and further diversification (1985 - 1989) | - Reduction of labor cost  
  - Upgrade of local industry  
  - Promotion of high-tech manufacturing industry  
  - Internationalization of local firms | - Privatization of some statutory board (1985)  
  - Flexible wage system  
  - Venture Fund (EDB) | - National IT Plan (1986)  
  - TradeNet initiative (1986)  
  - Small Enterprise Computerization Programme (1986) |
| **Phase V:** Restructuring into an information economy (1990 - ) | - Enhancement of ordinary people's life  
  - Creation and promotion of service sectors | - The Next Lap (1990)  
  - National Science and Technology Board (1990)  
  - Strategic Economic Plan (1991)  
  - National Technology Plan (1991) | - Commencement of IT2000 project (1990)  
  - National IT Committee (1992)  
  - IT2000 report (1992)  
  - Privatization of Singapore Telecom (1992)  
  - Public listing of Singapore Telecom (1993) |

Source: Soon et al., 1993 and Wong, 1993
Singapore. Like other developing countries, to meet these policy ends, the government has taken a monopolized telecommunication market policy to provide a unified, cheap, and convenient telecommunication service. Government has also implemented an effective IT industry promotion policy to overcome absolute labor shortages as it noticed that high-tech industry, such as IT, has a capability to transform an industrial structure from a labor-intensive to skill-intensive one.

An historical overview of economic development policies in Singapore is shown in Table 2.3. The history of Singaporean economic development since its independence can be divided into five phases according to the primary developmental goals in response to external environmental changes sought by the government in each phase. Note that the table does not include all government initiatives, because the purpose of following discussion is not to elaborate Singaporean economic development history but to assess how this affected IT, telecommunication, and economic policy formation in the Singaporean economic development context.

2.2.1. Labor-intensive export-oriented manufacturing (1965 - 1972)

The first phase began with Singapore's independence from the Malay federation in 1965. Until then Singaporean economic policy had traced a labor-intensive import-substitution strategy. Local Singaporean government did so because that was the only plausible measure to solve a high unemployment problem which had consistently existed since it gained self governance from Britain and joined the federation in 1959. Another reason is that Singapore could benefit by doing so because it could fully take advantage of its good tradition as an enterpot center inherited from the former British colony. However, as a result of Singapore's independence which was caused by political conflict with the Malay government, it lost a significant part of its economic access to the Malaysian market. The Singaporean government, observing its still high unemployment rate, had to change its policy course to a labor-intensive export-oriented manufacturing strategy (Phase I). Generous tax relief and exemption measures were offered to foreign manufacturers willing to establish their manufacturing operations in Singapore. The Economic outcome of these policy measures was very impressive. During the 1965-72 period, real GDP grew at an annual rate of about 13% (Figure 2.1).
2.2.2. Industrial upgrading (1973 - 1978)

In the early 1970s, Singapore achieved almost full employment and conversely faced a serious labor shortage. In the previous phase, Singapore had concentrated on a labor-intensive export-oriented manufacturing strategy to solve a severe unemployment situation. However, unemployment was soon solved partly due to the government's extensive effort to promote labor intensive industry, partly due to a relatively small population that the state originally had. Ironically, government efforts to create employment yielded another problem of severe labor deadlock, and Singapore had come to be no longer able to run its industrial sector without importing a labor force from neighboring countries. Worst of all, foreign investment inflow also significantly declined in this period. Seeing this environmental change, the policy course the government took was to upgrade the technological contents of manufacturing sectors (Phase II). As there was no hope for a sudden increase in domestic manpower, what the government sought was to make the whole economic structure less dependent on the absolute scale of the labor force by promoting the development of more skill- and knowledge-intensive...
industries. The policy measures the government took were two-fold; the promotion of industrial training of workers in high-tech industry by giving tax relief for training costs, and the introduction of a minimum wage policy to make existing labor-intensive industries less attractive to foreign firms.

Infrastructure development was also intensified in this period as an incentive for foreign investors. Since independence, the Telecommunication Department under the Ministry of Communication had taken a role of a regulator, and the Singapore Telephone Board (STB), a statutory board, had been given a sole license as a telephone service provider. In 1974, the Telecommunication Authority of Singapore (TAS), a statutory board, was established through the merger of the Telecommunication Department and STB. TAS was vested as a sole authority as a telecommunication service provider and regulator. This restructuring of the telecommunication regulatory environment indicates the government's strong intention to promote telecommunication infrastructure development through its strong leadership.

Despite a variety of aggressive policy measures, economic outcomes were not successful. Although the government set up a national institution to control minimum wage levels, an orderly increase in the wage level was not accomplished because of the fear of recession and resulting unemployment (Soon et al., 1993). However, the low wages ironically led to the further growth in manufacturing sectors, and the intensification of infrastructure development led to growth in the construction industry. As a result, Singapore could achieve a relatively high annual real GDP growth rate of about 7% during this phase though other neighboring countries had been struggling with economic difficulties facing the oil crisis in 1973.

2.2.3. Economic restructuring (1979-1984)

By the end of the 1970s, the government's policy to attract foreign investment had succeeded. Especially in the manufacturing sector, the share of foreign firms in industrial output exceeded 70%, which is an unusual number compared with other neighboring Asian NIEs. On the other hand, there was a trend of emerging harsh competition around

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3 According to Soon, et al. (1993), foreign firms provided 73.7% of gross industrial output and 58.8% of employment in the manufacturing sector in 1980.
Southeast Asia while the government intention to upgrade the industry had not met much success as discussed above.

Observing this situation, the government proceeded to adopt a more open financial policy, but did not abandon its high wage control policy to encourage industrial upgrading. It tried to expand the foreign share further by allowing 100% foreign ownership in almost every sector, even though the share was already very high. In its further effort to upgrade the economy, along with the continuing high-wage policy, the government designated particular industries for targeted industry promotion. EDB conducted an extensive survey on world high-technologies, and specified several manufacturing sectors to be promoted in its report in early 1980. The government provided special financial incentives for those targeted industries. Furthermore, extensive investment introduction activity was conducted through EDB's overseas offices in over 20 industrialized countries.

In an effort to promote industrial upgrading, the government began to pay more attention to productivity enhancement in the civil service. Government saw that a competent and productive civil service would be essential to help industry gain international competitiveness through industrial upgrading. To realize these ends, the government launched the first integrated computerization project as part of a productivity enhancement project in the civil service. In 1980, the Committee on National Computerization (CNC) was formed by high-level ministerial officials, and in the same year, it released the CNC report, which is the first national IT policy. The report recommended government promote civil service computerization, and establish a firm institutional framework to lead the project. In response to the report, National Computer Board (NCB), a new statutory board, was established and was expected to spearhead a newly launched Civil Service Computerization Programme (CSCP) in 1981. The details of these movements are discussed in the following chapter, but it must be noticed here that the first national IT policy emerged in the context of industrial upgrading policy.

In the telecommunication development area, a new institutional framework was formed in this period. The TAS Act of 1982 created a new statutory body, Singapore Telecom (ST) under TAS, and vested ST with an exclusive right to regulate and operate a telecommunications business (Wong, 1993). Under the Act, the Postal Service Department was hived off from the Ministry of Communication and merged with the
TAS. Thus, TAS became a sole authority overseeing all communication activity in Singapore. This would seem to be moving backward compared with the world trend of divestiture of telecommunication industry, but the intention of the TAS Act was to facilitate communication infrastructure development under a strong institutional framework (Heng et al., 1989). The outcomes of this telecommunication industry restructuring proved to be successful. ST succeeded in providing an excellent telecommunication infrastructure by the mid-1980s with no state subsidy. The success in the telecommunication infrastructure development contributed to the economy as a further incentive for foreign firms to establish their operation in Singapore.

However, the economic performance of these policy measures was not so appealing. Real GDP growth during this period was about 8% but most of the growth came from the construction and financial service sectors. Economic diversification policy had much worked on the financial sector but the manufacturing sector suffered a relatively low growth rate of about an annual 5% despite the government's high-tech industry promotion effort, partly due to the oil crisis and continued high-wage policy. However, an electronics industry grew gradually because Japanese electronics manufacturers rushed to shift their production operation to this area suffering from rapid Japanese-yen appreciation (Hayashi, 1990). Government efforts to educate highly skilled workers enabled a synergy with this boom of Japanese electronics firms shifting manufacturing off-shore, and resulted in attracting other foreign electronics firms in later years.

2.2.4. Retrenchment and further diversification (1985 - 1989)

In 1985, the Singaporean economy experienced the first negative real GDP growth. Many economists analyzed that the recession occurred because the Singaporean economy lost its competitiveness in the foreign investment market compared with other neighboring Southeast Asian countries mostly due to its continuing high-wage policy. The government quickly responded to the recession by forming a special high-level ministerial council to analyze and discuss the cause of the recession. Several recovery measures were designated. Government temporarily gave up its high-wage policy and introduced a flexible wage policy to recover the international competitiveness of its labor force. Furthermore, special attention was paid to the competitiveness of local small and medium-sized enterprises (SMEs) for the first time. EDB established an S$100 million
venture fund to encourage the co-investment of MNCs and local SMEs in founding new technology companies, expecting technology transfer occurring between them. Another initiative for enhancing the local SME's productivity, the Small Enterprise Computerization Programme (SECP), later renamed as Local Enterprise Computerization Programme (LECP), was launched in 1986. SECP offered SMEs various financial and technical incentives to proceed to their internal computerization. The details of the programme are elaborated in the following chapter.

Among several strategies designated, one of the most challenging was probably the review of the Singaporean economic structure itself. Government saw that the manufacturing-centered industrial policy would continue to dampen the possibility of economic growth, and decided to change the policy course to reduce the dependency on the manufacturing sector. Promotion of an information and service sector was one of the measures then taken. As discussed in the previous subchapter, the government's effort to facilitate the telecommunication infrastructure had been successful by mid-1980s, and the world-class telecommunication infrastructure had already become a competitive advantage for the Singaporean economy. Usage of computers in all economic sectors had also become prevalent by this phase partly thanks to the government efforts to promote computerization. The government saw a new economic possibility in merging IT and telecommunications, and began discussing a more strategic national IT policy. Such movement was materialized by the formation of the National IT Plan (NITP) in 1986. NITP was the second integrated national IT policy, and its scope was extended to include the private sector for the first time. Thus, IT policy became one of the major components of Singaporean economic development policy.

In the telecommunication field, the trend of privatization hit the industry. Government saw that excessive dominance of statutory boards was damping the competitiveness and vitality of the economy, and decided to proceed to privatize them to induce a freer economy. In 1985, the government announced its intention to privatize some statutory boards, and TAS was included in the list. Discussion of privatization

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4 World competitiveness report in 1990 praised Singapore for offering the most convenient and excellent telecommunication infrastructure in the world. This fact partly proves that those statutory boards, ST and TAS, have worked very economically efficiently though they can be seen as a kind of a public corporation, which is regarded as relatively inefficient in general.
continued, and finally in 1992, the Singapore Telecom was completely separated from TAS as a private limited company responsible for a telephone network service provider. The shares of the Singapore Telecom were held by Temasek Holdings, a government-linked company (GLC) under the Ministry of Finance (MOF), but in the next year, the Singapore Telecom became a public listed company and some shares were allowed to be held by the private sector. With this restructuring, the Telecommunication Authority of Singapore (TAS) was reconstituted into a new a statutory board responsible for regulation and policy planning in the telecommunication industry.

As a result of these policy measures, the economy quickly recovered from the recession. Real GDP growth was 1.8% in 1986, and continued to grow about from 8 to 11% annually until 1990.

2.2.5. Restructuring into an information economy (1990-)

In 1990, fundamental environmental change came from the political arena. Lee Kuan Yew, the prime minister leading Singapore with his strong leadership since independence, resigned his post, and Goh Chok Tong took over the post of the prime minister. Lee's resignation was said to occur because he recognized the political stagnation resulting from over 30 years of his strong and absolute leadership as the prime minister, but another cause was the criticism from foreign countries against his too long authoritarian control over Singaporean politics.

This change in the political environment shocked various societies and some fears for the future development of the nation arose because the leadership by Lee had been too strong and dependable for Singaporean people to accept a new leadership. PM Goh responded to the people's fear by quickly presenting a new policy course for the 1990s. The policy statement, called the Next Lap, was compiled by a cabinet committee and released in 1990. In the Next Lap, PM Goh emphasized the importance of the people's unity and effort to collaborate to make their own future livings. Singapore, with considerable physical constraints, had to rely on its people to develop its economy and society, but the PM's message impressed the people in another sense because the people

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5 As of 1994, 89.19% of the shares is held by the Temasek Holdings, and the rest of them is held by private banks including foreign banks (ST, 1994).
had not had to worry about themselves since they had been protected under Lee's paternal leadership.

Various policy responses to the Next Lap arose from various communities. The Strategic Economic Plan (SEP) was released in 1991 as an economic policy strategy by the Ministry of Trade and Industry (MTI). Reportedly as a response to the Next Lap from NCB, IT2000 initiative was informally commenced in 1990 and the IT2000 official report was released in 1992. IT2000 proposed the construction of a more integrated information network which incorporates not only government and business activities but the life of ordinary people. The details of IT2000 and its policy formation practice are discussed in the following chapter.
2.3. Conclusion for chapter 2

Significant growth of the Singaporean economy has been accomplished through extensive interventionist measures by the government. The government recognizes that foreign firms are an essential backbone of Singapore economic development, and has always tried to provide a pro-business environment for them. However, the government has never forgotten the long-term policy aim, industrial upgrading, even when it reacted to sudden environmental change. Government policy has in most case been corrective rather than reactive as seen in the high-wage policy and industrial education promotion.

Telecommunication policy has very effectively worked as one of the incentive measures for attracting foreign firms. Government has taken a strongly centralized telecommunication market policy to keep a stable and monopolized industry. Authority to regulate and operate the industry has been strengthened through every economic development phase, though this centralized strategy seems contradictory with the world trend of divestiture of the telecommunication industry. All measures to facilitate telecommunication infrastructure development have been successfully implemented. Singapore has succeeded in implementing these policy measures and in providing its world famous telecommunication infrastructure, which had become a new competitive advantage for Singapore in attracting foreign firms by the mid-1980s.

IT policy was at first implemented as a part of an industrial upgrading policy. The government noticed that computerization had a capability to transform an economic structure itself by enhancing the productivity of workers in every economic sector. Computerization efforts began at first in the civil service and expanded to include other sectors in an incessant effort to develop a more integrated information infrastructure.

Success in telecommunication infrastructure development and national computerization has given Singapore a new economic opportunity. The latest national IT plan, IT2000, is trying to extend its scope to local industry and ordinary people. IT2000 will be a new engine for economic growth by developing IT awareness and convenience more broadly into "the rest of the world."
Chapter Three

Development of Singapore's computerization policy

3.1. Overview and analytical framework

Computerization policy has played a complementary but very important role in Singaporean economic development. As discussed in the previous chapter, the government considered an efficient and productive civil service essential for managing the state and helping other sectors to survive in a difficult competitive business environment. The government aimed to demonstrate its seriousness in adapting itself to the rapidly changing economic environment and in producing industrial development with its strong leadership. It is interesting and should be noted here that the government sought to maintain its organizational strength by enhancing its internal efficiency rather than by expanding its organizational scale. The absolute size of the labor force might have been too small to allow the government to choose another option. In other words, inherent constraint on growth in the labor force helped the government concentrate on productivity enhancement and encouraged the transition of the economic structure into a more advanced one.

This chapter investigates the institutional framework to form and implement a national IT policy by looking at the historical practices of IT-relevant organizations. The Development of Singapore's computerization policy can be divided into three phases: (1) an effort to computerize internal civil service operations, (2) an effort to create industrial IT infrastructure through a strong government initiative, and (3) an effort to integrate whole social and industrial IT infrastructures under a unified NII framework. From a time series perspective, those three phases correspond to the economic development periods discussed in the subchapter 2.2.3, 2.2.4, and 2.2.5 respectively. Their implementation style was very different in each phase. Sometimes Singapore adopted a top-down style and sometimes a bottom-up one. Even though the Singaporean political regime is regarded as strictly authoritarian, changes in actual leadership has been observed very often among relevant parties. This can be said to be one of the characteristics of national IT policy implementation practices in Singapore. The following subchapters discuss how those policies have been developed and what kinds of institutional framework have actually emerged in the course of the development of them.
3.2. First Phase --- Civil service computerization

3.2.1. The Committee on National Computerization and the establishment of the National Computer Board

Computerization in the civil service began in 1963 when the first computer was installed at the Central Provident Fund (CPF), a statutory board under the Ministry of Labor. Since then, government computerization had been totally led by the Computer Services Department (CSD) of Ministry of Finance (MOF), even though there were a few exceptions of independent computer systems development in the Ministry of Education and Ministry of Defense (MINDEF). In other word, civil service computerization policy had taken an extremely centralized style controlled by MOF (Koh, et al., 1992). However, this centralized computerization policy had not succeeded because of the absolute shortage of computer professionals both inside and outside the MOF.

In 1980, a government initiative to form a centralized national IT policy emerged as it established a high-level ministerial committee, the Committee on National Computerization (CNC) in 1980. This was a response to the Singapore Economic Development Plan for the 1980's compiled by the Ministry of Trade and Industry (MTI), which pointed out that Singaporean economy needed to be transformed into a more skill- and knowledge-intensive economy through extensive computerization. CNC was formed by the permanent secretaries of interested governmental ministries, the chairpersons of the interested statutory boards, and the presidents of universities. CNC conducted an extensive study on the current situation of the Singaporean IT industry and the extent of computerization of the Singaporean economy. In its Report of Committee on National Computerization (CNC report) in October 1980, the Committee on National Computerization (CNC) presented initial objectives for CNC in forming a national computerization policy. The designated objectives were three-fold: the promotion of (1) extensive civil service computerization, (2) IT education to increase the number of IT professionals, and (3) IT-related service industry such as the software industry. The recommendations of the report led to the launch of the Civil Service Computerization Programme (CSCP) in the following year. The National Computer Board (NCB) was established as a special statutory board under MOF and was mainly expected to spearhead the CSCP (NCB, 1981). The board of directors of NCB was formed by the representatives from various sectors such as the IT industry, universities, and other
interested statutory boards and ministries to represent various interests in the IT society.\footnote{Initial members of the NCB board of directors were formed by the representatives from the Singapore Computer Society, the National University of Singapore, the Economic Development Board, the Ministry of Finance, the Ministry of Education, and a proposed Computer Industry Association which represented software and computer service industry (NCB, 1981).}

In its statement issued on the day of establishment, NCB presented above three CNC designated missions to be carried out. However, the most imminent mission was apparently to work as an organizer and facilitator of CSCP by overseeing governmental agencies involved in the CSCP.\footnote{Although this thesis does not mention much about other two missions, IT education and software service industry development, some facts need to be cited for readers' convenience. An IT education project was conducted through the creation of educational facilities both inside and outside existing institutions. The Institute of System Science (ISS) of the National University of Singapore (NUS), the Japan-Singapore Institute of Software Technology (JSIST), and the Centre for Computer Studies (CCS) of Ngee Ann Polytechnic are three major IT educational institutions. The Institute of System Science (ISS) later played a significant role as a collaborator of the Small Enterprise Computerization Programme (SECP). The IT education project has been very successful. The number of IT professionals increased by tenfold in the 1980's from only 850 in 1980 to 9000 in 1989 (Raman et al., 1991). Generous tax incentives for industrial upgrading costs (ref. chapter 2) also encouraged IT education. Software industry development was encouraged both by IT professional education efforts and tax incentives planned by the Economic Development Board (EDB). The tax incentives were offered selectively to software firms who developed sophisticated software (Koh et al., 1992).}

\subsection*{3.2.2. Civil Service Computerization Programme (CSCP)}

CSCP changed the process of policy implementation. Before the CSCP, as discussed above, civil service computerization had been totally led by MOF's centralized leadership. However, under CSCP, each ministry was now required to have a specialized section responsible for their own computer systems development. The section, called the Computer Information Systems Department (CISD), was given responsibility for developing and managing the ministry's systems development, and for presenting an appropriate justification of development projects to MOF for getting the projects funded (Koh et al., 1992).
The National Computer Board's role was to support each ministry involved in the Civil Service Computerization Programme (CSCP) by staffing the Computer Information Systems Departments (CISDs). Top management of Computer Information Systems Department (CISD) was done by a director selected from the senior administrators of each ministry, but low-level managers for overseeing every-day operations were sent by NCB to supplement the absolute lack of computer experts at that time. NCB was also responsible for reviewing the budget plan submitted by each ministry to the Ministry of Finance (MOF). It sometimes coordinates various ministries' interests to implement and materialize those systems development plans effectively under a unified concept (Figure 3.1).

In sum, what the Civil Service Computerization Programme (CSCP) and the National Computer Board (NCB) brought to civil service computerization was a combination of a centralized and decentralized policy implementation style (Gurbaxani et al., 1991). Each ministry became responsible for its own computerization effort. The National Computer Board (NCB) worked as a supporter and coordinator, but not as an administrator in the projects. The expert staffing system by NCB succeeded not only in

![Figure 3.1: CSCP project implementation framework](image-url)
supporting each ministry's effort without dampening the sense of the self-responsibility in each ministry but in achieving a high economy of scale with the centralized recruiting and training of computer professionals. The common training of the NCB professionals sent to each ministry also helped the rapid implementation of CSCP projects. All methodologies used in CSCP were standardized by NCB, and the dispatched NCB professionals followed them. This centralized staffing system also helped NCB to accumulate experience in several different government situations, and consequently to trace an experience curve to pursue more effective CSCP implementation (Lee, 1988).

The consequences of CSCP were very significant. A cost-benefit analysis conducted by NCB in 1987 reported that the total computerization expenditure in 1986 was S$77.3 million while the total tangible benefits in the same year amounted to S$198.3 million (Koh et al., 1992). That gives a return on investment of 171%. From the manpower point of view, the number of employees in public sectors as a whole has experienced zero-growth since the launch of the CSCP. The same NCB study reported that the CSCP resulted in saving 1,398 posts and avoiding 3,264 posts, each amounting to S$27 million S$48 million annually. New labor needs for operating computer systems have been met by retraining existing staff and restructuring organizations, not by replacing or laying off the personnel. The government's attitude as a result yielded raising productivity among civil servants, and the government has been able to realize the increase in revenue associated with CSCP. The same 1987 study showed that annual revenue increase was $119 million.

As described above, the first phase of the computerization effort was oriented to inside the government. NCB had worked as a good supporter in government computerization, and in so doing it had accumulated experience in large scale computerization projects. The authority to direct the computerization projects was decentralized and rested with each ministry, and NCB concentrated on the centralized recruitment, education, and staffing of computer professionals. It was this combination of centralized and decentralized policy implementation styles that led CSCP to be a tangible success in 1980's.
3.3. Second Phase --- National computerization and multi-agency collaboration

3.3.1. National IT Plan (NITP)

A second phase of Singaporean computerization policy began with the release of the National IT Plan (NITP) in 1986, when the government could perceive a gradual success in telecommunication infrastructure development, industrial upgrading, and government computerization. NITP is the second national IT policy since the CNC report in 1980, but it is totally different from its forerunner because it was not initiated by a top-down process at the a ministerial level but by a spontaneous multi-agency initiative from interested statutory boards and institutions (Wong, 1992). In fact, spontaneous discussion for the formation of the NITP commenced in late 1984 by the Economic Development Board (EDB), the National Computer Board (NCB), the Singapore Telecom (ST), and the Institute of Systems Science (ISS) of the National University of Singapore (NUS). The formal working committee for the NITP was set up in early 1985. An Interim report for NITP was submitted to CNC in late 1985, and the final issue of NITP was released in late 1986. The first economic recession in 1985 led the NITP to emphasize its characteristic as a new economic strategy. In fact the benefits productivity enhancement through investment in IT of all the economic sectors was further emphasized in the final report (NITP Committee, 1985 and Wong, 1992).

NITP had two designated goals: (1) development of strong export-oriented industries, and (2) significant improvement of competitiveness and productivity through the extensive use of IT in all sectors of the economy. Apparently, NITP was no longer just a computerization policy but an economic policy in a sense that it stated economic objectives such as industrial productivity enhancement. Another characteristic was that NITP expressly stated government's intention to intervene into private sectors to promote IT exploitation in "all sectors of economy."

The implementation strategies proposed in NITP were seven-fold, as shown below (NITP committee, 1985, and Gurbaxani et al., 1991)

1. **IT Manpower:** To develop and educate highly-skilled computer professionals to help firms to exploit the latest IT applications and products.
(2) **IT Culture:** To promote a supportive culture among ordinary citizens for the coming information economy age.

(3) **Information Communication Infrastructure:** To develop and maintain the best telecommunication infrastructure in the world to maintain a competitive advantage in the information economy age.

(4) **IT Application:** To facilitate the full exploitation of IT in all economic sectors and provide appropriate applications for removing barriers for new users of IT.

(5) **IT industry:** To encourage further IT industry development.

(6) **Climate for Creativity and Entrepreneurship:** To develop and promote local capability in IT applied research.

(7) **Co-ordination and Collaboration:** To unite individual efforts of various organizations under a new leadership by a new national IT committee, which would be evolved from the current CNC.

Participation in NITP implementation processes was not limited to EDB, NCB, ST, and ISS. It was extended to include various sectors such as other governmental agencies, business associations (chamber of commerce, manufacturer's associations, and trade associations), professional societies, and IT industry associations. This wide-ranging multi-agency collaboration was made possible not by the top-down effort from the CNC. It emerged because each relevant community had more or less the same sense that they had to cooperate closely with each other otherwise this tiny state couldn't survive in the competitive world economy. The tiny size of the state and economy also helped top industry managers and government officials to make an opportunity to meet with each other often and to form such a common sense of purpose (Wong, 1992). In addition, there was a custom in the government personnel appointment system that some top level government officials would experience the top management of various GLCs and statutory boards in a short period (King, et al., 1990). Close connections among relevant agencies were established somewhat by such a system. In sum, both the size of the state and characteristic governmental practices largely was responsible for the effective implementation of the National IT Plan (NITP).
Since the wide-ranging multi-agency collaboration had become common, integrated industrial IT application projects had also become possible. Deployment of industry-wide IT usage was promoted by the Small Enterprise Computerization Programme (SECP) and integration of industry-wide IT applications was promoted by several Electronic Data Interchange (EDI) projects such as TradeNet. These projects were undertaken through the multi-agency collaboration which is discussed in more detail in the following subchapters. Industry-wide IT application projects completed by the early 1990's and those IT infrastructures had become a new competitive advantage for the Singaporean economy. The next two subchapters discuss how these two project approaches had emerged in the National IT Plan (NITP) implementation context.

3.3.2. Small Enterprise Computerization Programme (SECP)

Small Enterprise Computerization Programme (SECP), later renamed Local Enterprise Computerization Programme (LECP), was an action plan to raise the productivity and competitiveness of local Small and Medium-sized Enterprises (SMEs) by extensive computerization. Another underlying objective was to encourage entrepreneurship by enhancing the capability of SMEs to be more innovative and creative about their business with the use of IT. SECP was launched in 1986 by NCB, the Small Enterprise Bureau of EDB, and ISS. The Economic Development Board (EDB) had an incentive in participating in this project because it needed to take a practical action against the change of the government's policy course after facing serious recession in 1985. The upgrade of the local SMEs, as well as the promotion of high-tech industry and technology transfer, was one of the imminent missions of the Economic Development Board (EDB) in its industrial upgrading efforts (ref. chapter 2). The National Computer Board (NCB) also had an incentive in participating in private sector computerization and accumulating experience in this field. Thus, the interests of participating parties were met.

Local SME computerization had hardly progressed when the Small Enterprise Computerization Programme (SECP) was launched. Civil service computerization had seen a gradual success thanks to the Civil Service Computerization Programme (CSCP), and the computerization in large firms, most of which is a multinational company (MNC), had been also progressed due to then trend of international data networking among the MNCs. However, SMEs had been given no incentives to promote their
computerization, and actually had been reluctant to do so because it was too costly. A study conducted by NCB revealed that 84% of all firms with less than 50 employee did not have and even did not intend to have computers then. The study also revealed the causes of the reluctance as follows (Raman, 1988a).

(1) **CEO's lack of IT awareness**: Chief Executive Officers (CEOs) of SMEs were ignorant of the benefits of IT. They thought that they would be able to manage their businesses without the help of computerization.

(2) **Lack of expertise and support**: Most SMEs could simply not afford to develop in-house IT expertise. Even for those who could afford it, they had given up employing skilled computer experts because those experts tended to join larger companies.

(3) **Rapid innovation of IT products**: CEOs of SMEs were confused by the rapid innovation of IT products, and not able to decide which products they should introduce.

(4) **Lack of appreciation of the value of software**: CEOs of SMEs did not appreciate the value of non-material services, such as software, consultation, feasibility studies, and advisory services.

(5) **Lack of absolute financial resources**: SMEs did not have the financial resources to fund computerization, and even had difficulty to getting credit for loans for computerization investments.

With these problems in mind, the Small Enterprise Computerization Programme (SECP) incentives were designated as follows (Raman, 1988a and NCB, 1992e).

(1) **Education and awareness seminars**: The Institute of Systems Science (ISS) conducts a short-hour seminar for both CEOs and application level professionals.

(2) **Technical "hand-holding" and advice**: A qualified SECP advisor conducts an initial study for computerization, and advises the CEOs in selecting a consulting firm.

(3) **Technical expertise and support**: A consulting firm conducts actual feasibility studies and systems development implementation.
(4) **Financial support**: 70% of the SECP advisory fee and the initial services fee by a consulting firm are subsidized by SECP. 50% of the actual systems development and implementation fee by a consulting firm or a software house is also subsidized. Loans are given at a lower interest rate than the market rate for the purchase of hardware and software.

In order to be eligible for participating in SECP, SMEs were required to have a minimum 30% local ownership, less than S$8 million of fixed assets, and less than 50 employers except for the case of manufacturing firms.

Thus, SECP had given great incentives for SMEs to proceed with computerization. Even in the first year of SECP, a large number of SMEs applied to SECP expecting that they could construct computer systems at much lower costs with generous financial support. Consequently, NCB had to set up a screening process to limit the number of those demanding applicants. According to Raman (1988a), the number of SMEs...
SECP enrollment was 114 in 1987. Even though precise data about SECP progress is lacking, Tan (1992) reported that the accumulated number of SMEs which had received any kind of technical or financial incentives had reached about 200 by 1992 since the launch of the programme. This data somehow indicates that SECP is a long time process until accomplished and that the application screening process has more or less been getting severe as the programme is becoming popular.

As a secondary impact, SECP had helped the healthy growth of software industry, and consequently contributed to the EDB’s policy objective of promoting industrial upgrading. Even though the exact effect on the growth of the software industry given by the SECP is difficult to estimate, there is some feedback from industry (Raman, 1988a). Some consultant firms found it difficult to persuade the CEOs of SMEs, and some software firms easily tended to just sell their products to the ignorant SMEs. NCB checked those firms’ activities and removed unfavorable firms from the SECP software consultant firms registry. This point is important because the software firms had not seen such difficulties so far in the government computerization projects which they were involved. SECP thus helped both NCB and the software industry to gain experience in dealing with the reluctant SMEs, and encouraged the proper development of the industry. In sum, this experience in private sectors greatly helped NCB in planning industry-wide IT applications such as TradeNet which is discussed in the following section.

3.3.3. TradeNet

Electronic Data Interexchange (EDI) is an international standard for exchanging various commercial and official document information electronically. TradeNet is probably one of the most famous EDI applications in the world. In fact, the launch of TradeNet project was initiated by both NITP and the recession in 1985. As discussed in the previous chapter, Singaporean economy faced a serious recession in 1985. A high-level government committee discussed recovery measures, and one of the prioritized policy goals was the improvement of productivity in external trade processes. Historically, external trade has taken very unique position in the Singaporean economy. The volume of the external trade was 3.5 times that of GDP. The government expected great economic effects in enhancing the trade process productivity with the use of EDI. In the same year, NITP was formed as explained in the previous subchapter. NITP expressly stated its aim to facilitate IT use in all economic sectors, and implied the
government's intention to intervene extensively into private sectors to develop and implement industry-wide IT applications. Both the government's strong initiative for economic recovery and the interests of the NITP relevant agencies jointly led to the launch of the TradeNet project (Neo et al., 1994).

What was the most challenging and at the same time amazing about the TradeNet was that relevant project participants quickly reached an agreement to change their trade practices. Trade is a multi-lateral process involving many participants with diversified interests. Creating an inter-organizational EDI network meant changing business practices fundamentally. Therefore, the first barrier that had to be surpassed was not technical but political. Thus, most of the planning efforts were to coordinate the interests of the participants. NCB and Trade and Development Board (TDB), a statutory board, played a very important role in this interests coordination process among the project

Figure 3.3: TradeNet committee structure and the implementing framework
Source: King et al. (1990)
participants. What occurred at first in the project planning process was the high level agreement among TDB, NCB, and EDB. After the quick agreement, they assigned tasks to each other for the effective implementation of the project. Some personal connections between the high level officials in TDB, EDB, and NCB encouraged the rapid progress of this initial planning stage (King et al., 1990). Under the agreement, TDB was given the task of coordinating the interests of trading community, and therefore NCB could concentrate on a macro level streamlining study. A number of meetings were held under the coordination of TDB. Participants included both private and governmental organizations. After those meetings, agreement was eventually reached among all the participants.

The progress of the project after the agreement was very rapid. A high level TradeNet steering committee was first set up with the three sectoral subcommittees under it (Figure 3.3). NCB IT experts were placed outside the subcommittees and given the tasks of supporting the technical aspect of the project implementation in each sector and compiling a realistic integrated plan. Compared with the institutional framework used in the CSCP (Figure 3.1), the leadership structure had changed. The combined usage of technical coordination (by NCB) and political coordination (by TDB and the steering committee) is observed in this TradeNet project implementation framework.

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8 As discussed a little in the chapter 2, there is a custom for the government officials to appoint high level officials to gain experience of acting as the chairperson or other important posts of various statutory boards or GLCs for a short period. In this case, Yeo Seng Teck, then chairman of TDB, had been the former chairman of EDB before Philip Yeo, then chairman of both EDB and NCB, became the chairman. So, they had known each other very well even before meeting and discussing the way to proceed with the TradeNet project.
Functional specifications for the TradeNet had been formed by 1988. Singapore Network Services (SNS), a state-owned company (SOE) responsible for developing and operating the TradeNet services, was established in 1988. The Singapore Network Services (SNS) designed technical specifications for the TradeNet so as to conform to the international standard of EDIFACT (EDI for Administration, Commerce, and Transport), and commissioned local software firms to develop software for TradeNet users. Thus, TradeNet had become operational by early 1989.

The progress of TradeNet deployment was very significant. Partly because TDB announced that the TradeNet would be mandatory for the trade community at the early
stage of its planning,\textsuperscript{9} TradeNet had captured 95\% of all trade document volume and 1,800 subscribers out of 2,200 possible subscribers by mid-1991 (Neo et al., 1994). Although measurable benefits are hardly estimated, a study in 1993 showed that the TradeNet reduced the time required to process trade applications from 2-4 days to 15 minutes, and cut the associated documentation costs by 20\% or more (Neo et al., 1993b).

Another proof of profitability of the TradeNet is the performance of SNS. SNS reported that its revenues had grown from S$4 million in 1989 to more than S$20 million in 1992 (Neo et al., 1993b).

The success of the TradeNet induced the emergence of other industry-wide EDI applications, such as MediNet for the medical industry, LawNet for the legal society, and BuildNet for the construction industry. These EDI projects enhanced the capability of NCB in developing the industry-wide IT applications, and at the same time in effectively coordinating the diversified participants' interests. These successes increased the NCB's confidence to develop a new, and more integrated national IT policy, called the National Information Infrastructure (NII). The next subchapter discusses how the NII concept emerged and how it has been implemented so far.

\textsuperscript{9} TDB announced its intention to make the TradeNet mandatory for all the trade community by early 1993 in December 1986.
3.4. Third Phase --- IT2000 and emerging leadership

3.4.1. IT2000 and its project planning process

The nation's third national IT policy, IT2000, emerged as an initiative from NCB. The necessity for a new national IT plan had been perceived by high-level NCB officials by early-1990 (Neo et al., 1993a). So, in fact, IT2000 was not a direct policy response to the Next Lap which was discussed in the previous chapter. An official announcement for the launch of the IT2000 planning efforts came shortly after the release of the Next Lap. NCB was fortunate because it could impress the public that IT2000 was a quick response of Singaporean IT community to the Next Lap. Unlike the previous two national IT policy forerunners, IT2000 was solely initiated by NCB. That was possible because NCB had gained experience and confidence as a systems integrator through the last 10 years of public and private sector IT projects.

The primary objective of IT2000 was to enhance overall business competitiveness. NCB, through the NITP implementation effort, had been successful in developing sectoral IT applications such as the TradeNet; however, there had been almost no effort to integrate them into more coherent inter-sectoral applications. NCB found a new economic opportunity in integrating those sectoral applications under a unified framework, called the National Information Infrastructure (NII).

In 1990, NCB had launched the project internally by first researching the project planning process itself. NCB regarded such a large scale project would require a new institutional framework. NCB conducted overseas studies to find an appropriate planning process, but could not find one as it recognized that there was no forerunner in the world to such a nation-wide NII project. Consequently, NCB had to develop its own methodology, and in fact developed it in late-1990. The planning methodology took two characteristic approaches: demand- or application-driven, and the combination of top-down and bottom-up approach. These two approaches were developed and introduced solely based on the business practices in Singapore.
The organizational framework for planning the IT2000 project began with the identification of eleven target industry sectors: (1) Construction and Real Estate, (2) Education, (3) Financial Services, (4) Government, (5) Healthcare, (6) IT Industry, (7) Leisure and Tourist Services, (8) Manufacturing, (9) Publishing and Media, (10) Retail/Wholesale/Distribution, and (11) Transportation. The IT2000 steering committee was set up to oversee all sectoral development efforts. The committee was chaired by the NCB chairperson, and was comprised of the chairpersons of each sectoral group, representatives from other governmental agencies, statutory boards, and tertiary institutions, and the NCB secretariat. Each sectoral group was chaired typically by the CEO of a relevant industry association and comprised of about fifteen CEOs or senior managers of both business and government agencies. However, NCB had a right to select the members of the sectoral groups. NCB in fact selected the members among CEOs who were supportive of IT implementation (Neo et al., 1993a).

The actual planning process was helped by the strong leadership of NCB. A five-person support team staffed by NCB personnel worked closely with the chairpersons of

![Figure 3.5: IT2000 project planning framework](image-url)
each sectoral group to advise them in proceeding with the planning process. Almost all underlying research was done by the NCB team for each sector. The other members of the sectoral group simply needed to review the report compiled by the NCB staff at the group meetings. Partly because the member CEOs were too busy, and partly because NCB was in a hurry to compile the final IT2000 report, the project planning process proceeded in a rush. NCB higher officials later confessed that they were in a hurry because they simply did not want to lose momentum in riding a trend of NII, but another study evidenced that they simply wanted to present the final plan by the NCB's 10th year anniversary which would come in several months (Soh et al., 1993). In sum, the planning period actually given was too short at only several months, during which period NCB personnel had to work very hard but the other members could not contribute to it very much. This imbalance in the degree of participation resulted in the NCB's strong leadership in the IT2000 planning process.

3.4.2. The IT2000 report and a new institutional framework

The interim version of the IT2000 report was submitted to the government in September 1991, and PM Goh endorsed it at the NCB's 10th year anniversary celebration held in the same month. The official IT2000 report was made public in April 1992, after much discussion at the cabinet level to streamline and modify the plan. In the official version of IT2000, a list of sixty sectoral applications from eleven sectoral groups was removed because the government regarded that they were so futuristic that they might give the public too unrealistic expectation. In addition, some societal applications were added to reflect government's intention to enhance ordinary people's life, which was expressed in the Next Lap.
The IT2000 report conceptualized three major components of the NII; Conduit, Content, and Compute. Figure 3.6 illustrates the concept of Singaporean NII showed in the report.

(1) **Conduit**: Physical pipelines that carry information. Examples of it are a telecommunication or broadcasting facilities.

(2) **Content**: Information that flows through the conduit. Examples of it are multimedia programs or government documents.

(3) **Compute**: The processing of the content. Examples of it are user authentication or document processing.

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**Figure 3.6: Components of the NII**

Source: Hu (1993)
IT2000 is the first national IT policy that emphasized the importance of the "content." The CNC report emphasized the automation of civil service with extensive

Figure 3.7: NITC representation and organizational structure
Source: NCB (1993i)
computerization (compute), and the NITP emphasized the integration of those computerized systems with extensive networking (conduit). Information and media policy in Singapore had been very restrictive, reflecting Singapore's strict political authoritarian tradition. All domestic papers and broadcasting media are run by GLCs or statutory boards, and the government has not yet admitted the establishment of other media agencies as of 1994. The contents of foreign media are strictly censored, and even prohibited in Singapore if they violate Singaporean morals or if they explicitly state a strong criticism against the authoritarian political regime. It is very interesting that NCB included content as a major component to be promoted and the government approved it.10

Organizational restructuring both inside and outside NCB was done largely by referring to those three components of NII. Inside NCB, the National Information Infrastructure Division (NIID) was newly created, and was expected to spearhead NII application development. Under the NIID, the Planning and Infrastructure Department (PID) and Application and Promotion Department (APD) were formed. The development of sectoral applications was led by APD and the development of common network service and backbone software was led by PID. Outside NCB, the Committee on National Computerization (CNC) was reconstituted into a new high-level committee, National Information Technology Committee (NITC) in March 1992 (Figure 3.7). The members of the newly formed NITC included the representatives from the Ministry of Communications (MOC), the Ministry of Information and the Arts (MITA), and Singapore Broadcasting Company (SBC). MOC and SBC were expected to account for "conduit," and MITA for "content." NITC was given the task of overseeing and coordinating multi-agency efforts.

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10 In fact, there is still harsh discussion going on between the IT community such as NCB and other parts of the government about the liberalization of media regulation. Some proposals have been presented in an effort to promote the electronic media industry without Singaporean morals deteriorating. However, no distinctive measure has been implemented so far.
NCB continued studies on feasible NII applications after the release of the IT2000 report in early 1992, and developed a strategic framework to realize the NII concept as shown in Figure 3.8 (Chin, 1992). Eight sectoral applications were identified as the NCB's answer to the NII concept. In the strategic framework, NCB presented the concept of middleware, which provides the security and reusability part of the network. NIID accounts for the development of application and middleware service layer, and common carriers such as ST and SBC account for telecommunication network layer. This framework seems to follow the OSI (Open Systems Interconnection) layered model, but it is distinctive in that it presented the necessary vertical coverage of the policy and legal framework layer and the technical standard layer. They are, so to speak, interface layers with external society. Legal issues such as validity of electronic documents must be solved and incorporated into the NII framework. Standard issues also must be solved to assure international connectivity of the Singaporean NII. However, neither Singapore IT society nor any other part in the world has experienced or presented a clear answer to them. Those issues will be discussed and studied at NIID, NITC or higher level, and will

![Figure 3.8: NII strategic framework](image)

Source: Hu (1994)
be the hardest part of implementation of the Singaporean NII project.

As discussed above, the emergence of the NII caused a leadership transition again. The initiative to create the new IT2000 project solely emerged from NCB. Leadership had been totally held by NCB during the policy planning period; however, after the policy became public, the gigantic scale of the project required the emergence of higher level leadership and coordination. Thus NITC was formed and the leadership was integrated into higher levels. More stakeholders had become able to represent their interests in NITC, but private sector participation on the contrary might be limited by this leadership transition.
3.5. Conclusion for chapter 3

In conclusion, a national IT policy in Singapore has taken various implementation styles in each phase. The first IT policy, the CNC report was formed as a part of economic policy with the top-down process from the government, and actually implemented by NCB. The second IT policy, the NITP, was spontaneously formed by interested agencies. This had been made possible because underlying IT manufacturing and telecommunication infrastructure policy had shown a considerable success by the time of policy formation. The implementation of NITP was done by the extensive collaborative effort of the interested agencies; however, participation in it had been gradually extended to other sectors including private sector. The third IT policy, the IT2000, was initiated and formed under the strong leadership of NCB. This was made possible because NCB have gained much experience in both public and private sector computerization projects in the previous period. However, the huge size of IT2000 project required the emergence of higher level governmental leadership again. This led to the creation of NITC which will work as an absolute authority until this huge NII project is actually materialized in the 21st century.
4.1. Methodology and basic assumptions

This chapter investigates the influences of construction industry productivity enhancement on the national economy by using an econometric technique. Establishing a feasible econometric model is difficult. Investment in telecommunication or computerization is an important input to the national economy as they contribute to the economy as a productivity enhancer rather than just as consumption goods. Many econometricians and statisticians have tried to establish a feasible econometric model picking telecommunication or informatization factors as independent variables and economic output as a dependent variable. However, their efforts have not been able to explain this causal relationship. Some econometric studies explored the relationship of the economy as an input and telecommunication or computerization as an output (Saunders et al., 1994). They have failed to find significant causal relationships because the situations in which telecommunication or computerization is used as a efficiency enhancer are too complex and varied by each country to be generalized. Some empirical studies have shown the latter relationships but they are less useful in the economic development context because they do not explain any causal relationships but focus instead on the statistical joint variation of each variable. Even if we concentrate on a particular sectoral study, the causal relationships are difficult to investigate because actual data about IT investment and telecommunication consumption are generally lacking or confidential. In the Singaporean construction industry case, there is some numerical data from the Department of Statistics (DOS) (1992) or the National Computer Board (NCB) (1994i), but they are isolated data at a given time and not suitable for econometric analysis. Another difficulty is how to incorporate other factors into the econometric model of productivity. Industrial productivity enhancement involves many factors such as technological progress, wage control, and process automation. Obtaining these data numerically is a way which can be meaningfully aggregated and combined, is a very challenging task, and beyond the scope of this thesis. For example, the influence of technological progress on industrial efficiency varies by applied technology, and
productivity enhancement occurs as a result of overall industrial process reengineering including the technology applied and process automation. This complexity is one of the reasons that there have not been any established econometric model directly connecting technological investment or training factor to the industrial productivity.

Given this constraint, this chapter attempts to establish an econometric reference model for measuring the dependency of the national economy on construction industry productivity enhancement, using industry time series data. Basic assumptions used in the analysis are illustrated in Figure 4.1. To focus the discussion, this chapter investigates the relationships drawn by a thick arrow in the figure. First, the subchapter 4.2 examines the effect of the number of computer and technical professionals on the industrial
productivity. Second, the subchapter 4.3 examines the effect of productivity enhancement on industrial output, which is measured by the fixed capital formation added by the construction industry. Finally, the subchapter 4.4 examines the dependency of the national economy on the construction industry output. The data used are time series data obtained from annual publications of industry data. Because computerization in the industry began just a decade ago, the number of data points may not be enough to ignore the possibility of a statistical discrepancy. In this chapter, such discrepancies are treated solely based on the econometric theory.
4.2. Computerization and productivity enhancement

As discussed in the previous subchapter, the causes of productivity enhancement are very complex. They involve various technological as well as non-technological factors. Therefore, if we were to construct an accurate econometric model representing all the factors involved, the formula would be very long and complex. Furthermore, it is very difficult to obtain all the numerical data. For example, organizational restructuring or technical education may largely affect industrial productivity, but a quantitative measure of them hardly appears as numerical statistics. To simplify discussion, this subchapter concentrates on the effect of technological factors on productivity. Computer installation statistics are selected for measuring the degree of computerization, and the ratio of technical staffs to all the industry's employees are selected for measuring the degree of technical concentration in the industrial process. They are available on a time series basis and are shown in Figure 4.2. Computer installation statistics are drawn from a study conducted by the Construction Industry Development Board (CIDB) in 1992 (Chow, 1992). Industry manpower statistics are drawn from the national manpower

![Figure 4.2: Computerization in the construction industry](image)

Source: Chow (1992) and DOS (monthly)
census, and the ratio of technical and professional staffs to the all industrial employees are calculated based on them (DOS, monthly).

In constructing an econometric formula to be estimated, this subchapter assumes that computer installation variables follow an exponential path while other variables follow a linear path. This assumption is plausible because computer installation appears to grow exponentially as observed in Figure 4.2 while it is impossible for the ratio of technical staffs to grow exponentially. Productivity index may or may not follow the linear path but observation from Figure 4.3 lets us conclude that linear representation is appropriate. Thus, the assumed model takes a semilog form as follows.

![Productivity Index (1978=100)](figure)

**Figure 4.3:** Construction industry productivity

Source: DOS (annual)
PRDIDX = a + b_1 \cdot \ln \text{MICRO} + b_2 \cdot \ln \text{MINI} + b_3 \cdot \text{PPAR} \tag{4.1}

Where:
PRDIDX: Construction productivity index (1978=100)
MICRO: Number of microcomputer installation

![Image of Figure 4.4: Regression results of formula (4.1)]

**Table 4.1: Regression results of formula (4.1)**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>106.22972</td>
<td>8.1541634</td>
<td>13.027666</td>
<td>0.000</td>
</tr>
<tr>
<td>LNMICRO</td>
<td>2.6613804</td>
<td>2.6788709</td>
<td>0.9934710</td>
<td>0.344</td>
</tr>
<tr>
<td>LNMINI</td>
<td>4.8461140</td>
<td>3.3409484</td>
<td>1.4505205</td>
<td>0.178</td>
</tr>
<tr>
<td>PPAR</td>
<td>0.9155112</td>
<td>1.4444302</td>
<td>0.6338217</td>
<td>0.540</td>
</tr>
</tbody>
</table>

R-squared 0.936253 Mean of dependent 140.2472
Adjusted R-squared 0.917129 S.D. of dependent 20.63210
S.E. of regression 5.939442 Sum of squared resid 352.7698
Durbin-Watson stat 1.434187 F-statistic 48.95654
Log likelihood -42.45245

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MINI: Number of minicomputer installation
PPAR: Ratio of professional and technical staffs to all the construction industry employees

Regression is conducted with the ordinary least squares (OLS) scheme and the results are shown in Figure 4.4 and Table 4.1. Simulated equation for formula (4.1) is

![Figure 4.5: Regression results of formula (4.3)](image)

**Table 4.2: Regression results of formula (4.3)**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>112.60833</td>
<td>2.7366008</td>
<td>41.148982</td>
<td>0.000</td>
</tr>
<tr>
<td>LNMINI</td>
<td>8.4177761</td>
<td>0.6852626</td>
<td>12.284015</td>
<td>0.000</td>
</tr>
</tbody>
</table>

R-squared 0.926334 Mean of dependent 140.2472
Adjusted R-squared 0.920195 S.D. of dependent 20.63210
S.E. of regression 5.828523 Sum of squared resid 407.6602
Durbin-Watson stat 1.302514 F-statistic 150.8970
Log likelihood -43.46478

---

63
thus as follows.

\[
\text{PRDIDX} = 106.23 + 2.66 \cdot \ln \text{MICRO} + 4.84 \cdot \ln \text{MINI} + 0.92 \cdot \text{PPAR} \tag{4.2}
\]

\[
(13.03) \quad (0.99) \quad (1.45) \quad (0.63)
\]

The values inside the parenthesis are a t-statistic. In fact, the t-statistics do not show a significantly high confidence level about the null hypothesis that each individual coefficient is zero. The two-tailed significance probability (2-TAIL SIG.) in Table 4.1 indicates the confidence level at the given degree of freedom (df)\(^{12}\) in this regression. Thus, the confidence level at which we can reject the null hypothesis is calculated as follows.

\[
\begin{align*}
\ln \text{MICRO}: & \quad 1 - 0.344 = 0.656 = 65.6 \, (%) \\
\ln \text{MINI}: & \quad 1 - 0.178 = 0.822 = 82.2 \, (%) \\
\text{PPAR}: & \quad 1 - 0.540 = 0.460 = 46.0 \, (%) \\
\end{align*}
\]

As noted, these values are not statistically significant. For example, the coefficient for PPAR is not zero at only 46% confidence level and it may become zero in other 54% of probability in the course of regression. However, we can not conclude that all the coefficients are jointly zero because the F-statistic\(^{13}\) in Table 4.1 shows a relatively significant level at 48.96. The critical value for F-statistic at the given degree of freedom is 6.55 at 99% confidence level (Pindyck et al. 1991). Because 48.96>6.55, we can reject the null hypothesis that all the coefficients are jointly zero at 99% confidence level. Furthermore, when we look at the R\(^2\) and adjusted R\(^2\) in the table,\(^{14}\) we can conclude that

---

\(^{11}\) The t-statistic shows the confidence level in which each individual independent variable is not zero. Usually, t-statistic of less than 2 (95% confidence level) is considered less significant.

\(^{12}\) Degree of freedom (df) in the econometric regression means statistical freedom in calculating regression coefficients. When the size of samples is N and the number of independent variables including a constant term in the estimated formula is k, the degree of freedom is given by N-k.

\(^{13}\) The F-statistic shows the confidence level in which all the independent variables are jointly not zero. If F-statistic is larger than the critical value at the given degree of freedom, we reject the null hypothesis that all the independent variables are jointly zero.

\(^{14}\) The R\(^2\) and adjusted R\(^2\) both show the degree in which all involved independent variables as a whole explain the variation of the dependent variable in the regression. R\(^2\) of close to 1 means that fitted values have a small difference from the actual values. Therefore R\(^2\) is often used to measure the regression's "goodness of fit" to the actual data.
the simulated formula is well fitted to the actual movement of the dependent variable (PRDIDX), because they are well close to 1 at 0.93 and 0.92 respectively.

Next, the validity of the model itself needs to be examined. As we investigated the individual t-statistics, individual coefficients can not show that it is far from zero at a significant confidence level. We test the null hypothesis that two less significant coefficients, those of LNMICRO and PPAR, are jointly zero. The restricted model follows.

$$\text{PRDIDX} = a + b_2 \cdot \ln \text{MINI} \quad (4.3)$$

The regression results of this restricted model are shown in Figure 4.5 and Table 4.2. The F-statistic for testing the null hypothesis that the coefficients of omitted variables are jointly zero is calculated as follows (Pindyck et al., 1991).

$$F_{q,N-k} = \frac{(\text{ESS}_R - \text{ESS}_{UR})/q}{\text{ESS}_{UR} / (N - k)} \quad (4.4)$$

Where: $\text{ESS}_R$: Sum of squared residuals in the restricted model  
$\text{ESS}_{UR}$: Sum of squared residuals in the unrestricted model  
$q$: Number of omitted variables  
$N$: Number of samples  
k: Number of explanatory variables including the constant term in the unrestricted model.

From Table 4.1 and 4.2, $\text{ESS}_R$ and $\text{ESS}_{UR}$ are read as 407.66 and 352.77 respectively. Two variables are omitted in the restricted model, then $q=2$. From the original model specification, $N=14$ and $k=4$. Hence, the F-statistic is calculated as follows.

$$F_{3,10} = \frac{(407.66 - 352.77)/2}{352.77/10} = 0.78$$

The critical value for the F-statistic at the given degree of freedom is 4.10 at 95% confidence level. Because 0.78<4.10, we accept the null hypothesis that those two variables are jointly zero and the restricted model is more plausible.
Finally, a serial correlation\textsuperscript{15} and heteroskedasticity\textsuperscript{16} in a residual term need to be examined. In the Figure 4.4, heteroskedasticity is observed, but it is hard to tell whether serial correlation is present from the figure.

To check the presence of heteroskedasticity, the White test is conducted on the original model (Pindyck et al., 1991). In the White test, the squares of residuals from original regression are regressed by all the independent variables and squares and cross products of them. Then, the formula to be estimated becomes as follows.

\[ \hat{\varepsilon}^2 = a + b_1 \cdot \ln \text{MICRO} + b_2 \cdot \ln \text{MINI} + b_3 \cdot \text{PPAR} \\
+ b_4 \cdot \ln \text{MICRO} \cdot \ln \text{MINI} + b_5 \cdot \ln \text{MICRO} \cdot \text{PPAR} \\
+ b_6 \cdot \ln \text{MINI} \cdot \text{PPAR} \\
+ b_7 \cdot (\ln \text{MICRO})^2 + b_8 \cdot (\ln \text{MINI})^2 + b_9 \cdot (\text{PPAR})^2 \] \hspace{1cm} (4.5)

Where: \( \hat{\varepsilon}^2 \): Squared residuals in the original model

\textsuperscript{15} When adjacent residual values have some relations over a regression, the residual is said to have a serial correlation. In general, a time series data tends to have the serial correlation because a data at a given time somehow tends to affect the subsequent data over time.

\textsuperscript{16} When the magnitude of residual values are not uniform over samples, the residual is said to have a heteroskedasticity.
If the product of $R^2$ in this regression and the number of samples, i.e., $N\cdot R^2$, is more than the critical value of the $\chi^2$ distribution at the given degree of freedom, we reject the null hypothesis of homoskedasticity and have to correct the model with an appropriate heteroskedasticity correction scheme. The results of the regression for the formula (4.5) are shown in Table 4.3. $R^2$ from this regression is 0.90 and $N$ is 14 as before. Then, $N\cdot R^2 = 12.6$ while the critical value of $\chi^2$ distribution at the given degree of freedom (in this case, the number of independent variables in the formula (4.5)) is $\chi^2_{14} = 14.68$ at 90% confidence level. Because $12.6 < 14.68$, we accept the null hypothesis of homoskedasticity and we do not conduct a heteroskedasticity correction.

For the serial correlation, the Durbin-Watson statistic (DW) is used to judge the existence of them. Pindyck et al. (1991) gives the upper ($d_u$) and lower ($d_l$) critical values for DW at the given degree of freedom. From Table 4.1, $DW = 1.43$ while the critical values are excerpted from Pindyck et al. (1991) as $d_u = 1.75$ and $d_l = 0.82$ at $N = 15$ and $k = 3$. Because $d_l < DW < d_u$, the results are inconclusive and we are not sure whether there is a serial correlation in this regression.

In sum, the regression of the assumed model apparently gives a significant result.

### Table 4.3: Regression results of formula (4.5)

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>537.23441</td>
<td>169.01273</td>
<td>3.1786624</td>
<td>0.034</td>
</tr>
<tr>
<td>LNMICRO</td>
<td>691.54598</td>
<td>553.15303</td>
<td>1.2501893</td>
<td>0.279</td>
</tr>
<tr>
<td>LNMINI</td>
<td>-720.24208</td>
<td>582.46040</td>
<td>-1.2365511</td>
<td>0.284</td>
</tr>
<tr>
<td>PPAR</td>
<td>-115.46328</td>
<td>57.357282</td>
<td>-2.0130536</td>
<td>0.114</td>
</tr>
<tr>
<td>SQLNMIICR</td>
<td>-404.00271</td>
<td>266.87266</td>
<td>-1.5138408</td>
<td>0.205</td>
</tr>
<tr>
<td>SQLNMINI</td>
<td>-647.47660</td>
<td>440.56170</td>
<td>-1.4696616</td>
<td>0.216</td>
</tr>
<tr>
<td>SQPPAR</td>
<td>4.3218454</td>
<td>5.0880471</td>
<td>0.8494114</td>
<td>0.444</td>
</tr>
<tr>
<td>LNMCPPAR</td>
<td>-1.7710929</td>
<td>28.138538</td>
<td>-0.0629419</td>
<td>0.953</td>
</tr>
<tr>
<td>LNNMPPAR</td>
<td>13.618591</td>
<td>37.273553</td>
<td>0.3653687</td>
<td>0.733</td>
</tr>
<tr>
<td>LNMNLMNC</td>
<td>985.59554</td>
<td>661.48130</td>
<td>1.4899825</td>
<td>0.210</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mean of dependent</th>
<th>S.D. of dependent</th>
<th>Sum of squared resid</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-squared</td>
<td>0.899849</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.674509</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>20.17964</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.968739</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-53.16124</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Although there is still some room for refining the model, the F-test from the assumed model shows the computer installation statistics explains the productivity growth while microcomputer installation is less significant. Usually a minicomputer is used as a host in a computer network, but a microcomputer is used on a stand-alone basis in most cases. Considering this point, we can conclude that the installation of networked computers somehow affect the productivity enhancement in the industry while that of stand-alone-basis computers does not much. Increase in technical staffs is least significant in the assumed model and may be irrelevant to the productivity growth. However, room for further discussion remains because the number of data points is few and the data are picked on a time series basis. Cross sectoral study inside the industry is required for a more accurate estimation of the causal relationship.
4.3. Productivity enhancement and industrial output

There are two indicators for measuring the construction industry output. A rather general one is value added to national GDP by the industry. Another one is the national capital formation added by construction. Capital formation generally means the purchase of durable goods by industries or individuals. However, the outputs of construction, i.e. buildings, are also generally accounted as capital formation because they namely work as a capital asset in the nation's economic activity. This subchapter picks capital formation as a construction industry output indicator and investigates the effect of productivity enhancement on it.

The historical change of construction manpower and productivity is shown in Figure 4.6, and that of capital formation by the construction industry is in Figure 4.7. As discussed in the previous subchapter, productivity is assumed to grow linearly. Capital formation apparently follows the exponential path as observed in Figure 4.7. It is hard to tell whether construction manpower follows a linear or exponential path from Figure 4.6, but it is assumed that the construction manpower growth follows the linear path in this

![Figure 4.6: Construction manpower and productivity change](image)

Source: DOS (annual) and DOS (monthly)
subchapter. As observed in Figure 4.6, construction manpower has hardly grown exponentially historically. Furthermore, construction is still a very labor-intensive industry, and as discussed in chapter two, Singapore has always suffered from a severe labor shortage. For these reasons, this subchapter assumes that construction manpower growth follows the linear path. Given these assumptions, the regression model to be estimated takes the semilog form again as follows.

\[
\ln \text{CCF} = a + b_1 \cdot \text{CLALL} + b_2 \cdot \text{PRDIDX} \tag{4.6}
\]

Where: CCF: Capital formation added by the construction industry
      CLALL: Construction industry manpower
      PRDIDX: Construction productivity index (1978=100)

Results of the regression for formula (4.6) are shown in Figure 4.8 and Table 4.4. Thus, the simulated equation for formula (4.6) becomes as follows.

\[
\ln \text{CCF} = 6.42 + 0.0043 \cdot \text{CLALL} + 0.0145 \cdot \text{PRDIDX} \tag{4.7}
\]

(9.77) (0.58) (1.87)

From the t-statistics observed, the confidence levels at which we can conclude the coefficients for each variable are not individually zero are calculated as follows.

Figure 4.7: Capital formation by the construction industry
Source: Ofori (1993)
CLALL: $1 - 0.571 = 0.429 = 42.9\%$
PRDIDX: $1 - 0.088 = 0.912 = 91.2\%$

The effect of productivity on capital formation is not zero over the regression at

Figure 4.8: Regression results of formula (4.6)

Table 4.4: Regression results of formula (4.6)
LS // Dependent Variable is LNCCF
Number of observations: 14

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>6.4241388</td>
<td>0.6572306</td>
<td>9.7745585</td>
<td>0.000</td>
</tr>
<tr>
<td>CLALL</td>
<td>0.0043063</td>
<td>0.0073760</td>
<td>0.5838165</td>
<td>0.571</td>
</tr>
<tr>
<td>PRDIDX</td>
<td>0.0145471</td>
<td>0.0077822</td>
<td>1.8692826</td>
<td>0.088</td>
</tr>
</tbody>
</table>

R-squared 0.644660 Mean of dependent 8.832008
Adjusted R-squared 0.580053 S.D. of dependent 0.476644
S.E. of regression 0.308881 Sum of squared resid 1.049481
Durbin-Watson stat 0.482342 F-statistic 9.978142
Log likelihood -1.729808
over a 90% confidence level, but that of construction manpower is not zero only at less than the 50% of confidence level. On the other hand, from the F-statistic observed (9.98), we can conclude that both variables are not jointly zero at 99% confidence level, since the critical value of F-statistic at the given degree of freedom is excerpted from Pindyck et al. (1991) as \( F_{2,11}=7.21 \). In terms of the goodness of fit, \( R^2 \) and adjusted \( R^2 \) indicate 0.68 and 0.62 respectively. They are not significantly close to 1 but it can be said that the simulated equation is reasonably fitted to actual data.

Although the residual plot in Figure 4.8 does not show any significant heteroskedasticity, the White test should be conducted for checking the necessity of the heteroskedasticity correction on the regression. Following equation is constructed for the White test.

\[
\hat{\varepsilon}^2 = a + b_1 \cdot \text{CLALL} + b_2 \cdot \text{PRDIDX} + b_3 \cdot \text{CLALL} \cdot \text{PRDIDX} + b_4 \cdot (\text{CLALL})^2 + b_5 \cdot (\text{PRDIDX})^2
\]

(4.8)

Regression results for formula (4.8) is shown in Table 4.5. \( R^2 \) shows 0.37 then \( N \cdot R^2 \) is calculated as 14\( \times \)0.37=5.18. Since the critical value of the \( \chi^2 \) distribution at given degree of freedom is \( \chi^2_{3}=11.07 \) at a 95% confidence level, we accept the null hypothesis of homoskedasticity and do not apply the heteroskedasticity correction.

Table 4.5: Regression results of formula (4.8)

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-2.3549248</td>
<td>1.7818104</td>
<td>-1.3216473</td>
<td>0.223</td>
</tr>
<tr>
<td>CLALL</td>
<td>-0.0117559</td>
<td>0.0398975</td>
<td>-0.2946533</td>
<td>0.776</td>
</tr>
<tr>
<td>PRDIDX</td>
<td>0.0450907</td>
<td>0.0449341</td>
<td>1.0034862</td>
<td>0.345</td>
</tr>
<tr>
<td>SQCLALL</td>
<td>0.0000138</td>
<td>0.0001221</td>
<td>0.1127710</td>
<td>0.913</td>
</tr>
<tr>
<td>SQPRDIDX</td>
<td>-0.0001873</td>
<td>0.0002516</td>
<td>-0.7441738</td>
<td>0.478</td>
</tr>
<tr>
<td>CLALLPKR</td>
<td>0.0000617</td>
<td>0.0003747</td>
<td>0.1646822</td>
<td>0.873</td>
</tr>
</tbody>
</table>

R-squared 0.368750 Mean of dependent 0.074963
Adjusted R-squared -0.025782 S.D. of dependent 0.076630
S.E. of regression 0.077611 Sum of squared resid 0.048188
Durbin-Watson stat 1.143186 F-statistic 0.934652
Log likelihood 19.83674
On the other hand, the presence of a serial correlation is possible since the residual plot in Figure 4.8 strongly suggests it. DW in Table 4.4 is 0.48 while the critical

![Figure 4.9: Regression result after serial correlation correction (formula (4.9))](image)

**Table 4.6: Regression result after serial correlation correction (formula (4.9))**

LS // Dependent Variable is LNCCF  
Number of observations: 11  
Convergence achieved after 3 iterations  

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>11.804802</td>
<td>1.0792904</td>
<td>10.937559</td>
<td>0.000</td>
</tr>
<tr>
<td>CLALL(-1)</td>
<td>0.0044070</td>
<td>0.0022899</td>
<td>1.9244818</td>
<td>0.096</td>
</tr>
<tr>
<td>PRDIDX(-2)</td>
<td>-0.0205685</td>
<td>0.0067374</td>
<td>-3.0528604</td>
<td>0.019</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.6378082</td>
<td>0.0881158</td>
<td>7.2382988</td>
<td>0.000</td>
</tr>
</tbody>
</table>

R-squared 0.830766  
Mean of dependent 9.043828  
S.E. of regression 0.108566  
Sum of squared resid 0.082506  
Durbin-Watson stat 1.840711  
F-statistic 11.45431  
Log likelihood 11.30193
values are excerpted from Pindyck et al. (1991) as $d_u = 1.54$ and $d_l = 0.95$ at $N=15$ and $k=2$. As $DW < d_l$, we fail to reject the null hypothesis of no serial correlation. Then, some form of serial correlation correction needs to be applied. Some variables taking lag form are introduced for checking the presence of distributed lags in the disturbance term of the original model. After many trials, the following corrected model is constructed for taking the lags and serial correlation into account.

$$\ln CCF = a + b_1 \cdot CLALL_{t-1} + b_2 \cdot PRDIDX_{t-2} \quad (4.9)$$

The subscript $t-i$ means that past $i$ year's data for each individual variable is taken in the regression. Furthermore, Cochrane-Orcutt procedure is introduced to correct a first order serial correlation in the residual term (Pindyck et al., 1991). The regression result is in Figure 4.9 and Table 4.6. Coefficients for $CLALL_{t-1}$ and $PRDIDX_{t-2}$ indicate high $t$-statistics. The $F$-statistic of 11.45 indicates that both variables are significantly different from zero (since the critical value at the given degree of freedom is $F_{2,11}=7.21$ at 99% confidence level). $DW$ of 1.84 indicates that there is no longer a serial correlation in the residual term since $d_u = 1.75$ and $d_l = 0.82$ at $k=3$ and $N=15$, and $DW > d_u$ in this case.

When we look at the coefficients in the corrected model, we find some interesting facts. Productivity improvement of two years ago affects the current capital formation output negatively, which means the increase in the productivity index of 1 unit results in 2% decrease in the output at two years later (since coefficient is -0.02). Furthermore, increase in the construction manpower of 1000 people has little effect on the next year's output since coefficient is very small at 0.004.

In overall, if we compare the results from formula (4.6) and (4.9), we conclude that current productivity change has some immediate effect on current construction output if we do not take the presence of the serial correlation in the disturbance term into account. In the corrected model, we conclude that neither of productivity nor manpower increase affects the construction output. Thus, room for discussion remains in the source of the strong serial correlation. The necessity of the serial correlation correction indicates that it must exist but it is hard to conclude it only from the models specified in this

---

17 Coefficient for the AR(1) term indicates the correlation between adjacent disturbances term, and that coefficient of close to 1 indicates the presence of the positive serial correlation in the regression.
subchapter. Time series data tends to have a serial correlation as its nature. As discussed in the previous subchapter, cross sectoral study with larger sample is necessary for concluding this point.
4.4. **National economy's dependency on construction industry output**

This subchapter investigates more historical characteristic of Singaporean economy. It is assumed that the nation's economic output is formed purely by its capital and labor. In addition, it is also assumed that national economy as a whole follows the Cobb-Douglas production function form in yielding the output. For checking the economy's dependency especially on the construction industry, only capital input from the construction industry is picked. Thus the model to be estimated follows.

\[
GDPCR = a \cdot MPALL^{b1} \cdot CCF^{b2}
\]

Where:
- **GDPCR**: Gross domestic products in current price
- **MPALL**: Number of all industrial manpower
- **CCF**: Capital formation added by the construction industry

![Graph showing GDP and Capital Formation](image)

**Figure 4.10**: Capital formation by construction industry and National GDP

Source: Ofori (1993) and UN (annual)
Taking the natural logarithm of both hands yields the following linear form.

$$\ln \text{GDPCR} = a + b_1 \cdot \ln \text{MPALL} + b_2 \cdot \ln \text{CCF}$$  \hspace{1cm} (4.11)

Figure 4.11: Regression results of formula (4.11)

Table 4.7: Regression results of formula (4.11)

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>2.3550550</td>
<td>0.4821128</td>
<td>4.8848626</td>
<td>0.000</td>
</tr>
<tr>
<td>LNMPALL</td>
<td>0.3712475</td>
<td>0.1789087</td>
<td>2.0750665</td>
<td>0.048</td>
</tr>
<tr>
<td>LNCCF</td>
<td>0.6221679</td>
<td>0.1014574</td>
<td>6.1323045</td>
<td>0.000</td>
</tr>
</tbody>
</table>

R-squared 0.968975  Mean of dependent 9.659217
Adjusted R-squared 0.966493  S.D. of dependent 1.023845
S.E. of regression 0.187413  Sum of squared resid 0.878091
Durbin-Watson stat 0.190337  F-statistic 390.4048
Log likelihood 8.740662
This model again may or may not be appropriate because the previous subchapter assumed that construction manpower growth follows the linear path. Consistency of the

Figure 4.12: Regression results of formula (4.11) after the inclusion of AR(1) term

Table 4.8: Regression results of formula (4.11) after the inclusion of AR(1) term
LS // Dependent Variable is LNGDPCR
SMPL range: 1965 - 1991
Sample endpoints adjusted to exclude missing data
Number of observations: 27
Convergence achieved after 5 iterations

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>STD. ERROR</th>
<th>T-STAT.</th>
<th>2-TAIL SIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-140.72425</td>
<td>4136.7619</td>
<td>-0.0340180</td>
<td>0.973</td>
</tr>
<tr>
<td>LNCCF</td>
<td>0.1978303</td>
<td>0.0489673</td>
<td>4.0400481</td>
<td>0.001</td>
</tr>
<tr>
<td>LNMPALL</td>
<td>0.2538168</td>
<td>0.0839436</td>
<td>3.0236577</td>
<td>0.006</td>
</tr>
<tr>
<td>AR(1)</td>
<td>1.0005010</td>
<td>0.0144224</td>
<td>69.371390</td>
<td>0.000</td>
</tr>
</tbody>
</table>

R-squared 0.998619 Mean of dependent 9.724131
Adjusted R-squared 0.998439 S.D. of dependent 0.982879
S.E. of regression 0.034686 Sum of squared resid 0.034686
Durbin-Watson stat 1.245112 F-statistic 5544.079
Log likelihood 51.56173

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model is still not clear but as far as we observe on Figure 4.10, it is not so inappropriate to assume that national manpower as a whole grows exponentially. To follow the classic form of the Cobb-Douglas production function, this subchapter stays on assuming the model defined in formula (4.10) and (4.11).

The regression results for formula (4.11) is in Table 4.7. From the coefficients in the table, the simulated equation is constructed as follows.

\[
\ln \text{GDPCR} = 2.36 + 0.37 \cdot \ln \text{MPALL} + 0.62 \cdot \ln \text{CCF} \quad (4.12)
\]

The t-statistics for each coefficient are very significant at above 2. Two-tailed significance probability in the table shows both coefficients are not individually zero at 95% confidence level. The F-statistic is also significant at 390.41. Because the critical value of the F-statistic is \(F_{2,25}=5.57\) at a 99% confidence level, it is highly plausible that both variables are not jointly zero. The \(R^2\) and adjusted \(R^2\) also show the high degree of the goodness of fit to the actual value at 0.97 for both terms. However, the DW is very low at 0.19, which suggests the existence of a serial correlation in the residual term. Then, model modification needs to be made for the serial correlation correction.

Model modification is conducted on a trial-and-error basis; therefore, the process itself may not be accurate. After some trials, it is concluded that the inclusion of AR(1) term in the regression simply solves the problem. The regression results are in Figure 4.12 and Table 4.8. All the t-statistics, F-statistic, and \(R^2\) are improved with the new regression, but the new DW of 1.25 suggests that we are still inconclusive about the existence of a serial correlation (since \(d_1=1.65\) and \(d_2=1.16\) at \(N=27\) and \(k=3\), then \(d_1<\text{DW}<d_2\)).

In sum, capital formation added by construction strongly affects the national GDP. The sum of the coefficients for each variable is almost 1 (constant return to scale) in the original model and far less than 1 (decreasing return to scale) in the corrected model. Because the model specification is still primitive, there still must be the source of serial correlation in those models. The high coefficient for AR(1) in the corrected model strongly suggests this point. Only we can conclude from these regression results is that the capital formation by construction positively affects the national economy. However,
its effect does not exceed 20% per unit output increase since the coefficient of LNCCF is 0.20 and it will decrease when we add new variables in the original model.
4.5. **Conclusion for chapter 4**

Three econometric models are tested for measuring the effect of computerization in the construction industry on the national economy. Although the model specification employed is still primitive, they suggest some noticeable results. The first regression result suggests that the installation of minicomputer somehow improves the overall construction productivity but microcomputer installation and increase in technical staffs have little effect on the productivity improvement. The second regression result suggests that the productivity improvement somehow affects the industry's output following a fair amount of the lag. However, the influence is very small as far as the regression results indicate. Third, and consistent with the initial premise of this thesis, the regression result suggests that the construction industry output plays a very significant role in the national economic development.

For all of the three models estimated, a more refined model specification is necessary for a more accurate estimation. Because the data regressed in this subchapter is time series data, the data is expected to contain a great deal of serial correlation. The number of data points is also a problem. Economic and computerization statistics are available only on an annual basis, and the publication of productivity and computerization data began only a decade ago. Room for discussion remains in assessing both the accuracy of the model specification and the statistical discrepancy resulting from a little amount of data.
Chapter Five

The Construction Industry and Information Technology

5.1. Overview and analytical framework

This chapter investigates the influence of IT on the construction industry and assesses the potential of a proposed integrated construction industry network, the Construction and Real Estate Network (CORENET). CORENET is one of the main components of Singaporean NII, as is discussed in the chapter three. Its primary functional purpose is to reduce transaction time required for the exchange of various information among construction relevant parties, by integrating and standardizing exchange processes and data formats under a unified framework.

In addition, it is the only "industrial" IT application presented under the IT2000 NII concept. Preceding industrial IT applications such as the TradeNet have met great success, by riding effectively on the trend of the strategic economic plan at the late 1980s. However, the inclusion of CORENET in the IT2000 plan is not a result of such a trend. In fact, the economic plan for 1990s, called the Next Lap, aims to make Singapore a financial and information center in the Southeast Asia. In sum, its aim is the informatization of the economy rather than industrial promotion. Although construction still takes up an important part of industrial output in the economy as discussed in chapter four, the growth trend is going downward recently and construction is now regarded as a sun-set industry among economic sectors. In sum, this particular effort to revitalize the construction industry did not come from the strategic promotional effort at a national level. Rather, it emerged when industry leaders perceived that the construction industry was far behind other industries in terms of productivity and computerization.

CORENET is facing some difficulties which other industries have not met yet in their effort to implement a large scale computerization project. To analyze the problems and potentials of the proposed integrated network, this chapter takes the three-step approach. First, it examines the characteristics of professional practices in the industry and environmental thrusts faced by the industry. Second, it describes how the IT has been implemented in those practices. Finally, it analyzes technical and non-technical
problems in implementing such an integrated network, and considers some possible measures to correct those problems.
5.2. Professional practice and current environmental thrusts for the industry

5.2.1. Institutional and regulatory framework

Unlike manufacturing, construction is a very dispersed and discontinuous process involving many participants. Industrial practices are illustrated briefly in Figure 5.1. Once a contract on a particular construction project is made between a client and contractor, several pieces of information must be exchanged among various practitioners.
The contractor consults outside technical specialists to do the most of technical part of the construction works such as planning, designing and building. Those specialists include architects, quantity surveyors (QS), engineers, and other consultants in various fields. The technical firms also must have a connection with the client to exchange information about actual technical requirements and production information on the project. The contractor must submit an application to a development control agency to obtain a permission to develop a particular portion of a land. The land to be developed also has to be registered in a registry in the Ministry of Law (MinLaw). The technical firms must follow the technical regulations set by building control agencies. They must refer to those technical regulations from the various agencies at the same time before deciding on the final architectural design. They then must submit an application to those different agencies depending on relevant technical fields (electricity, gas, structural safety, etc.) to obtain approvals for conforming the regulation. More technically specific information also must be exchanged among the technical firms to allow the architects to come up with an actual production design under a unified project concept. However, those technical information is in very dispersed forms when it comes to the contractors. It is often inconsistent with each other because information exchange channels in those practices are so complicated.
Other than those practical participants, there is another agency for industrial development, which is characteristic in the Singaporean construction industry. The Construction Industry Development Board (CIDB) is a statutory board under the Ministry of National Development (MND), and responsible for industrial upgrade and the overall

Table 5.1: Relevant parties involved in the construction industry practice

<table>
<thead>
<tr>
<th>Agencies or organizations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of National Development (MND)</td>
<td>Government ministry responsible for the development of public infrastructure and land development. It funds CIDB, URA, PUB, HDB, and PWD.</td>
</tr>
<tr>
<td>Ministry of Law (MinLaw)</td>
<td>Government ministry responsible for legal affairs. All national land must be registered in a registry in the MinLaw.</td>
</tr>
<tr>
<td>Construction Industry Development Board (CIDB)</td>
<td>Statutory board under MND responsible for the development and technical upgrade of the industry. Conducts the qualification of contractors and the technical standardization of design and production processes. Also responsible for construction export promotion and construction R&amp;D.</td>
</tr>
<tr>
<td>Urban Redevelopment Authority (URA)</td>
<td>Development control agency under MND responsible for a land management, especially concerning the conservation of historic sites and environmental protection.</td>
</tr>
<tr>
<td>Housing and Development Board (HDB)</td>
<td>Statutory board under MND responsible for the provision of public housing.</td>
</tr>
<tr>
<td>Public Utility Board (PUB)</td>
<td>Statutory board under MND responsible for the construction of public utility such as gas, water, and electricity. PUB is expected to be privatized in 1995. It stipulates technical regulations regarding the installation of public utility facilities in every building and construction work.</td>
</tr>
<tr>
<td>Public Works Department (PWD)</td>
<td>Building control agency under MND responsible for other public construction works and civil engineering projects. It stipulates technical regulations regarding the safety of buildings in public projects</td>
</tr>
<tr>
<td>Fire Safety Bureau (FSB)</td>
<td>Department under the Singapore Civil Defense Forces (SCDF) responsible for the technical regulation for the fire safety of every building in Singapore.</td>
</tr>
<tr>
<td>Singapore Contractors Association Limited (SCAL)</td>
<td>Trade association of local contractors. Foreign contractors are given associate membership.</td>
</tr>
<tr>
<td>Singapore Institute of Architects (SIA)</td>
<td>Trade association of local architects. It stipulates the architectural standards to be followed in a planning and design process.</td>
</tr>
<tr>
<td>Institution of Engineers Singapore (IES)</td>
<td>Trade association of construction engineers. It holds several conferences on the development of construction technologies including the construction IT applications.</td>
</tr>
</tbody>
</table>
development of the Singaporean construction industry. Major relevant agencies and organizations are listed and explained in Table 5.1. As shown in the table, several public agencies are involved in the construction practice. Some agencies sometimes play multiple roles in the practice. For example, HDB is the largest client in housing projects, but at the same time, it is a building and development control agency. PWD and PUB are also main clients in public projects, but also a building control agency at the same time.

Usually, contractors and architects must provide almost ten application forms to different public agencies and offices to obtain a planning approval for the project, and architects must consult at least almost twenty public departments and agencies for referring to relevant regulations, submitting an appropriate applications, and getting a certificate of conforming to the regulations (SIA, 1993). There are indeed many number of information exchange channels between relevant parties. Worst of all, the process is often discontinuous. Therefore, the practice becomes extremely complicated when a project gets larger.

When viewed from a time series perspective, construction is a very long process, taking generally over 2 years (Figure 5.2). A development application must first be made and applicants have to wait generally 1 to 2 month until they get approval from controlling agencies. Building plan applications can be submitted only after a particular development plan is approved. The approval process takes even longer, usually 3 to 4 months. During this period, architects and other technical firms have to clear all the regulations regarding architectural design and building safety. Reference and
consultation processes until getting the final building plan approval are extremely complicated as discussed above, and at the same time, very time consuming.

5.2.2. Productivity improvement and internationalization

Construction industry is facing various environmental thrusts. Construction is intrinsically a very labor-intensive process. Although some assembling and design work has been automated thanks to the rapid progress of robotics and information technology, most production work in construction sites still has to depend on a large amount of labor. However, as discussed in chapter two, labor shortage have been consistently a severe problem in the Singapore economy. In addition, the public impression of construction works is still unfavorable, because of the dirty image of a construction site. Consequently, the construction industry has had to rely on foreign labor to fulfill the shortage to a greater extent than other industries. The ratio of foreign to domestic workers exceeded 5.0 in 1992, and there is no possible immediate remedy for improving it in near future (Ofori, 1993). Because the foreign labor pool is transient, a skilled construction worker pool has hardly been developed. One of the major causes of low construction productivity growth in the industry has been attributed to this problem. In fact, a technological utilization level (machinery or IT utilization) in the industry is not much behind that of other industrialized nations (CIDB taskforce, 1992). However, the absolute shortage of skilled workers is dragging the utilization level down, and consequently making an unequipped, labor-intensive construction process more economical than an automated process.

Thus, construction productivity improvement has been identified as an imminent thrust which the industry has to overcome for further development. A CIDB task force report in 1992 made several recommendations for productivity improvement. Standardization of a prefabricated assembly process and a computerized design process were major components of the recommendations. Prefabrication improves the easiness to build in a construction site, and the computerized design improves the complexity of the information exchange processes. A strong initiative for re-engineering and standardizing the whole industrial practices is necessary because the process is so dispersed and distributed, involving various participants. Further difficulties arise because current practical participants tend to regard current situations as economically optimal. Each participant does not and can not care about the overall efficiency of the whole practice
because of its complicated and dispersed nature of the practice. A similar situation was also observed in the TradeNet case, but the implementation of a new re-engineered process is apparently harder than that case because each participant has already proceeded with the automation and computerization to some tangible extent at a local level.

On the other hand, the economic environment surrounding the construction industry is rapidly changing in recent years. As shown in Figure 5.3, the growth of

![Graph](image)

**Figure 5.3:** Trend of construction output growth
Source: Ofori (1993)

![Graph](image)

**Figure 5.4:** Trend of construction export
Source: Ofori (1993)
capital formation added by the construction has been fluctuating in recent years at lower level than that of national GDP although the growth rate is higher than the national GDP only in 1991. On the other hand, construction exports have been steady in the same period since 1984, partly thanks to the promotion effort of the CIDB and the industry's cost competitiveness in the international construction market. Figure 5.4 shows the trend of construction export of local contractors. The ratio of export to domestic contracts exceeded 10% in 1988 and shows gradual decline in recent years but showed the symptom of upturn in 1992. The volume of export in 1992 is 1.6 million Singapore dollars and it grew by over 1300% since 1984. Construction exports have now become an important part of construction earnings.

In sum, the Singapore construction industry is facing lower productivity growth and declining output problems domestically, but at the same time it is getting a competitive edge in the international market. It should be stressed that they are not an isolated issue. As the trend of internationalization is becoming apparent, Singapore contractors have to compete with major foreign counterparts. As a project gets large in the international level, better productivity and competitiveness are immediate thrusts for the further development of the industry. However, the burden put on the industry is heavier than that of the foreign counterparts because of the hopeless absolute labor shortage.
5.3. Current IT use in the industry

5.3.1. Computer-aided design and data exchange

Computer-Aided Design and Drawing (CADD) is the most prevalent usage of IT in the construction industry. The CADD usage is mainly prevalent among Singaporean architectural firms, and is also becoming prevalent among contractors in recent years. However, existing CADD data formats are proprietary for a particular software in its nature. There are some interexchangeable formats existing, but they generally lack elaborate design and production information which are required for more advanced production automation and prefabrication. Generally, only the graphical and drawing parts of the CADD data are kept in those compatible formats. From the user's perspective, although architects have had incentives to introduce the CADD systems for raising their own design productivity, they have not had those for exchanging the data.

Table 5.2: Major CADD data formats used in the Singaporean construction industry

<table>
<thead>
<tr>
<th>Neutral CAD format</th>
<th>Number of supported softwares</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawing information only</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IGES (Initial Graphics Exchange Specifications)</td>
<td>21</td>
<td>Most commonly used format originally published by ANSI. Strongly supported by the US public sector.</td>
</tr>
<tr>
<td>DXF</td>
<td>7</td>
<td>Originally developed by Autodesk, the developer of AutoCAD. Almost de-facto standard for microcomputer-based CADD systems.</td>
</tr>
<tr>
<td>SIF (Standard Interface format)</td>
<td>NA</td>
<td>Originally developed by Intergraph and supported by several vendors</td>
</tr>
<tr>
<td><strong>Drawing with some production information</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDES (Product Data Exchange Standard)</td>
<td>-</td>
<td>Prospective CADD format. It includes product information such as automated processing, manufacturing, inspection and management.</td>
</tr>
<tr>
<td>STEP (Standard for the Exchange of Product Definitions)</td>
<td>-</td>
<td>Currently emerging prospective CADD formats defined by ISO. It includes product information such as automated processing, manufacturing, inspection and management.</td>
</tr>
</tbody>
</table>
with other users. The necessity to exchange the CADD data has only recently emerged when contractors and engineers also began to introduce the CADD system (Ho et al., 1989). Major interexchangeable CADD formats used in the Singaporean construction industry are described in Table 5.2. IGES, DXF, and SIF are major three such formats currently used. Their usage is almost the same in terms of the number of firms employing them, but IGES leads others in terms of the amount of supported CADD software.

Having no compatibility among those interexchangeable formats led to a serious problem when firms began to consider the data exchange. To solve this problem, the Gruman International / Nanyang Technological Institute CAD/CAM Centre (GINTIC) has begun research on the CADD data exchange by 1989 in collaboration with the CAD-CAM Data Exchange Technical Centre of the UK. GINTIC's research concentrated on the development and validation of the IGES translator which enables the data transfer from local proprietary CADD data formats to the neutral IGES format. The selection of the IGES as the industry standard was based on survey responses from CADD vendors. The development of the translator was vested on each CADD vendors, and the service offered by the GINTIC was limited to the validation of the developed translator. GINTIC conducted extensive performance evaluation of various translators in 1989. GINTIC reported that the success rate of translation fell between 60 to 80% then (Ho, 1989). GINTIC attributed the cause of the imperfect translation to the improper understanding of the CADD vendors on the IGES format. Notifying this problem, GINTIC began researching on the flavoring program, which does pre- and post- processing on the data made by the IGES translators. This flavoring program improves the translation success rate. GINTIC offers the bureau service of this flavoring program and will continue to research on the improvement of the program to catch up with the development of new CADD software and the new version of the IGES format. The objective of this research is to raise the translation success rate to 100%, but GINTIC at the same time considers the transition of the standard from the IGES toward the PDES, a more advanced standard. PDES features a production information support as well as drawing information, while IGES only supports drawing information. PDES is expected to be one of the next generation CADD format standards.
The progress in the compatibility technology facilitated the development of a CADD data exchange system. CADBase, a floppy-disk-based data exchange service for the standard details of building products, became operational in 1990 (Ofori, 1993). CADBase was established under collaboration of the Design Support Centre (DSC) of CIDB and the Singapore Institute of Architects (SIA). CADBase enabled CAD users to access the standardized building design information in a digital format. Its eventual functional objective is to raise an architectural design productivity by 25%. It basically offers the comprehensive digital library of standardized product symbols and matching data sheets from 42 material manufacturers and public agencies. The number of subscribers of the CADBase grew rapidly in initial years from 110 in 1991 to 210 by 1992, and is currently around 400 as of 1995. In 1991, the Graphical Data Exchange for Construction Industry (GDECON) was introduced to this CAD-based information exchange system (Ofori, 1993). GDECON is basically a data transfer system which translates the CADD data of one software package to another. This was one of the practical applications resulted from the CADD data compatibility technology development. With the GDECON, almost all CADD users have no longer had to care about the graphical incompatibility of the data among various CADD systems. This CADBase system later got online with the introduction of the GraphNet. GraphNet was jointly developed by SNS, NTU, and CIDB, and is operated by SNS. Its service includes the translation service between different CADD formats, the online database service for

![Figure 5.5: Concept and architecture of CADD data interexchange system](image-url)
the digitized drawings of standardized symbols and components, and the exchange service for engineering specifications and architectural drawings among different architects, contractors, and governmental agencies. In sum, it is exactly the online version of the GDECON. The GraphNet service began only recently, but its subscription has been very low due to the high cost of large graphical data transmission and the lack of sophisticated computerization at a local level (Neo et al., 1993b).

5.3.2. Electronic application system and integrated land databases

The electronic application and approval system is another important IT application development in the construction industry. Usually, application to a building control and development control agency for the planning and technical regulation approval is made by a paper. Although computerization in the design process is prevalent among architectural and technical firms, they have to provide various different application forms in a paper form. As described in the first section in this chapter, the number of applications they have to provide is about ten at least and over twenty at most. This complexity is one of the causes of lower productivity in the planning stage from an applicant's perspective. From a governmental agency's perspective, the manual evaluation and approval of such paper-based applications is also a tedious work. An integrated electronic application system and database of site and regulation information improves the approval process productivity. Construction of such a system could help building and development control agencies to manage their site information, planners in the agencies to make an effective decision on a particular application, and eventually could improve civil service productivity a great deal. Therefore, the incentive to construct such a database is very strong among those controlling agencies.
Figure 5.6: Concept model of the ILUS

Historically, the development of an electronic application and database system has been done separately by each relevant agency. The Integrated Land Use System (ILUS) of the Urban Redevelopment Authority (URA) is a good example of the agency-based electronic application and land data reference system (Ng, 1990). ILUS was developed under collaboration of the NCB and URA, and the first part of it has become operational by 1992. The functional objective of ILUS is not an application process automation. Rather, it aims to construct an integrated national land database by employing the Geographic Information System (GIS) technology. GIS can deal with both textual and graphical information in an integrated way, which means not just as drawing or mapping information. GIS can identify each building component or land parcel as it is while showing them in a display in a graphical way. With the GIS, planners in the agencies can easily identify the development constraints of a particular land portion, and can make an effective and quick decision on whether to approve a particular development application. Electronic planning submission subsystem has been developed as a mean for realizing the input function of ILUS. Development planning part of the subsystem has already been completed and the building planning, land safeguarding, and road planning part of the subsystem are still under development. ILUS will also feature the reference service of land information for relevant outside parties at free of cost. Therefore, there is also an incentive for outside parties to introduce and subscribe the ILUS. According to a report
from a high level URA official, the reference system is expected to be offered on the EDI system to the professional community and by Teleview\textsuperscript{18} to the public.

Similar system, called the Integrated Land Information System (ILIS), has been developed by the Housing and Development Board (HDB). ILIS is a land development management system for HDB-managed land, similar to ILUS. ILIS employed the same hardware architecture and equipment to maintain a compatibility with the ILUS (NCB, 1993h). Although the HDB expects the integration of ILIS and ILUS to form an integrated national land database, a practical proposal for such integration has not yet been made.

\textsuperscript{18} Teleview is a public information kiosk system located in major public places around Singapore. Its service includes the offering of civil service information, corporate information, and media information. It can also deal with some civil service transactions electronically without stopping by the public office. It offers those service basically at free of cost.
The Singapore Land Data Sharing Network (SLDSN), later renamed the LandHub, is another example of an agency based application. SLDSN has been developed in the context of the Civil Service Computerization Programme (CSCP), which is discussed in chapter three. The civil service basically involves many kinds of registry work. Each relevant ministry and statutory board often tried to collect a necessary set of data individually; therefore, the collected data were often duplicated and fragmented among the agencies. This inefficient situation called for the civil service re-engineering study on a national database hub in 1983. The study identified three
integrated databases to be constructed: land, people, and establishments (Figure 5.7). Each of which was to be constructed by the Ministry of Law (MinLaw), the Ministry of Home Affairs, and the Ministry of Trade and Industry (MTI). SLDSN commenced as a CSCP project under the MinLaw. The initial functional objective of the SLDSN system was concentrated on the automation of digital map production, but later the MinLaw perceived the construction of a more integrated land information system for effective land planning as a more important objective. To realize this function, the project objective was set to integrate all the duplicated and scattered land information which had been so far managed by several governmental agencies. Thirteen governmental agencies were involved in the management of the land data then; therefore, a necessity to coordinate the interests of those agency emerged. A high level committee called the Land Systems Committee (LSC) was appointed to conduct this mission. The LandHub was implemented in 1990, and 27 government agencies currently subscribe to this service.

While SLDSN featured some dreamy functions, it yielded other problems which were currently unexpected. The issues are mostly regarding the legality of electronic documents. Usually registration of land requires a legal signature. Therefore, a registration process itself must be done manually to follow the legality. Furthermore, new security issues regarding the confidentiality and privacy of the data would emerge if all the data are digitized. Copyright issues would also emerge if the data becomes easily available. The definite solutions for these legislative problems has not yet been identified although the effort to legislate them is still under rigorous discussion among relevant agencies.\(^{19}\) Because a land registry is basically a property issue, it is expected that the solution would not easily come in a short term.

While above three examples in the developmental control and the land registry areas have emerged in the context of the agencies' strong initiative to construct their own database, there had not been any such agency based IT application in the building control area. The concept of the BuildNet emerged in an effort to fill this gap. BuildNet was developed jointly by the National Computer Board (NCB) and the Construction Industry Development Board (CIDB) (Ko, 1990). Therefore, it is different from the three applications discussed above in that it is a result from industrial promotion efforts by the

\(^{19}\) From the author's interview to a NCB official.
CIDB rather than that from internal spontaneous initiatives by the building control agencies. BuildNet is basically an integrated application processing system comprising an electronic application submission system, a regulation codes reference system, and an intelligent database system (Ofori, 1993). Applicants can refer to the database for retrieving regulations, legislation, and official circulars, and can submit building plan applications electronically with the submission system. The planners and designers in the controlling agencies can evaluate and process those applications with the intelligent database, and make a quick and effective decision on a particular approval.

Currently, the submission system of the BuildNet employs a text-based EDI; therefore, the information retrieved or submitted is limited to text-based information. BuildNet is expected to employ graphic-based EDI standards to expand its capability, but practical plan has not been made. In fact, standardization for graphic-based EDI is not yet settled in international community. Several CADD software vendors employ their own graphic-based EDI, and the specification of them is generally proprietary (Ko, 1989b). Some attempts to establish a graphic-based EDI standard specifically designed for the construction industry have been made such as the one used in the GraphNet, but a certain standard has not emerged yet. Because conforming to the international standard is especially important for the Singaporean construction industry, whether a graphic-based standard for the industry will emerge in the short term is still uncertain.
5.3.3. Low IT usage and initiative for inter-organizational applications

Some practical forms of the inter-organizational network have already emerged in an attempt to facilitate the computerization level in the industry. As was previously noted, historically, the level of computer usage in the Singaporean construction industry has been low compared with other economic sectors. Even though computer usage has been prevalent among architects and technical firms, it has been very low among non-technical firms such as contractors. A study by NCB in 1994 picked up the number of employees per computers as a statistic for measuring IT installation in the industry (NCB, 1994i). The number is 5.9 people per one PC, WS, or other computer terminal in the construction industry, while the numbers are 5.2 people in a manufacturing sector and 3.0 people in a transport sector (Table 5.3). Even among the firms which use computers, they mostly use the computers in non-strategic fields such as word-processing, accounting, and local databases. Furthermore, the percentage of networked computers is still relatively low. The same NCB study reported that the percentage of the computers which have a network connection with others was 50% in an intra-organizational level and 46% in an inter-organizational level (NCB, 1994i). Those percentages are the lowest among all the economic sectors (Table 5.4 and 5.5). The major cause for the low networking deployment has been identified as the high complexity of professional practices. Furthermore, the high ratio of SMEs in the industry also identified as a cause of the lower computerization and networking deployment. SMEs have been hesitant to implement

<p>| Table 5.3: Number of employees per PC, WS, or other computer terminal (1994) |</p>
<table>
<thead>
<tr>
<th>Construction</th>
<th>Manufacturing</th>
<th>Transport</th>
<th>Public sector</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.9</td>
<td>5.2</td>
<td>3.0</td>
<td>1.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Source: NCB (1994i)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| Table 5.4: Percentage of PCs / WSs networked to other computers inside firms employing 10 or more people (Intra-organizational networking) |</p>
<table>
<thead>
<tr>
<th>Construction</th>
<th>Manufacturing</th>
<th>Transport</th>
<th>Public sector</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 %</td>
<td>57 %</td>
<td>67 %</td>
<td>92 %</td>
<td>66 %</td>
</tr>
<tr>
<td>Source: NCB (1994i)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| Table 5.5: Percentage of network links connected to at least one business partner among firms employing 10 or more people (Inter-organizational networking) |</p>
<table>
<thead>
<tr>
<th>Construction</th>
<th>Manufacturing</th>
<th>Transport</th>
<th>Public sector</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>46 %</td>
<td>61 %</td>
<td>80 %</td>
<td>96 %</td>
<td>70 %</td>
</tr>
<tr>
<td>Source: NCB (1994i)</td>
<td></td>
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</tbody>
</table>
such a large scale computer system because of the high cost of equipment and the ignorance of the rapid technological changes in the IT field (Ofori, 1993). These reasons are almost the same as the ones identified in the survey conducted before the implementation of the Small Enterprise Computerization Programme (SECP), which is discussed in chapter three.

The Construction Industry Network (CoInNet) has emerged in an attempt to facilitate computer usage among the local contractors (Ofori, 1993). CoInNet is basically an information reference service for contractors. It was developed with the collaboration of NCB, CIDB, and Singapore Contractors Association Limited (SCAL), and launched by SNS in 1992 (Neo et al., 1993b). CoInNet offers subscribers (contractors) information on material's prices, tender results, contractor profiles, and market analyses to help them make an effective decision in bidding for a tender. In an effort to facilitate computer usage in contractors' community, NCB, CIDB, and SCAL also jointly developed general specifications for local contractors for choosing appropriate computer equipment (Ofori, 1993).

Figure 5.9: Concept model of the CoInNet

Figure 5.10: Concept model of the RealNet
RealNet is another such IT development in the real estate industry. RealNet was developed with the collaboration of SNS and real estate industry and became fully operational by 1992 (Neo et al., 1993b). Unlike the CoInNet, the RealNet is not just an information service. It offers an online co-brokerage practice in the industry by employing EDI technology (Figure 5.10). RealNet lists clients' properties which are tended to be sold. Real estates agents can easily search a list of properties which meet the needs of a buying client with the database function equipped in the RealNet.

These efforts to construct an inter-organizational data network have begun only recently, but an incentive for local SMEs is still not so significant. Although information on the number of subscribers of those networks have not been made available to the public, the NCB survey in 1994, which is mentioned above, shows still lower usage of IT in the industry. Additional policy measures for the deployment of IT among the SMEs is apparently necessary to realize high IT deployment and network subscription in the industry.
5.4. Integration into CORENET --- features and difficulties of implementation

5.4.1. Technical features and difficulties

The Construction and Real Estate Network (CORENET) is a new concept jointly developed by NCB and MND in 1993 as an answer to the IT2000 sectoral application presented in the IT2000 report of 1992. The concept model of the CORENET is shown in Figure 5.11. Its basic concept is to link all the existing relevant IT applications under a standardized framework. In so doing, CORENET aims to shorten the transaction time required for the information exchange among various parties involved in the construction and real estates practices, and to yield a new economic value by enhancing overall industrial productivity. The BuildNet concept had disappeared since the release of this concept. The reason for it is uncertain, but it might be incorporated into the CORENET concept because of the similarity. In the public release of the CORENET in 1993, NCB presented the following application services to be implemented in the first stage of its development.

1) **Integrated submission:** Electronic submission, notification, and payment of both text
and graphics based applications made to regulatory agencies.

(2) **Information services**: Information reference service at all stages of building life cycle.

(3) **Procurement services**: Material acquisition, tendering, and procurement of all the construction related services offered by both government and private sectors.

The electronic submission concept presented in the BuildNet is again presented as the Service (1), Integrated submission. This service function is partly realized currently in the ILUS and ILIS. Service (2), Information services, are realized in all applications discussed in the previous subchapter. Service (3), Procurement services, are partly realized in the CoInNet. Therefore, it seems that the integration of these local and agency based applications is easy from the service function’s perspective. However, technical difficulties emerge if the technical infrastructure and standards currently used in each service are considered. Figure 5.12 illustrates the categorization based on these factors. RealNet and CoInNet currently use text-based EDI standard. Among the graphic-based applications, only GraphNet formally stated the use of a graphic-based EDI, although precise technical specification for it has not become public. The transition of the CADD data standard is another issue in this field. The current recommended standard is IGES, but it is expected that a more advanced standard such as PDES or STEP would become prevalent in the near future. In responding to the author's interview, a responsible NCB official expressed an interest in STEP as the CORENET standard, but it is still uncertain if it would become the next generation international CADD standard because it is reported that GINTIC research on the CAD data exchange concentrates on PDES as the next generation standard. ILUS and ILIS are also expected to employ a graphic-based EDI, but those for ILUS and ILIS will be different because they need to be more suitable for their GIS system rather than the architectural CADD system. The hurdle between them may not be so high, but some coordination or translation system is necessary to

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**Figure 5.12**: Categorization based on technical factors

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incorporate them into the unified CORENET framework. On the other hand, no apparent statement to implement the EDI standard has been announced yet about the LandHub.

5.4.2. Non-technical issues

Implementation of the CORENET involves various constraints other than the technical factors described above. In the TradeNet case, TDB announced the overall re-engineering of the professional practices in the industry, and made the subscription to the network mandatory for the trade community. The situations are somewhat similar, but also somewhat different in this CORENET case. From the discussions made in the previous subchapters, constraints specific for the construction industry can be identified as follows.

(1) Distributed and discontinuous practice: Construction is a far more distributed and discontinuous process compared with other industries such as manufacturing or trading. If re-engineering of the practice of construction is required to implement the plan, a higher level coordination is necessary because it involves different ministerial realms (law, land development, and commerce). Coordination led by a statutory board, which has played a significant role in the TradeNet case, will not be satisfactory in this case.

(2) Legal issues: Disputes on the legality of electronic documents have not been settled yet at a parliamentary level. Because real property issues are largely involved in the construction industry case, solutions would not easily come like other cases which only involve monetary and trade transactions. The re-engineering of those monetary and trade transactions is easier than that of the real property transactions because most of the former cases do not involve the transactions between public and private sectors. In the TradeNet case, such public-private transaction exists in the clearing process of trade documents between TDB and traders, but such legal clearing issues were incorporated into the TradeNet re-engineered model under the leadership of TDB. However, in the CORENET case, no significant coordination or leadership effort by NCB, CIDB or a higher level to solve this issue has been observed yet. Unless this legal issues is solved, the integration of the land related databases such as ILUS and the LandHub will be difficult. This would make the subscription to such services unattractive for prospective users.
(3) **High graphical data transmission cost:** Unlike other industries, the data exchanged during the construction practice is mostly graphic-based. The largeness of the graphic data imposes a huge transmission cost on network subscribers. As Singapore contractors and other technical firms are mostly SMEs, this would be a hampering factor for an incentive to subscribe to such a graphic-based network.

To solve the problems caused by the first problem of the construction processes, distributed and discontinuous nature, there is apparently a need for a higher level authority to coordinate the interests of relevant parties. The National IT Committee (NITC), which is discussed in chapter three, may work as a coordination mechanism, but a new special task force is necessary for effective coordination. The second problem caused by legal uncertainties is a fundamental bottleneck for the successful implementation of CORENET. It must be discussed thoroughly at a parliamentary and ministerial level. The third problem, the cost of graphics transmission, can be approached dually by the reduction of network costs and the provision of further financial incentives to the SMEs. The rate reduction for the high-speed data network must be done in a long run, but a sudden decrease in the network subscription prices can not be expected. The financial schemes for SMEs are mostly offered by Economic Development Board (EDB), which is discussed in chapter three, but they are currently not enough to deploy graphic-based computer terminals among most SMEs. Development of another incentive scheme which specifically for the construction industry is necessary like the SECP case, which is discussed in chapter three.
5.5. Conclusion for chapter 5

The construction industry has an extremely complicated professional practice. The transactions to be done during the whole construction practices are so many that the complexity of the practice lowers the planning and design productivity. The construction industry is also facing severe environmental concerns; a consistent labor shortage and resultant low industrial productivity. As the labor shortage problem will not easily be solved, the enhancement of productivity in the planning and design stage is one of the most important agenda items for the overall productivity enhancement for the construction industry.

IT use in the industry is progressing rapidly in the CADD data exchange and land information databases areas. CADD data exchange is currently done in the IGES format which only supports drawing information. It is expected that the next generation CADD standard would include drawing and production information in one format, but standardization for such a format is still uncertain in both the Singaporean and international communities. On the other hand, the development of land database services has shown remarkable progress. However, because an effort to construct such a database has emerged through each agency's own initiative, no idea of future integration has been conceptualized in the process of constructing those databases.

The newly released IT2000 NII policy presented a new IT application in the construction and real estates sector. Currently, the only practical plan presented is to integrate currently existing applications with a unified framework, and in so doing, enhance the overall industrial productivity. However, as we observe the problems associated with database integration, there are still both technical and non-technical problems to be solved for successful implementation. Some technical and political measures must be taken to realize that dreamy network.
Chapter Six

Conclusion

6.1. Key findings on the role of IT in the development of the Singaporean construction industry

This chapter reviews the findings of the previous chapters and draws conclusions to the question presented in chapter one.

Can the proposed CORENET project really be a new economic engine as the IT2000 plan expects? Overall, what policy measures should the government take to realize this expectation? (Chapter one of this thesis)

Chapter two reviewed the history of Singaporean economic development while paying attention to the role of IT and telecommunications as a catalyst for activating the economy. It was shown that all three stages of the national IT development effort have been carefully planned to meet the state's strategic economic goals. Chapter three further investigated the institutional framework for national IT policy formation. It found that initiatives by the NCB have played a very significant role in forming national IT policies, but there is also evidence that multiagency collaboration is another critical factor for the successful implementation of the IT policies. Chapter four analyzed the economic presence and contribution of the construction industry through an econometric analysis. Although the models assumptions are still primitive, it is evident from the simulations that computer installations of minicomputers have been related to productivity improvement. However, the analysis results also suggest that the productivity improvement has hardly been related to overall industrial output. This suggests the existence of other significant factors which discourage output. Chapter five investigated current use of IT in the construction industry and analyzed the potential and difficulties regarding the integration of various databases and information services into the proposed CORENET. Both technical and non-technical factors are identified as constraints for the successful implementation of the proposed plan.

As we review these discussions, we can see the following important points as a key to answer the question presented at the beginning of this thesis.
(1) **IT in the economy:** IT has been a critical strategic tool for both economic and industrial development. Technically, it improves the productivity of professional practices substantially. However, the successful implementation of inter-organizational IT applications in a particular industry requires the resolution of a large number of non-technical issues. In the so far successful cases such as the TradeNet, the non-technical issues have been solved by multiagency collaboration efforts at a statutory board level, but there is no guarantee that this framework works in more complicated situations in other industries. IT may improve professional productivity at a local level, but the key for contributing to the overall economic success of the industry mostly remains in the non-technical field. Therefore, appropriate policy measures should be taken to make IT implementation a real industrial development tool. Those measures may include the institutionalization of a project-specified framework for each particular project, and the solution of other social and legal issues inherent in a particular industry.

(2) **Construction in the economy:** Environmental concerns surrounding the construction industry are very severe. Low productivity is mostly the result of the severe labor shortage in the economy, high professional turnover, and the dirty image of the construction industry. The construction boom has already passed, and the industry's presence in the national economy is declining in recent years. The industry also has now to face severe international competition for survival. It has been identified by the construction industry professional community that productivity enhancement is important for further development of the industry. However, progress in productivity enhancement has not been significant historically. The complicated nature of professional practices in the industry is identified as a limiting factor. Automation in the planning and design process has shown a tangible progress to some extent, but only at a dispersed level. The proposed integrated IT applications may have the potential to solve these issues. However, the key to successful implementation is how and to what extent the IT application can catch and absorb the problems that the industry currently has. This is exactly what is identified in the point (1) above. Unfortunately, the current CORENET proposal only states the objective of the integration of existing systems, and does not express how such a social and industrial objective can be achieved. A more comprehensive discussion at a higher level is definitely necessary to draw a fundamental solution for the further development of the industry.
6.2. Policy recommendations

The questions presented are again cited from chapter one as follows:

Can the proposed CORENET project really be a new economic engine as the IT2000 plan expects? Overall, what policy measures should the government take to realize this expectation? (Chapter one of this thesis)

The above analyses answer these questions. The contents of the currently proposed CORENET plan are not enough to realize its fundamental objective. Considering the problems and environmental pressures presented above, this thesis presents the following policy recommendation for the successful implementation of the project.

(1) **Provide a new financial incentive to SMEs:** A high subscription rate to CORENET among the small and medium-sized companies (SMEs) is apparently a key to the overall improvement of construction industry productivity. The current financial incentives offered by the Economic Development Board (EDB) or the National Computer Board (NCB) can not be regarded as sufficient to facilitate the installation of high-priced graphic-based computer terminals among the SMEs. A substantial budget must be planned if government expects high subscription to the network. Because of the substantial cost imposed on the SMEs, which take up the most part of the Singaporean construction industry, simply making a subscription mandatory is not a good policy, although such measures did work in the TradeNet case, which only required the text-based computerization. SMEs will suffer economic difficulties and therefore industrial output will not be improved if such mandatory policy is implemented without the financial support and subsidy from the state.

(2) **Establish a higher level control committee:** Currently, the CORENET project is steered by the sectoral group inside the National Information Infrastructure Division (NIID) of the National Computer Board (NCB) as described in chapter three. However, as discussed in chapter five, there are some non-technical issues that have to be solved to create the integrated network. A higher controlling authority specially designed for these construction industry and property issues is definitely necessary. Creation of a new institution under the current National Information Technology Committee (NITC) framework is one idea to realize it, but representation from the Ministry of Law (MinLaw) is anyway necessary to solve the fundamental legal and land registry issues.
(3) Carefully observe the development of international standards: Technically, a standard for graphic data exchange has not been settled internationally for either the Electronic Data Interexchange (EDI) or Computer-aided Design and Drafting (CADD). Each agency has to carefully monitor progress in international standardization and has to avoid employing a non-standard technology to implement the project. This means that each responsible agency does not have to rush into the immediate implementation of the project. Conforming to the international standard is particularly important as internationalization in the construction industry has been progressing rapidly in recent years. Needless to say, the Singaporean technical community has to continue to cooperate with the international community to establish the international standards in these fields.

Only if all these policy recommendations are properly implemented, will the CORENET project meet great economic success. It is highly recommended that the National Computer Board (NCB), the Construction Industry Development Board (CIDB), and other policy planning agencies consider these factors, and possibly expand the currently proposed project to incorporate them.
6.3. Concluding remarks

Contrary to the dreamy image of the NII, implementing network integration projects such as CORENET are an extremely hard task. As Singapore is a leading country in such IT application projects at a national level, it has to find its own solution with its own effort. IT2000 identifies the CORENET as a new engine for further economic growth, but the currently proposed plan is not enough to meet this goal. The responsible policy planning agencies have to perceive this point, and proceed with the plan with careful attention to the particular environment surrounding the industry.
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