PERFORMANCE STRATEGIES FOR THE KNOWLEDGE DRIVEN BUILT ENVIRONMENT - THE SINGAPORE CASE

By

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Master of Science

at the

Massachusetts Institute of Technology

September 2003

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Abstract

The Internet and Technology Revolution has created a new business environment, one in which traditional business rules are being challenged, and even repudiated. Information Communication Technology (ICT) has made a major impact to many business sectors, ranging from retail, stock trading, banking, logistics and the built environment. It has created new market opportunities for governments, companies, and offers existing businesses new ways to reach out to customers and to deliver services more effectively, often at lower costs. It has also allowed businesses to transcend geographical boundaries and enter new global markets. Clearly, this new environment poses new business challenges, and governments must now quickly figure out how to identify ICT opportunities and effectively compete in the new economy. Pervasive adoption of ICT will have an important multiplier effect for the economy through the transforming the way people live and boosting the way companies and industries do business.

As a country, Singapore must also effectively address the challenges of the new economy. The vision is to position Singapore as a trusted global hub in the Internet economy, one in which ICT plays a dominant role in government, business and consumer transactions. Going forward, Singapore must also extend its reach to new markets and move up the value chain in its usage of ICT solutions. To achieve this, Singapore will need to create an ICT centric and equipped built environment in which e-lifestyle and e-business is pervasive, and where the hard and soft ICT infrastructures are well developed.

Thesis Supervisor: John de Monchaux
Title: Professor of Architecture and Planning
Acknowledgement

This past year has been very eventful, emotional and enriching. It was eventful because of the loss of my father and also eventful because of the birth of my son. It was emotional because I managed to gained admission to MIT, my lifelong dream, and also emotional because I had to leave behind my young wife and son to come to Cambridge to pursue this dream. It was enriching because of diverse range of new knowledge that I have experienced at MIT and also enriching because of the many friends I made here. The time with the SPURS faculty and Fellows was especially special.

I came to US knowing the basics of the geography of the world, but came away understanding this geography in more details. I learnt about the struggles and problems of the nations represented at SPURS, and spent many hours discussing the possible solutions to these problems. I tried to share as much as I could from my Singapore experience and in the process learnt to treasure and appreciate more about my own country. It was with this concern in mind that I decided to focus my thesis on the performance strategies for a built environment. I wanted to leave behind a document that future SPURS fellows could read to understand more about how Singapore have developed it's technology infrastructure and built environment to be competitive. In the process, I was glad to have been able to crystallize some of our strategies and understand what are some of the important policies to focus on in order for Singapore to stay competitive.

I would like to thank Professor John de Monchaux for providing guidance throughout the last 12 months and for making insightful suggestions on the concepts and contents of the research. He has this wonderful gift of providing me with macro key points that helped me to formulate my thoughts. I am also thankful to Nimfa for her excellent support beyond her call of duty. Her devotion to her work made it possible for me to share the good news of my admission to my father just before he passed away. For this, I am eternally grateful to Nimfa. I would also like to thank my bosses and colleagues at Temasek Polytechnic for without their support, an education at MIT would be out of my reach.
I am also indebted to my family for giving me unconditional support and love throughout these past months. My mum has made my journey to this stage possible, because without her love and strong will, it would have been difficult to accomplish what I have achieved. My late father left me with valuable lessons about how to be a good husband and father, which I will always remember.

I would also like to express my special gratitude to my in-laws, because they took great care of Irene and Benjamin while I was away and gave them their love and support. Without their support, it would have been difficult for me to concentrate on my research at MIT. My father in law has been my greatest motivation and he is the one that have guided me in my career and life. He has taught and shared with my many of his personal experiences, without which my life journey would have been more difficult and uncertain. My mother in law has been the comforting factor that relieved of my worries because I knew she would love Irene and Benjamin as much as we love her.

Last but not least, my eternal love to my wonderful wife, Irene. She has filled my life with so much love and joy and gave birth to our love child, Benjamin. As we take sometime off before I start work, I look forward to another love child, “Belinda”.

Finally, I would like to thank God for blessing me with such a wonderful family.
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"To move backwards is unthinkable; to stand still is to court ruin. We must move forward and upward. We must climb up the education ladder, up towards better technology, towards higher skills, towards better management, towards higher productivity. “

Lee Kuan Yew  
Prime Minister, Singapore  
National Day Message  
The Straits Times, 10 August 1980

1.0 INTRODUCTION

There is currently a compelling debate about the changing nature of business environments and the sources of competitiveness in advanced economies. It is asserted that knowledge is fast overtaking capital and labor as the key economic resource in advanced economies (Edvinsson, 2000). The intangible assets in an organization are widely celebrated as vital elements in improving competitiveness (Egbu, 2000; Edvinsson, 2000). This has compelled academics and practitioners to discuss the way in which knowledge assets are managed, shared and utilized.

Many have suggested that ICT, if introduced appropriately, can have a positive effect on the performance of cities and its business environment. ICT is defined as comprising the Information Technology (IT), Communication and Multimedia components. In this thesis, IT is defined as software services, whereas Communication components include wired; wireless; broadband; broadcasting, and Multimedia components include content creation; content delivery. This thesis examines the evidence available to support this claim to show how Singapore have utilized ICT to re-engineer the business processes of the national industries, in particularly the built environment, in order to achieve a quantum leap in turnaround time, productivity, quality and to become more competitive globally, where knowledge assets can be effectively and efficiently managed, shared and utilized.

In this thesis, several strategies like the establishment of the e-Government Action Plans I & II, SingaporeOne and CORENET are discussed and presented as the evidence to show
that ICT does have a positive effect on the performance of Singapore’s competitiveness. Other strategies like the collaborative and transnational initiatives, market penetration plans, techniques/technology/manpower combination, and ways to improve the industry professionalism of the industry, are also discussed in subsequent chapters. There will also be a special emphasis on how ICT can be utilized in the transformation of the built environment, in particularly the Architecture/Engineering/Construction (AEC) industry.

Chapter 2
In Chapter 2, a snapshot of Singapore’s economic growth and how she has reached today’s advanced economy status is provided and discussed. This chapter also outlined the economic strategies that the Singapore government have adopted since independence, including how ICT have become the key ingredient for economic growth and competitiveness.

Chapter 3
Chapter 3 will provide an outline of some of the national ICT strategies and infrastructures that have been implemented, which can help to propel the built environment to perform more effectively and efficiently, in this new economy. These strategies include the Government IT Plans, Government-to-Business (G2B) and Business-to-Business (B2B) network infrastructures, which can be used to facilitate electronic submissions and the processing of project-related documents within a technologically secured environment.

Chapter 4
An overview of the built environment in Singapore is provided in Chapter 4, where an analysis of the current state of the built environment, including the construction demand and prospect for the construction industry for 2003 and beyond, is discussed. This chapter also provides a glimpse of the future state of the built environment through the strategic, cultural and political lens. An industry process analysis covering issues like techniques, technologies, manpower and ways to improve the professionalism of the built environment is also included in this chapter.
Chapter 5

The built environment, in particularly the construction organizations have been slow to acknowledge the benefits of IT in managing knowledge (Egbu et al., 2001), suggesting that the role of IT for these organizations in the built environment, needs to be addressed. Browning (1990) contends that "information technology is no longer a business resource; it is the business environment". Since the 1960s, IT has become an all-pervasive force in the business world, superseding more conventional tools for data storage and communication. It has been argued that IT has the potential to “redefine the management and control of innovation on a global basis through the removal of barriers such as time and distance” (Egbu, 2000).

The use of IT as a strategic weapon has also been described by Earl (Earl, 1989), and Porter and Millar (Porter and Millar, 1985). Betts (Betts, 1992) develops the concept, applying a five level framework of (1) national construction industry, (2) professional institution, (3) construction enterprise, (4) construction project and (5) construction product. Issues surrounding the use of electronic communications affect all five levels in different ways and it would seem from the work that the strategic and technological coordination of all five levels is essential for the successful use of IT for a national industry, a factor that rose to prominence from the work of Porter (Porter, 1991).

The concept of the Construction and Real Estate Network (CORENET) was conceived to provide these five levels of framework for the built environment to perform more efficiently and effectively. This concept is outlined in chapter 5, where the idea of e-submission and integrated plan checking systems are discussed. The objective of e-submission is to provide a one-stop, non-stop technology platform for industry players to submit documents via the Internet to the various regulatory authorities for processing. Other than being an electronic channel for plan submissions and permit applications, e-Submission will also become an industry-wide ICT infrastructure to promote e-commerce to the built environment. The Integrated Plan Checking Systems aim to automate the checking process for the various plan types. These are leading-edge systems that require
the integration of expert knowledge in plan checking as well as Artificial Intelligence (AI) and Object Oriented Computer-Aided Design and Drafting (OCADD) technologies.

Chapter 6

Chapter 6 introduces the concept of an intelligent building, total building performance and the diagnostic tools for measuring and assessing this performance. It emphasized the need to fully address the fundamental building performance mandates of thermal comfort, acoustic comfort, air quality, lighting comfort, spatial comfort, and building integrity. Integrated within the building delivering process, which in itself a key component of the built environment, these performance mandates and the associated diagnostic measurement and assessment tools suggest new quality assurance procedures for providing suitable and reliable conditions for occupancy comfort in new as well as in existing buildings.

Chapter 7

Intelligent communities may be large or small, and appear in both the developed and developing world. Big-city examples include New York and Chicago in the US, Toronto in Canada, Osaka and Tokyo in Japan, and Rio de Janeiro in Brazil. Small-city examples include LaGrange, Georgia, USA; Sunderland, UK; Calgary, Canada; Putrajaya, Malaysia; and Gelsenkirchen, Germany. Chapter 7 provides an overview of several case examples of these communities that have also utilized technologies to gain a competitive edge. These case examples are important reminders for Singapore that the rest of the world is catching up with the technology race.
2.0 SINGAPORE – AN OVERVIEW

2.1 Advanced economy, New Economy

Singapore is a small island city-state in South East Asia. It has an area about 648 sq.km. Despite the inherent disadvantages of a small domestic economy and the lack of natural resources, Singapore has established itself as one of the top trading nations in the world, and is consistently voted as one of the best business destinations. It is recognized as one of the most competitive economies in the world, supported by an increasingly globally competitive workforce. Singaporeans enjoy one of the highest quality of life, with the latest per capita Gross Domestic Product (GDP) of US$24,000 (Ministry of Trade and Industry). It is catching up with the United States (US), and has outstripped Canada. (refer to tables 1 and 2)

<table>
<thead>
<tr>
<th>Table 1: Competitiveness and Major Economics Indicator</th>
</tr>
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<tbody>
<tr>
<td>Size ('000 sq.km)</td>
</tr>
<tr>
<td>-------------------</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Population (millions)</td>
</tr>
<tr>
<td>GDP per capita (US$'000)</td>
</tr>
<tr>
<td>Unemployment Rate (%)</td>
</tr>
<tr>
<td>Growth Competitiveness Ranking,2000</td>
</tr>
</tbody>
</table>

Source: Global Competitiveness Report 1999
Table 2: Competitiveness of Human Resources

<table>
<thead>
<tr>
<th></th>
<th>Singapore</th>
<th>US</th>
<th>Mexico</th>
<th>Canada</th>
<th>Japan</th>
<th>China</th>
<th>Australia</th>
<th>New Zealand</th>
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<tbody>
<tr>
<td>Skilled Labor (Ranking)</td>
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<td>13</td>
<td>29</td>
<td>11</td>
<td>23</td>
<td>44</td>
<td>2</td>
<td>20</td>
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<tr>
<td>University Education meets the Needs of a Competitive Economy (Ranking)</td>
<td>4</td>
<td>6</td>
<td>37</td>
<td>13</td>
<td>47</td>
<td>45</td>
<td>8</td>
<td>15</td>
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<tr>
<td>High Economic Literacy (Ranking)</td>
<td>1</td>
<td>14</td>
<td>41</td>
<td>15</td>
<td>9</td>
<td>45</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>Urban Population (% of total population)</td>
<td>100</td>
<td>77</td>
<td>74</td>
<td>77</td>
<td>79</td>
<td>33</td>
<td>85</td>
<td>87</td>
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<td>Home Ownership Rates (% of households that are owners)</td>
<td>90.2</td>
<td>64</td>
<td>78</td>
<td>-</td>
<td>61.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Value of Society (Hard work and innovation Support Competitiveness, Ranking)</td>
<td>1</td>
<td>5</td>
<td>33</td>
<td>13</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>25</td>
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</tbody>
</table>

Source: World Competitiveness Yearbook 2000

2.2 Trading Hub and Business Destination

Singapore’s trade is about 2.7 times the size of its GDP in 1999. In 1999, Singapore was ranked by the World Trade Organization (WTO) as the 16th largest trading nation in terms of both merchandise and services in trade. Since 1979, its total trade has grown approximately 7 times reaching a total of $470 billion in 2000. Of this, export and import figures were approximately on par. Its major trading partners are Malaysia, US, Japan, European Union (EU) and Hong Kong which accounted for about 64% of Singapore’s total trade (Economic Development Board). As Singapore is recognized as one of the most competitive
economies in the world, more than 10,000 trading companies use Singapore as their distribution point for markets in the Asia-Pacific. In addition, more than 5000 foreign companies (including many of the Global 500) also use Singapore as their Asia Pacific Base. Among the accolades that Singapore has won recently include:

- Top business city in Asia (Fortune, Dec 99).
- World’s 2nd most competitive economy after the US (World Competitiveness Yearbook, Apr 2000).
- World’s most competitive economy, ahead of the US (Global Competitiveness Report, 1999).

2.3 Factors Contributing to Singapore’s Success

Strategic Location
Singapore’s strategic location has made it one of the most attractive business locations in Asia. It is situated within Association of South East Nations (ASEAN), which represents a combined market of over 500 million people.

Market Access in Hours of Flight Time
Singapore can also access a market catchments size of 2.8 billion people within just 7 hours flight time.

Excellent Infrastructure:
More than 140 thousand vessels from more than 400 lines called at Singapore’s seaport in 1999, generating 15.9 million Tones Equivalent Units (TEUs) (Port of Singapore Authority). In terms of world container port traffic, Singapore Port handled more container traffic than busy ports like Rotterdam (Netherlands), Long Beach (US), and Hamburg (Germany).
Besides having outstanding seaport facilities, Singapore's Changi International Airport is also renowned worldwide for its efficiency. It has bagged a total of 16 best airport awards from major international publications and organizations in 1999. This was a record win for the airport, which handled 12.3 million passengers in 1999 (Civil Aviation Authority of Singapore). (refer to table 3)

**Good Telecommunications Network**

Singapore is one of the most competitive telecommunications hubs in the Asia Pacific. This is further enhanced by its recent liberalization of the telecommunication industry in early 2000.

**Financial System**

Singapore is also is well plugged into the international financial system. It is the 4th largest foreign exchange trading centre in the world, the 5th largest trader in derivatives and the 9th-largest offshore lending centre (Monetary Authority of Singapore). It is behind only London, New York and Tokyo in foreign exchange trading. The Singapore Exchange (SGX) is recognized as a leading stock market in Asia and one of the world's leading derivatives exchanges.

**Others Factors**

Singapore's success is also the result of a combination of many other factors, such as a clean and efficient government, emphasis on education and science and technology, excellent labor/employer relations and a competitive and flexible labor force. (refer to table 4)
### Table 3: Competitiveness of Infrastructure

<table>
<thead>
<tr>
<th></th>
<th>Singapore</th>
<th>US</th>
<th>Mexico</th>
<th>Canada</th>
<th>Japan</th>
<th>China</th>
<th>Australia</th>
<th>New Zealand</th>
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<td>Port (Ranking)</td>
<td>1</td>
<td>9</td>
<td>41</td>
<td>7</td>
<td>16</td>
<td>46</td>
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<td>Roads (Ranking)</td>
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<td>13</td>
<td>38</td>
<td>14</td>
<td>12</td>
<td>43</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Air Transport (Ranking)</td>
<td>1</td>
<td>3</td>
<td>33</td>
<td>10</td>
<td>27</td>
<td>52</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Telephone Service (Ranking)</td>
<td>6</td>
<td>13</td>
<td>41</td>
<td>7</td>
<td>9</td>
<td>49</td>
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<td>Cellular Phones Usage</td>
<td>9</td>
<td>19</td>
<td>50</td>
<td>13</td>
<td>11</td>
<td>53</td>
<td>8</td>
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<tr>
<td>Computers per 1000 population</td>
<td>429</td>
<td>458</td>
<td>45</td>
<td>330</td>
<td>238</td>
<td>9</td>
<td>407</td>
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</table>

Source: Global Competitiveness Report 1999

### Table 4: Competitiveness of Science and Technology Factors

<table>
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<th>US</th>
<th>Mexico</th>
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<th>China</th>
<th>Australia</th>
<th>New Zealand</th>
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<tr>
<td>Science and Education (Ranking)</td>
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<td>24</td>
<td>39</td>
<td>17</td>
<td>19</td>
<td>32</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>Basic Research which supports long-term Economic Growth (Ranking)</td>
<td>5</td>
<td>1</td>
<td>37</td>
<td>11</td>
<td>13</td>
<td>12</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Development and Application of Technology is supported by Legal Environment (Ranking)</td>
<td>1</td>
<td>6</td>
<td>37</td>
<td>16</td>
<td>24</td>
<td>21</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Company University Cooperation (Ranking)</td>
<td>3</td>
<td>2</td>
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<td>12</td>
<td>25</td>
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<td>20</td>
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<tr>
<td>Availability of IT Skills (Ranking)</td>
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<td>8</td>
<td>27</td>
<td>17</td>
<td>34</td>
<td>46</td>
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<tr>
<td>Availability of Qualified Engineers (Ranking)</td>
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<td>12</td>
<td>27</td>
<td>20</td>
<td>18</td>
<td>47</td>
<td>7</td>
<td>31</td>
</tr>
</tbody>
</table>

Source: World Competitiveness Yearbook 2000
2.4 Singapore’s Economic History and Future Direction

Over a 30-year period, Singapore has transformed itself from a small trading node to the business hub and advanced bustling city that the world sees today. A look at the different phases will show that this did not happen by accident, and will also show how Singapore intends to further enhance its competitiveness.

1960 – 64 (Import Substitution)

In the late 1950s, Singapore’s business community consisted largely of small merchants and financiers. Manufacturing was nascent and fragmented, comprising just 12% of GDP in 1960 (Economic Development Board). Most of the local industry consisted of small family-based workshops, connected to retail trade. As Singapore was merged with Malaya, Sabah and Sarawak in 1960, it expected its much larger neighbors to provide a large enough domestic market. It had therefore embarked on an industrialization policy based on an import substitution strategy.

1965 – 79 (Export-led Industrialization)

When Singapore gained independence in 1965, and separated from Malaysia in the process, it suddenly faced daunting challenges of weak economic fundamentals, low labor participation rate, high unemployment and a poorly educated labor force. Singapore abandoned the import substitution strategy for export-led industrialization. Going against conventional wisdom, it opened up its economy to foreign investments and leveraged on Multi National Corporations (MNCs) to gain access to technologies, markets and market experience that Singapore lacked. It established a pro-business environment, and embarked on the following:

- Developed industrial land and coordinated the expansion of related services like utilities, transport and communications;
- Implemented a strong basis education for the population with emphasis on technical skills;
Engaged in constructive labor management policies and introduced a host of investment measures to attract MNCs to Singapore.

A supportive international environment helped Singapore’s efforts. Until the oil crisis in 1973, the US and Europe were in a period of sustained growth. Singapore’s accession to the GATT in 1973 also presented market access opportunities for its exports. Its efforts paid off, with GDP averaging 10% per annum from 1965-1980 (Economic Development Board).

1979 – 80 (Industrial Restructuring)

By the late 1970s, industrial restructuring had become necessary. Rapid economic growth had created a labor shortage, leading to increasing labor cost. There was increased competition as lower cost countries in ASEAN reviewed their policies to emulate Singapore’s success. To respond to such new challenges, Singapore pursued a strategy of shifting its economy from intensive, low value added activities to more capital driven and higher value added ones.

As a result:

- Fiscal incentives were introduced to encourage automation and mechanization;
- Productivity was encouraged;
- New technology intensive industries such as the manufacture of computer peripherals and machinery were identified and aggressively promoted.

1980 – 86 (Coping with Recession)

Amidst a growing economy and tight labor market, Singapore kept up its industrial restructuring efforts. It embarked on a 3-year wage correction policy aimed at upgrading industrial structure. However, there was policy overshot and wages were raised too rapidly. This had coincided with an external environment that was weakening sharply. The US economy also slowed down considerably following the second oil crisis in the early 1980s. As a result, Singapore
experienced its first post-independence recession in 1985. Its economy contracted by 1.6% (Ministry of Trade and Industry).

The whole of Singapore worked together and responded in a positive manner. Several major cost-cutting measures were implemented, such as the reduction of employer’s Central Provident Fund (CPF) contribution, reduction of corporate tax and adoption of national wage restraint policy. These cost cutting measures, together with a recovery in external demand, helped the Singapore economy recovers. It grew by 2.3% in 1986 and 9.7% in 1987 (Economic Development Board).

1986 – 98 (Developing a World-class Manufacturing and Services Regionalization)

The crisis exposed structural strains in the economy, which had been masked by strong economic growth. The strategic focus during this fifth phase of economic development was therefore to bring Singapore’s capabilities to world-class levels. The first step was to enhance its technological capabilities. Singapore’s industrial strategy also took on a cluster development dimension. It identified and entrenched mutually supporting industries in both manufacturing and services. For the manufacturing sector, this included electronics, petrochemicals, precision engineering. Services would include financial services, international trading and IT.

Taking advantage of the regional boom, Singapore also moved to develop an ‘external wing’ for its economy. Regionalization allowed it to tap on the markets and resources of regional economies and to diversify its dependence on developed nations. It also helped us strengthen our MNC linkages through co-investment in the region.

1998 and Beyond (Towards a New Economy / Globalization)

The regional economic crisis in 1997 was a watershed event for Asia. Although Singapore emerged from the crisis in relatively good shape, the economic
challenges it faces remain enormous. Singapore aims to become an advanced and globally competitive knowledge economy within the next decade.

To this end, the Economic Development Board (EDB) identified eight strategies. These are:

1. Develop manufacturing and services as our twin engines of growth.
2. Strengthen its external wing and move from regionalization to globalization.
3. Build world-class companies. While MNCs will continue to be an integral part of the economy, it also wants to build up local companies as a complementary source of growth.
4. Strengthen its Small and Medium Enterprises (SMEs) as relevant partners of MNCs, so as to help them raise their technological capability, efficiency and service quality.
5. Build human capital and promote life-long learning for life-long employability. It also aims to attract foreign talent to augment its workforce.
6. Foster an environment that encourages risk taking, innovation and creativity. The Singapore government has set up a S$1-billion technopreneurship fund for this purpose.
7. Given scarce resources, Singapore encourages the efficient supply and usage of land and utilities.
8. The Singapore government will also position itself as a business facilitator. It aims to adopt a pro-enterprise and pro-business mindset. It will review its rules and regulations and streamline them to minimize compliance costs.

**Macro Strategies**

Therefore, the following plans have been drawn up:

- Besides attracting investments in the high growth and high value-added areas, it will also help industries to upgrade and develop capabilities in the
entire value chain, e.g. Research and Development (R&D), design, logistics. In addition, it will develop life sciences as the fourth pillar of Singapore’s manufacturing base, besides electronics, chemicals and engineering.

- To build up its competitiveness of its services sectors, it has also been opening them up to external competition. The deregulation of financial services led the way. This was followed by the telecommunications industry, 2 years ahead of schedule. Most recently it announced the opening up of the contestable parts of its electricity and gas industries to full competition.

Current Economic Structure and Free Trade Agreements (FTA)

Singapore’s employment and economic structure reflects its emphasis on manufacturing and services, as well as its efforts to move into the high-growth and high value-add areas. In order to move into these high-growth and high value-added areas, it is critical to have a technologically centric and ICT supported built environment to support, facilitate and managed these areas.

The US Congress recently approved the US-Singapore Free Trade Agreement (USSFTA) with an overwhelming majority. The Agreement, which was signed by PM Goh Chok Tong and President George W. Bush on 6 May 2003 in Washington DC, was approved by the House of Representatives on 25 July 2003 and by the Senate on 1 August 2003. The USSFTA is expected to come into force by January 2004. The USSFTA opens a new chapter in the bilateral economic relation between the United States and Singapore, and builds on the robust economic ties between the two countries. It is a cutting-edge Agreement that is comprehensive and ambitious. It sets new standards in areas such as services, intellectual property rights and electronic commerce, which are critical for the next phase of our economic growth. The USSFTA will increase the flow of trade, investment, talent, ideas and technology across the Pacific. The Agreement underscores Southeast Asia’s economic and strategic importance to the US.
It is a signal of the US’ confidence in the region, and its continued commitment to engage the region. The Agreement would also help APEC, of which the US and Singapore are members, move a step closer to the Bogor goals of free trade and investment.

Minister for Trade & Industry George Yeo said that "the USSFTA will bring many benefits to Singaporean businesses and create new and good jobs. It will enable EDB to attract more high-quality investments into Singapore and strengthen our position as a manufacturing and services hub. It will help us in our economic restructuring and make us more competitive in the global marketplace. The protection of Intellectual Property in the FTA lays a strong foundation for the development of a knowledge economy. This is an Agreement we celebrate with our American friends." In addition to the USSFTA, Singapore already has FTAs with Japan, Australia, New Zealand and the European Free Trade Association and is negotiating FTAs with several other countries.

2.5 Findings

Ever since the mid 1980’s, Singapore has shifted its industrialization strategy from being an offshore manufacturing center to a high-tech production location. Such a shift paid Singapore huge dividends as the city-state bolstered both in the quantity and quality of its exports in the 1980’s and the 1990’s. At the same time, however, Singapore finds itself increasing dependent to that of its biggest trading partner, the United States, and to its biggest exports type, the electronic sector. This dependant presents a disadvantage that any fluctuation in the United States economy or the global demand for electronic products will result in a corresponding and magnified effect on the Singapore economy.

As the Asian markets start to regain it’s robustness after the 1997 financial crisis, it presents a special opportunity for Singapore to redefine its role in the new era, find innovative ways to lead the regional economy, and reassess it’s future business missions. The goal of the FTAs with Japan, Australia, New Zealand and the EU is to develop high value-added businesses core services that will not only
enhance Singapore’s competitiveness in the new global economy, but will also be exportable to the surrounding regions so as to capitalize on the growing regional economy, hedge the current dependence on the two-way trade with the United States, and facilitate the emphasis put on the electronics sector. In addition, there are negotiations on FTA with ASEAN, China and India, resulting in an upside in terms of potential market size.

The services provided by the built environment, which encompasses the AEC industry, are a feasible option for the aforementioned goals, for they encompass technical prominence, exportability, stability, and growth. By demanding the technical know-how and effective management, the built environment services can help develop technical savvy and other qualities in a nation. As historic data may suggest, mature built environment services can be successfully transferred to projects in foreign countries. Since the duration of built environment projects is much longer than that of any economical cycle, the industry may be able to dilute setbacks resulting from the cyclical behavior of the economy. Improvements in ICT and international trade are expected raise the standards of living and efficiency of built environments and civil infrastructures. Singapore can take advantage of this growth by securing a solid market share in providing related built environment services.

According to a World Bank estimate in 1996, an expenditure of USD$1.2 - $1.5 trillion is anticipated for the development in the region for the next decade alone (Asia Law, 1997). If the built environment services account for a reasonable 10% of such expenditure, the capitalized market would represent roughly USD$130 billion, which certainly contains great upside potential. To put the upside potential in perspective, the total domestic construction orders, forecast by Building and Construction Authority (BCA) for Singapore will only be about SGD$12 billion for the year 2003. This forecast consists of SGD$4.1 billion for the private sector contracts and SGD$7.9 billion for the public sector contracts.
Singapore is the most socially developed, politically stable, and financially sound city-state in the South East Asian (SEA) region. By being the apparent leader in the region, it commands high credibility in its exportable services. Also, since Singapore is more developed than most South East Asian countries, it is in the position to provide those countries with valuable planning and development experience when they undergo economic, social and urban transformation in the coming years. Singapore possesses the strong financial structure and judiciary system that can assist its consultancy businesses. From its corporate culture and political stability, it will certainly be able to attract joint ventures opportunities from most countries in the world and help forge alliances among local companies.
3.0 TECHNOLOGY STRATEGIES AND INFRASTRUCTURES

3.1 Industry Motivation
We are being swept into a new, high-growth e-economy, one powered by the Internet and other ICT-related technologies. The Singapore government recognized the vast economic potential of the Internet Economy several years ago. Together with the private sector, they have invested heavily in ICT infrastructures to give Singapore the first-mover advantage in the region. The government has set up SingaporeONE, a broadband infrastructure, to provide the necessary bandwidth to carry multimedia-rich content and applications. SingaporeONE is now accessible by more than 99% of homes, all schools, and numerous public libraries and community centers (Infocomm Development Authority).

Singapore has also established high-speed, peer-to-peer Internet links with countries in the Asia-Pacific, US and Europe to provide global connectivity. It already has 21 terabits per second (Tbps) of high-speed submarine cable capacity, and it is the only country in the world with direct, high capacity submarine cabling to both India and China. There is more than 90 megabits per second (Mbps) connectivity to key regional markets like Japan and more than 1 gigabits per second (Gbps) connectivity to the US. There is also international and regional telecoms connectivity to over 100 countries and direct Internet connectivity to more than 30 countries. They have also put in place the secure infrastructure to support Internet commerce, such as the public key infrastructure with digital certificates (Infocomm Development Authority).

3.2 The Journey to e-Government

Reflective of the changing technological, business and social climate, the last 23 years have seen a total of four national IT plans and is now going into the fifth. For the Singapore Public Service, the e-Government journey started in 1980 with the launch of the Civil Service Computerization Programme (CSCP) as part of the National Computerization Plan (NCP). Since then, the CSCP has evolved with each national IT plan to bring about exciting changes to the way Singapore Government works, interacts and serves the public. The first e-Government Action Plan (2000 - 2003), which was developed as part of Infocomm 21, replaced the CSCP in 2000.

Fig 1: Singapore’s IT Plans

Source: Infocomm Development Authority (IDA)
3.2.1 Civil Service Computerization Programme (1980 - 2000)
Singapore is one of the first countries in the world to develop an integrated and coherent approach to computerizing the government. Information Technology (IT) has been seen as the key enabler to Singapore's global competitive advantage since the early 80s. The Civil Service Computerization Programme (CSCP) was conceived with a clear direction of turning the Singapore Government into a world-class exploiter of IT. Since its launch in 1980, the CSCP has evolved with each national IT plan to bring about exciting changes to the way Singapore Government works, interacts and serves the public.

The first e-Government Action Plan has provided a strong foundation for the implementation of the second Plan. The vision of the e-Government Action Plan was to be a leading e-Government to better serve Singapore and Singaporeans in the new knowledge-based economy. S$1.5 billion was committed to this plan.

The e-Government strategic framework was centered on three critical relationship dynamics:

- Government to Citizens (G2C)
- Government to Businesses (G2B)
- Government to Employees (G2E)

To move these three critical sectors towards the e-Government vision, the e-Government Action Plan prescribed the broad directions of ICT deployment with five strategic thrusts and six programmes. (refer to Fig 2)

Thrust I - Re-inventing Government in the Digital Economy
The public sector will be able to systematically cultivate a better understanding of the impact of infocomm technologies to make meaningful decisions in all aspects of governance and to continually innovate to harness the benefits of infocomm technologies in its public services.

Thrust II - Delivering Integrated Electronic Service Delivery
Citizens will be able to access more and more public services, delivered online, anytime, anywhere. The public sector can provide the catalyst to create an e-based society in the digital economy by creating electronic services that are integrated
and customer-centric. The e-Citizen Centre launched in April 1999 is one such example. The Government will be putting more services on-line, in tandem with advances in IT.

**Thrust III - Being Proactive and Responsive**

The public sector is encouraged to adopt a "sense and respond" approach to anticipating new trends. Systems and services must be delivered at "Internet speed" and continuously fine-tuned to respond to customer needs and feedback. The public sector will then be able to anticipate and set the trend, harnessing the power of infocomm technology to enhance policy delivery, simplify regulations and improve service levels.

**Thrust IV - Using Infocomm Technologies to Build New Capabilities and Capacities**

The public sector will need to go beyond using infocomm technologies as a system, but continually innovating and adapting business and operational processes to radically re-engineer and totally transform the way we do things. Infocomm technologies offer tremendous opportunities to create new value; to tap the power of collaborative knowledge management; and to provide instant knowledge and processing capability to make quantum leaps in service delivery.

**Thrust V - Innovating with Infocomm Technologies**

The public sector will need to go beyond tried and tested ways of deploying technology. IDA will be experimenting with new technologies, with a view to learning and developing capability, and being in a situation where there is nobody else to learn or copy from, simply because Singapore is the first one there. The procurement and project management approach must also be flexible or nimble enough to avoid deploying obsolete technology, and remain practical and pragmatic.

The goal of the first e-Government Action Plan (2000-2003) is to be a leading e-Government to better serve the nation in the digital economy. Since the launch of the S$1.5 billion Plan in June 2000, Singapore has become one of the most advanced e-Governments in the world, having e-enabled more than 1,600 government services. The first e-Government Action Plan envisioned all key public services suitable for electronic delivery would be placed online by 2002. This target has been met and users have responded favorably to e-services:

Fig 3: 2003 e-Government Perception Survey

75% of all those who transacted with the Government in the past year did so at least once electronically, out of which 4 in 5 expressed satisfaction with the quality of service.

Source: Infocomm Development Authority (IDA)

Singapore has been recognized internationally as a leader in e-Government. It has been consistently ranked 2nd in Accenture’s annual global e-Government report (2000-2003), and also topped the e-Government segment in World Economic Forum’s Networked Readiness Index two years in a row (2002-2003). Singapore won the prestigious Stockholm Challenge Award (2002) and the Explorer Awards (2002) that was part of the premier E-Gov 2002 Conference and Exposition in America.


By 2006, an e-lifestyle will be prevalent in Singapore. Both individuals and businesses will prefer to transact online with the Government. Citizens readily provide feedback and actively contribute to the policy review process through
electronic consultations and virtual communities. A vibrant infocomm industry works closely with the Government to transform work processes and service delivery through ICT.

This is the Singapore e-Government vision - to be a leading e-Government to better serve the nation in the digital economy. The focus of the second Plan is to transform the Public Service into a Networked Government that delivers accessible, integrated and value-added e-services to the customers, and helps bring citizens closer together.

The second e-Government Action Plan proposed to achieve three distinct outcomes:

1. Delighted Customers.
2. Connected Citizens.

**Fig 4: Vision of e-Government Action Plan II**

Source: Infocomm Development Authority (IDA)
Key Outcome 1: Delighted Customers

Whether you are an individual or business users of e-Government, e-GAPII seek to delight the customers with convenient and easy-to-use e-services. Today, more than 1,600 e-services have been implemented. This represents all key government services suitable for electronic delivery. Moving forward, e-GAPII intends to further improve the e-service experience, and to encourage greater usage of government e-services. E-GAPIIs’ 2006 goals are to:

• Implement 12 more cross-agency integrated e-services;
• have 90% of the Government's customers use e-services at least once a year; and
• have 80% of these users are satisfied with the overall quality of e-services.

For users, it means fewer forms to fill and fewer queues to join. The contact between customers and government agencies is redesigned and simplified.

Key Outcome 2: Connected Citizens

"We have also to strengthen our social compact - the bond between Government and the people, and between the people themselves". This call, made by Prime Minister Goh Chok Tong in November 2001, has inspired the government to seek new ways to encourage active involvement of Singaporeans in the re-making of our nation and bonding of the communities. To meet this challenge, the government intends to exploit ICT to:

• Explain public policies and their rationale online; and
• Provide another channel for public feedback on policy formulation and review.

Whether they live here or overseas, Singaporeans can participate in the policy making and review process through innovative technology means. For those who
wish to volunteer in community services, a centralized portal providing information on community services will be available. Internet enabling technologies will be used to form new virtual communities, or support existing ones.

**Key Outcome 3: Networked Government**

A 'Networked Government' is one that collaborates, shares information and leverages on its collective knowledge to serve the public seamlessly and effectively. ICT will be used as a key enabler in transcending agency boundaries to deliver value-added, integrated and responsive services to individuals and businesses.

### 3.3.1 Transcending Organizational Boundaries

To meet this challenge, the Singapore Public Service will need to evolve into a knowledge-driven enterprise where collective knowledge is harnessed effectively to add greater value to customers and enhance service quality. A government-wide policy on data protection ensures the privacy rights of users.

The Public Service will also need to continue to work collectively to ensure investment in ICT generates the best possible benefits. It is important to enhance ICT management and governance capabilities service-wide, and leverage on common architectures and infrastructures to promote cross-agency collaboration and optimize resource allocation. It is also important to build agility to effectively manage rapid changes in the ICT environment.

### 3.3.2 Networked Government

*Common Architectures and Infrastructures Service Wide Standards*

The Service-Wide Technical Architecture (SWTA) proposed under the e-CAPII is the key to "Networked Government". It is a technical framework comprising standards, policies and guidelines to help agencies in the design, acquisition and management of ICT systems. This in turn helps to facilitate inter-operability and information sharing across agencies. The domain architectures within SWTA
framework seek to reduce integration complexity, promote greater economies of scale and increase re-use of components among agencies' ICT systems. Compliance by government systems with the SWTA domain architectures is projected for mid 2007.

The Broadband Infrastructure for Government (BIG) and Government Access Infrastructure (GATE) gives government agencies flexibility in the choice of broadband and mobile roaming mediums. It leverages public telecommunication networks for access to government resources. The Government Access Infrastructure (GATE) provides secure access to the government network via a wide range of channels. These include dedicated dial-up, ADSL, cable modem and other subscription services provided by Internet Service Providers.

3.3.3 The Public Service Infrastructure (PSi)
Most government agencies develop services that perform fairly similar functions - collecting payment, authenticating customers, and ensuring security, collecting or exchanging data with other agencies. This can be a fairly long development lifecycle that is likely to be repeated for most e-services. By leveraging 'building blocks', Singapore's Public Service Infrastructure (PSi) shortens the development cycle. Its infrastructure, application services and e-service development environment allows agencies to rapidly develop e-services. Components such as payment, authentication and data exchange, are 'built-once, reuse-always' services that agencies do not need to develop on their own. By leveraging these building blocks, development time is drastically reduced from months to days.

The Singapore Government's PSi initiative has won the Intelligent 20 Award and the prestigious Explorer Award at E-GOV 2002 in Washington DC, United States of America.

3.4 Foundation of e-Business
Access to ICT services is vital and plays a significant role in the development of a robust Electronic Commerce (EC) infrastructure. As voice telephony is available
at almost every home and office, the focus has now shifted to sophisticated infrastructure services, such as broadband transmission, the Internet and wireless technologies. Such critical infrastructure services enable EC to be the next economic growth wave, in the new economy.

Singapore already enjoys advantageous attributes that help to position it as the leading commerce hub. To develop Singapore into a trusted global hub in the new economy, there is a need to create a state-of-the-art e-Business infrastructure framework that is comprehensive, cost-competitive, innovative and pervasive, with excellent international linkages. The core infrastructure framework roadmap (refer to Fig 5) defines the availability, development and deployment of third-party application services, infrastructure services, together with a pro-EC environment, as follows:

- A cost-competitive ICT infrastructure;
- Well-defined policy and regulation framework to build trust, confidence and pro-EC environment;
- Essential ICT infrastructure services and applications to enable broad-based community usage and sector-specific adoption of EC;
- Constant enhancement and introduction of new, innovative and leading edge ICT infrastructure services.
The Singapore Government have identified the following programs and initiatives to help deliver this infrastructure framework:

3.4.1 Creating a e-Business Legal and Policy Framework
EC needs to take place in a secure, trust-worthy and safe environment. Policies need to be aligned towards removing barriers and promoting opportunities for EC activities. Beyond the liberalization of the IT sector, the next major policy and regulatory challenge is to clarify how existing physical rules and regulations apply in cyberspace. A clear and transparent policy and regulatory framework is necessary to build greater trust among companies to transact electronically and create higher levels of confidence for online business deals to be protected from fraud and abuse. As EC provides a fundamentally new way of conducting
commercial transactions, acceptable ways of doing business must be modified. These changes require new procedures and may raise questions to the effectiveness of policies and regulations, pertaining to commerce and traditional commercial practices and procedures, which were formed in an earlier era.

3.4.2 Interactive Broad Band Multimedia (IBBMM)

The first step to take to jumpstart the built environment is the development and growth of an Interactive Broad Band Multimedia (IBBMM) industry in Singapore. The SingaporeONE infrastructure is the ideal platform for the development, pilot testing and deployment of innovative IBBMM content, applications and services. They are committed to creating a multi-player, competitive environment that makes access to broadband services cost-effective to developers and consumers alike (IDA, Singapore ONE report).

Fig 6 - Jumpstarting the Development and Growth of an Interactive Broadband

Source: Infocomm Development Authority (IDA)
To achieve this, they have mandated open interconnect access to Singapore Telecomm (SingTel) and Singapore Cable Vision (SCV) broadband infrastructures. This will allow other telecommunication players to also offer broadband services and provide consumers with the flexibility and freedom of choice. The InfoComm Development Authority (IDA) is now reviewing the broadband open access regulatory framework needed to achieve this, and will announce details in due course. Concurrently, the IDA is also reviewing the minimum quality of service framework for broadband access service providers in order to raise the overall technical performance.

A number of the new facilities-based operators licensed recently have also indicated that they will be deploying their own broadband access infrastructure, including fiber and via wireless technologies. IDA will be undertaking a comparative selection exercise to award fixed wireless broadband services before the end of 2003. They can therefore look forward to the presence of multiple broadband access networks and consumers will certainly benefit from this enhanced competition.

The Singapore Government have also announced the provision of a S$150 million package to stimulate both the demand for and supply of IBBMM content and services (IDA, Singapore ONE report).

The funds will be applied in four areas.

1. First, a large part of this package will be used to offset the high cost of infrastructure and equipment to enable broadband access at the 'last mile'. Benchmarked against the rest of the world, their local service providers are already offering competitive prices for broadband access through ADSL and cable modems today. But they want to accelerate the take-up rate further. This will make Singapore a more attractive and viable market to major content and service providers.
2. Second, the government will co-share some of the costs for the provision of the international leased circuits through the broadband infrastructure, as this is still a major cost item today. However, they expect competition in the liberalized telecommunications market to also result in prices of leased circuits dropping significantly in the near future. The need for them to co-share the cost of ILC will therefore reduce over time.

3. Third, they will set up an IBBMM Content Hosting Scheme to attract content providers to host or hub their content in Singapore. Modeled along the lines of the highly successful Online Hosting Scheme of SingaporeONE, this new scheme will co-share the risks of content providers who intend to develop and deploy IBBMM content in an untried market. With this financial offset, content providers will be more willing to develop new and innovative content for the market.

4. Fourth, the government will be providing incentives for the development of new media services brought about by the convergence of technologies, to make broadband services more accessible to consumers. Examples of new media services are those provided by wireless Internet, interactive TV and new information appliances.

In addition to the IBBMM package, there will be a major initiative to broadband-enable high-rise commercial buildings or industrial parks to create many cyber-precincts in Singapore.

3.4.3 New Capabilities and Innovations
Another strategy for accelerating the growth of the IT in the built environment is to build new capabilities needed for the new Internet economy. Besides technology prowess, new companies, especially local enterprises and start-ups, must be knowledgeable about operating in a global IT market space. They must be capable of achieving quick turnaround and time-to-market, and creating and protecting their intellectual capital. To help local enterprises, IDA has expanded the scope of the highly successful Local Industry Upgrading Program (LIUP) to
the built environment industry. Together with the global technology players, IDA proposed to involve other partners such as venture capitalists, patent lawyers, and financial and business consultants. (EDB)

Beyond the LIUP, IDA together with Economic Development Board (EDB) and A-Star (Formally National Science and Technology Board-NSTB), will also be facilitating the collaboration between industry players and research institutes in key emerging technologies. Such collaboration can be conducted through joint development projects or competency centers focused on cutting edge technologies such as 3G wireless and mobile computing, speech recognition and language translation, and embedded software technology.

IDA is also continuing to actively promote innovation in the ICT industry. Innovation is critical, in a fast moving sector such as the ICT industry. The convergence of computing, communications and content is creating new demands and opportunities, which the local enterprises can and must capitalize on. IDA has therefore decided to extend the Innovation Development Scheme (IDS) to cover the new growth areas of ICT development for the built environment industry.

3.4.4 Spurring Consumer Demand

Cyber based transactions are more impersonal, anonymous and automated than transactions made in the physical world. The de-humanization of businesses comes with a dependency on Internet technologies and provides many opportunities of fraud and abuse on both ends of the transaction: the buyer and the seller. Hence, building consumer trust and gaining consumer confidence are primary aspects to spurring consumer demand and to drive Business-to-Consumer (B2C) EC businesses to succeed.

The Singapore Government aims to promote the development of trust marks to enable the widespread adoption B2C EC transactions that can be performed anywhere at anytime. IDA is working with key government agencies such as Singapore Tourism Board (STB) and SPRING (formally called the Productivity
and Standards Board-PSB) to implement a two-pronged approach to enable Singapore to become a trusted global e-consumer hub: Promoting B2C marketplace and Building Trust Marks and Consumer Confidence.

1. **Promoting B2C marketplace**

Building cyber-consumer trust in the local e-marketplace is an important success factor. A strong education and awareness program will need to be implemented to proliferate online customers, and could include: regular online fairs and e-consumer events.

2. **Building Trust Marks and Consumer Confidence**

Businesses need to gain basic consumer confidence in B2C. IDA, in conjunction with STB and SPRING, will be driving programs to educate businesses to adopt ethical best practices, review EC privacy and security policies as well as provide accreditation to merchants through use of trust marks, trust labels and third party certification processes. In order to increase the revenue for e-tailer by boosting the consumer confidence, IDA will encourage the implementation of trust marks. Over 2 years, IDA aims to achieve 2000 trust marks for local online B2C e-tailers.

3.5 **Findings**

Since 1986, when the First National IT Plan was unveiled, the ICT environment in Singapore has been on the fastest growing amongst the services sectors, with a nominal average growth rate of 13% per annum between 1986 and 2000. Its productivity gain during the same period was also the highest at a nominal growth rate of 6% per annum (IDA). In 2000, the ICT environment accounted for SGD$10.9 billion in value-added terms, or approximately 7% of GDP (Infocomm Survey 2001), and employed some 52,230 workers (Survey of Infocomm Manpower 2000). Value-Added per worker was among the highest in the services sectors at SGD$208,000 in 2000.
Although the global ICT industry had taken a beating over the past years as a result of overspending in IT, the dot-com crash, and over investment in telecommunications, ICT remains a sector of growth and a key enabler to other sectors of the economy, including the built environment. Based on a survey conducted by the “The Economist” in December 2001, most respondents believed that information technology was a long way from exhausting its potential and would continue to drive future surge in economic activity. Ubiquitous communications and intelligent systems were mentioned as combination of technologies that would drive the next wave of growth. (In chapter 5 and 6, ubiquitous communications and intelligent systems for the built environment are discussed at length)

The ICT environment will continue to be an important sector that will continue to power Singapore’s economic growth. Singapore can capture global opportunities in the ICT environment by differentiating itself from the competition. ICT will also be an integral part of the economy, business environment and society. The pervasive adoption of ICT will have an important multiplier effect for the economy through the transforming the way people live and boosting the way companies and industries conduct their business.

Singapore can maintain a global mindshare for its ICT environment by positioning itself as a vital ICT Hub for the Asia and beyond, where innovative and complex ICT solutions are created, tested, commercialized and deployed. To capitalize on the potential growth in the ICT sector globally, Singapore needs to leverage its strengths and expertise to increase its competitiveness vis-à-vis regional rivals, for example Japan which is currently leading in mobile services, Korea in broadband services, Hong Kong in broadcasting and media services and Australia in IT and outsourcing services.

Going forward, Singapore must also extend its reach to new markets and move up the value chain in its usage of ICT solutions. Creating integrated solutions that require collaborations across the value chain could become Singapore’s
competitive strength. This positioning is sustainable as Singapore is already globally renowned for its pervasive adoption and speed of deployment of innovative ICT solutions and technologies. Singapore has an excellent ICT infrastructure and a technology savvy workforce, with traditional strengths in systems integration and project management. Singapore is also strategically positioned (as outlined in Chapter 2) at the crossroads between East and the West, and is able to work with various ICT centers of excellence globally.

To achieve these targets, Singapore must enhance its approach to industry development by becoming more demand-oriented through the leveling up the quality of the domestic demand and growing overseas demand. There are great opportunities present now where there are efforts to create greater co-operation within ASEAN, which will offer opportunities for Singapore to gain access to regional markets and resources. The various FTAs that Singapore has signed will also create possibility of more meaningful linkages with the rest of the world.

However, Singapore must also enhance the building of the “soft” infrastructure in the form of talents and intellectual property to complement our “hard” infrastructure, and by encouraging domestic industry leadership in these efforts. At the moment, the ICT environment lacks clear differentiating factors and declining cost competitiveness as there are limited and relatively less sophisticated domestic market. Consumer demand for ICT services is pervasive but fast reaching saturation level. The future growth will depend on the replacement market and increasing sophistication of usage. The domestic business users of ICT in Singapore tend to be less sophisticated compared to developed countries such as EU and US. There should also be more emphasis on IP creation, protection and exploitation.
4.0 SINGAPORE’S BUILT ENVIRONMENT – CITY PERFORMANCE

4.1 An Overview

The built environment in Singapore, as we see it now in the 21st century, is still characterized by a high degree of fragmentation and adversarial culture. It is also plagued by low productivity, heavy reliance on unskilled workers, poor quality, unsafe working environment etc. The fragmented nature of the industry with a large number of players in different disciplines has resulted in the perpetuation of the traditional approach to project delivery in which the various processes from planning, design, construction and commissioning proceed in sequence with little consideration for one another.

The general view is that this approach provides a measure of protection to less informed clients, who are concerned with the professionalism of contractors whom they have to deal with. Also, with fragmentation, the various industry players have little incentives to consider issues such as buildability, construction quality and safety, environmental performance, maintainability, life cycle costing, use of technology for project integration etc… which have a direct impact on the industry’s performance.

At the design stage, inputs from contractors and suppliers are seldom sought, very often leading to frustration, subsequent re-work and delays in project execution when the expectations of the designers and contractors do not meet. At the extreme, clients, consultants and contractors may end up in confrontation or litigation. To enable the industry to deliver the products to meet the expectations of clients in terms of timeliness, cost and quality and in progress with growing environmental consciousness of the society, the traditional roles and attitude of the industry players will have to change. There is now growing recognition that greater integration of planning, design, construction, training and supply services will lead to more effective and efficient delivery of projects. Adversarial relationships will have to give way to a more cooperative culture based on
fairness, mutual trust and respect and greater synergy of complementary roles of different players.

4.2 Current State of the Built Environment

Local AEC Industry

The Singapore economy recovered from the yearlong recession in the Second Quarter 2002, with the second half of that year looking very promising then. However, the softening of growth in the United States, war, higher oil prices, deterioration in regional security, other unfavorable factors and most recently SARS combined to slow the recovery in the Fourth Quarter. As a result, the year 2002 ended with a growth rate of only 2.2% (4th quarter Economic Results, Ministry of Trade and Industry). The economic prospects for this year still looks uncertain, with the Ministry of Trade and Industry (MTI) forecasting a range of 2% to 5% (2003 Economic Forecast, Ministry of Trade and Industry).

Construction Demand in 2002

Closely tied to economic outlook, private sector construction orders fell by 27% to $4.5 billion in 2002 from the 2001's $6.2 billion level. Private residential construction continued to remain sluggish, despite a short recovery in the Second and Third Quarter last year. The worst hit was private industrial construction demand, which saw the award of contracts worth less than 30% of 2001's level (4th quarter 2002, Real Estate Report, Urban Redevelopment Authority).

In contrast, there was a large increase in public sector construction orders, fuelled by the construction of the mega projects, such as the Kallang-Paya Lebar Expressway, the Mass Rapid Transit (MRT) Circle Line, and the Changi Water Reclamation Plant. As a result, the public sector construction demand rose by 31% to $9.7 billion, bringing total construction demand to $14.2 billion for the whole of 2000 (Construction Industry Report 2002, Building Construction Authority).
Prospects for 2003 and Beyond

In the year ahead, the government expect the current economic uncertainties to dampen the level of construction demand, in particular the private sector. The private sector is expected to award only $4.1 billion worth of contracts, with both the private residential and industrial construction demand expected to remain low.

There will be fewer large public sector projects this year. However, the industry can look forward to more smaller size projects. It is estimated that about $1 billion will be spent on various upgrading projects, including main and interim Housing and Development Board (HDB) Flats Upgrading, Lift Upgrading, Private Estates Upgrading and Hawker Centers Upgrading programs. The larger number of upgrading jobs expected this year would be of some help to smaller contractors to ride out the current rough patch. In total, the government expects the public sector to award a total of $7.9 billion this year (Housing Development Board Review 2002).

In 2003, the Building Construction Authority (BCA) expects both sectors to award a total contract value worth around $12 billion. Market watchers expect economic prospects in 2004 and beyond to be brighter, with the forecast of stronger growth of the United States' economy and the stabilizing of international oil prices. However, due to the recent Iraq conflict, these estimates will need to be revised.

4.3 Future State of Built Environment

4.3.1 Strategic Lens - Market Size and Overseas Market

To compete effectively in a global market, size is important. Given the small size of the domestic market, local firms need to venture overseas to grow. Over the years, a number of Singapore’s local firms have built up expertise in master planning and designing; development and construction of housing townships, MRT systems and tourism-related infrastructures; and facility and environment management. These capabilities are in great demand overseas, especially in India and China. For instance, housing township developments in China is expected to
increase from 770 to more than 1,000 over the next 15 years with the acceleration of urbanization to raise the standard of living of her vast population.

In 2001, the construction industries of India and China grew by about 13.7% and 7.4% respectively. Both countries are expecting their construction industries continue to grow at least 7% per year over the next 5 years. Regional construction prospects are also good, with countries such as Vietnam, South Korea and Sri Lanka showing positive growth of 2% to 7% in the last two years (Construction Prospectus 2003, Building Construction Authority).

4.3.2 Cultural Lens – Collaborative and Transnational Initiatives

Collaboration thru Consortium

To overcome the limitation of size, local firms have begun to come together to form consortium to take on projects that require sizeable investments and technologically integrated services. Together with International Enterprise Singapore (IE), BCA is actively exploring with a number of local firms across the construction value chain to form consortia for projects in development and construction of housing townships, MRT systems, waste and environment management systems, and tourism-related infrastructures in China and India.

Transnational Initiatives

To assist local firms venturing overseas, the Government has set up the Asian Business Fellowship (ABF) Program. This ABF Program will help local firms train their staff to be country experts who are familiar with the business practices of the target host countries. Currently, this program is for market immersing in China only. Possible extension to India and the regional countries are likely in later stages. In September last year, the government announced that BCA has been appointed by the Ministry of Trade and industry (MTI) to be its agent in administering this program for the construction industry. Till date, one firm has already sent one staff to its Shanghai office for immersion into the Chinese market, and over the next six months, seven more candidates from other firms
will follow suit to various major cities in China. For the whole year, BCA expects at least 15 persons to be approved under this program.

4.3.3 Political Lens – Market Entry and Market Intelligence

Early leads on information are important for firms to seize the business opportunities. BCA and IE Singapore are working together to provide the industry with market intelligence and project leads in key cities in China and India through the networks the Government has built up with the Chinese and Indian Governments over the years. Complementing IE Singapore, BCA proposed to have officers stationed in Chongqing and Shenyang, China this year to facilitate market entry for local firms in those two cities.

4.4 Industry Process Analysis

4.4.1 Techniques: Design-and-Build

The procurement method adopted for a project has an important impact on how members of the project team work and interact with one another. The government has identified Design-and-Build (D&B) as a form of procurement, which can play a positive role in encouraging collaboration among the project team members. Compared with the traditional Design-Bid-Build (DBB) procurement system, D&B will foster the integration of the expertise of the consultants and contractors at an early stage to incorporate buildable design and more innovative construction methods to save cost and labor minimize wastage etc.

In Australia and Japan, D&B projects account for about 60 and 50% of projects respectively. However, in Singapore, the D&B method of procurement is still not the preferred choice especially amongst the private sector clients and accounts for only about 14% of total projects (Construction Prospectus 2003, Building Construction Authority). If more integration in the project delivery processes is the way to go, there is then a need to look at ways and means to promote the D&B method and to eliminate practices, which inhibit the adoption of such a method.
Currently, the relevant legislations in Singapore governing the practices of architectural and engineering professions and those on building design and construction are inhibiting the formation of a single entity multi-disciplinary companies which can offer both design and construction services. To facilitate D&B practice, BCA has conducted a review of the Architects Act, Professional Engineers Act and Building Control Act with a view to removing the legal impediments to the formation of a single entity company to provide both design and construction services. This is timely as the codes and regulations were inherited from the British times. In order for the construction industry to be innovative and knowledge driven, these codes and practices need to be reviewed. In addition, BCA is now in the process of drafting a Standard Conditions of Contract for Design-and-Build Construction Works for the public sector.

The formation of integrated multi-disciplinary company offering both design and construction services will also enhance the competitiveness of these companies. These integrated companies will be in a strong position to provide a range of services to meet clients’ requirements especially in a globalize marketplace. BCA needs to work with the industry to see how firms can merge and grow in size in order to undertake more challenging projects including delivery of design and build services and be more competitive in the face of more intense global competition. This would include the review of the contractors registration system for public sector procurement.

4.4.2 Technology: Information Communication Technologies

The rapid advances in Info-Communications Technology in recent years have open up new possibilities for greater integration among firms. For example, electronic transmission and exchange of construction information and drawings are becoming increasingly more convenient and reliable.

In May 2000, BCA together with 13 major private sector developers in Singapore launched a pilot implementation of the use of Project Website - an electronic platform making use of Internet technology to enable clients, consultants and
contractors to share and exchange project information more efficiently and carry out design collaboration and project management online. Project Website is a radical step forward in reengineering the work processes in the construction industry. If successfully implemented, it would provide an efficient platform for integrating the various players and processes across the construction value chain.

In addition, it will provide a more superior way in which project information could be organized, stored and accessed at every stage of project implementation from planning and design to construction, commissioning and eventual operation and maintenance. Presently, 17 real-life projects are being managed using the Project Website under the pilot implementation involving about 200 firms. When completed, this pilot project will yield findings on how this electronic form of information sharing, exchange and storage for design collaboration and project management can be further enhanced as a working model for greater adoption in the construction industry. The Project Website has allowed the various members of the team to be more aware of the constant changes typical of a construction project. The team members are more informed and organized. What used to be tons of drawings in paper, is now conveniently stored in digital format for 24 by 7 access.

4.4.3 Manpower: Capability and Productivity

On the domestic front, over the past couple of years, BCA and the industry have taken steps to upgrade delivery capability and improve productivity. BCA have continued to help to defray costs for firms wishing to upgrade themselves. In year 2002, a total of $10.3 million in grants was given to local firms to upgrade their expertise in various areas. Grants are given to firms to implement quality, environmental and occupational health and safety management systems under the Local Enterprise Technical Assistance Scheme, (LETAS); for mechanization and purchase of selected Information Technology software under the Investment Allowance Scheme (IAS); for collaborative R&D under the Industry Productivity Fund (IPF); and for CORENET training under the Initiatives in New Technologies Scheme (INTECH). A total of 760 firms have benefited from the
grants as compared to 348 firms in the previous year 2001 (Training and Development Report 2002, Building and Construction Authority).

BCA have recently streamlined the Investment Allowance Scheme to focus on buildability and prefabrication. This will encourage companies to move away from manpower intensive practices. Higher support will be given to firms, which purchase equipment for such purposes. The LETAS scheme has also been liberalized to make public listed firms eligible, provided they meet the manpower and fixed asset investment criteria.

4.4.4 Improving Industry Professionalism
Through BCA's training arm, the Construction Industry Training Institute (CITI), the skill level of construction manpower has been raised through training courses and trade testing. In 2002, more than 7,900 construction personnel have attended CITI's Skills Training and Supervisory, Technical & Management training programs. In addition, more than 18,000 workers have taken the trade tests and more than 8,800 foreigners have obtained the Skills Evaluation Certificate (SEC) last year (Training and Development Report 2002, Building and Construction Authority).

BCA and the industry have also taken steps to reduce the industry's reliance on foreign workers. In addition to implementing buildability requirements since 1999, BCA has worked with the industry players such as developers, designers and contractors to promote more buildable solutions, which will require less construction labor. It is heartening to note that more than 50% of the building plans submitted today exceed the minimum buildable score requirements. These efforts complemented the Ministry of Manpower's reduction of foreign worker supply through the man-year entitlement scheme; the effect is that construction labor productivity began to show signs of improvement, and for the first time after six years of negative growth, the industry productivity growth rate turned positive in 2001, albeit a small 0.2%. Last year, the government estimated that the growth rate to double to 0.4% (Report on Labor Force 2002, Ministry of Manpower).
4.5 Findings and Recommendations

This chapter aims to address the current inefficiencies in the industry and transform it into a knowledge industry. The inefficiencies examined include issues across the construction value chain, from design to construction and to maintenance. The Singapore construction industry has played an important role in contributing to Singapore's economic development. However, it faces serious problems such as:

- Low productivity level and negative productivity growth.
- Heavy reliance on a large pool of unskilled labor.
- Malpractice and social problems associated with the employment of a large number of foreign workers.
- Labor intensive and backward construction techniques and practices.
- Poor safety performance.

Both upstream and downstream activities have contributed to the above problems. At the upstream stages, some professionals in the industry are slow to embrace world-class standards and practices. Design is segregated from construction considerations, leading to much re-work downstream. Also, the failure to take into account buildability, labor reliance, maintainability and other considerations at the planning stage hampers any saving-saving efforts at the construction stage.

At the downstream level, the availability of a large pool of low cost, unskilled foreign workers has depressed productivity while bringing about a host of social problems. This is best illustrated by the almost fourfold increase in foreign construction worker numbers between 1990 and 1998, while project volume over the same period has only gone up less than twofold (Manpower Report 2000, Ministry of Manpower).
To address the problems facing the industry, there is a need to change mindsets on how construction is carried out and to eradicate the inefficiencies in the industry. Becoming a "World Class Builder" in the new millennium will require a collaborative effort by all players in the construction industry value chain. There is currently a wide disparity in the professional standards of industry players, i.e. developers, architects, engineers, project managers and contractors. In fact, not many can measure up to world-class standards. It is crucial to change the image of the industry and raise the level of professionalism and competence among all industry players.

The construction industry in Singapore has about 13,500 construction firms, employing some 274,000 people. The industry has played a key role in Singapore's economic development. It contributes 6.8% to the annual GDP in 2000. Value added for the industry was $9.55 billion in 2000 (Ministry of Trade and Development). To remain competitive and relevant, the industry has to move along with the knowledge-based drive economy. The global trends that are emerging include greater application of lean construction. Along with it comes the increased use of information technology (IT) as a key enabler for integration and innovation to improve construction productivity, in areas such as project management and electronic procurement.

Already plans are afoot within the construction industry in Singapore to meet these challenges. The various professional bodies and trade associations in the construction and building industry are coming to together to deliberate and address common concerns in a more integrated manner. They see the need to transform and re-engineer business processes in the entire value chain in order to achieve better resource utilization and efficiency, and to reduce wastage and other costs. They are also keen to try out and adopt new technologies to raise productivity. Specifically, they aim to enhance buildability through more stringent legal specifications and requirements and through the greater use of prefabrication, as well as modular and standardized building components. They
also seek to improve construction management on site for greater efficiency and safety. At the same time, they are focusing on raising the skill levels of construction workers so that a larger pool of skilled workers is available in the industry.

Some ways to correct the current inefficiencies in the industry and transform it into a knowledge industry includes the following recommendations.

**Recommendation 1- Enhance the Professionalism of the Industry Enhancing Tertiary Education**

To forge a deeper understanding of the multi-disciplinary facets of the construction process and help foster teamwork among players, the local tertiary institutions can look into enhancing the curriculum for their students in engineering, architecture, building and other construction-related fields to make them sufficiently broad-based. This can be achieved through the introduction of common modules for engineering and architectural students, as is the case for Japanese under-graduates during initial years of study. This will not only allow our students to acquire more balanced and broad-based skills but also promote collaboration in future professional endeavors.

*Continuing Professional Development (CPD)*

To cultivate lifelong learning amongst industry players, professional and trade bodies can be encouraged to promote continuing developmental programmes for their members and to make CPD programmes mandatory for renewal of professional membership.

*Developing Individual Codes of Conduct*

The professional and trade bodies have also been urged to develop their respective codes of conduct, if not already in place. This is a first step towards self-regulation, image improvement and higher professionalism among industry players. The industry can then formulate a national code of conduct to spell out the working relationships and responsibilities of the various players. Reducing the
industry's dependence on low-skilled construction workers will eradicate the productivity, management and social problems associated with the situation.

**Recommendation 2 – Adopt an Integrated Approach to Construction**

*Promoting the Use of Design and Build Methods through Promotion*

The BCA will need to step up promotion on the use of this method as it encourages collaboration between industry players at the upstream level.

*Reviewing Legislations which Restrict Partnerships*

The BCA together with the Government Parliamentary Committee for National Development, GPC-MND, (which I am a resource member) will be reviewing the Architects’ Act, the Professional Engineers Act and the Building Control Act to remove any impediments to the formation of partnerships between design and building companies for construction work. Experience in other countries has shown that the construction industry can export part of its services and become a global player. Resolving the problems in the domestic industry will lay a solid foundation for local companies to venture abroad and contribute to Singapore's GDP.

This chapter epitomizes the collaborative effort needed to transform the industry. Many government agencies, industry players and members of the public will need to be involved in the implementation of this policy study. The stakeholders would include developers, architects, engineers, consultants, academics, contractors, regulatory bodies and consumers. The macro and micro recommendations outlined in this paper can help the stakeholders to upgrade all aspects of the construction industry, from processes (integrated approach to construction) and players (enhancing the professionalism of the industry) to products (exporting construction expertise).
5.0 ICT STRATEGIES FOR THE BUILT ENVIRONMENT

5.1 Why ICT?
A perceived lack of effective ICT exploitation in the built environment in the past often creates difficulty in justifying future expenditure and managing the benefits of ICT innovations. This reduces the motivation to innovate and translates into missed ICT business opportunities. In 1995, the UK Department of Environment IT strategy for Construction clearly defined the lack of perceived business case for IT investments as a major obstacle to effective adoption and application of the technology in the sector. The problem of identifying IT costs and benefits is neither new nor unique to the construction sector. It is a global problem experienced in all types of business sectors and organizations (Hochstrasser and Griffiths, 1991). However, the problem is more acute in built environment as a result of the industry's structure, fragmentation, and under capitalization. Many companies in the built environment industry are under financed. At any point in time there is only limited capital available for investment and IT investment must compete with other demands on capital. This means companies must recognize that the full benefits of an IT project can only be realized as part of an overall business strategy (Bruce, 1995). However, the built environment companies are often slow to formulate strategies that recognize the role of IT and result in corresponding ICT strategies. IT spending in the sector is significantly lower than business norms, in most countries.

The business case for ICT investment in the built environment is normally prepared by the IT manager of an organization for decision making by senior management. IT managers frequently lack a full understanding of their organization's business and are often not involved in the senior management decision-making of the company. Senior management who do understand the business is usually ill at ease with the emerging information technologies. When considering new ICT investments, senior management seldom has feedback from previous investments to provide comfort for their earlier decisions. Any tool
produced to evaluate new investments should also be capable of evaluating earlier investments and providing feedback on their success or failure.

There is a clear need for a framework that enables all parties to communicate and exchange information on possible ICT investments in a form that is readily recognizable within the culture of the business sector. This issue has been well understood in business more generally. Up to now, the specific needs of the construction sector with regard to this issue has been hindered by the lack of an appropriate sector-specific tool to deal with some aspects of sector-specific language and culture. If the built environment organizations are to benefit from ICT investments then new frameworks for identifying the costs and benefits of ICT are required in their language such that the built environment business managers can understand and feel fully confident in applying them. The concept of the Construction and Real Estate Network (CORENET) was conceived to provide such a framework for the built environment to perform more efficiently and effectively. Consideration of performance benefits and effectiveness must be considered as well as efficiency.

Efficiency is, in this context, defined as the rate in which inputs are converted to outputs (doing things right), effectiveness is the rate of actual outputs compared to the planned (doing the right things) and performance is the level of new outputs enabled (doing better things). The nature of modern business is such that, increasingly, senior managers are required to think beyond the direct tactical issues of efficiency and effectiveness and more towards strategic issues. Business performance, in its broadest terms, is a major strategic issue and one that ICT has much to contribute towards. A major argument being adopted within this thesis is that ICT benefits in the built environment extend beyond the tactical into strategic business performance improvement. This argument is widely adopted in other sectors but remains poorly understood and applied in the built environment.
5.2 Construction and Real Estate Network (CORENET)

CORENET is a major IT initiative led by the Ministry of National Development (MND) and driven by the Building and Construction Authority (BCA) in collaboration with other public and private organizations. The Objective of CORENET is to re-engineer the business processes of the construction industry to achieve a quantum leap in turnaround time, productivity and quality. CORENET revolves around developing IT systems and key infrastructures to integrate the four major processes of a building project life cycle.

**Fig 7: CORENET’s Four Major Process**

![Diagram showing the four major processes of a building project life cycle.](Image)

*Source: Building Construction Authority (BCA)*

Laying on the foundation of the IT infrastructure, the four processes will need to have specific IT systems to support each process. These individual IT systems are as follows:
Design Process: **Collaborative Design Systems**
IT systems to facilitate communication and workflow refinement in the design environment.

Procure Process: **Procurement Systems**
IT systems to facilitate measurement tender procurement and cost management.

Build Process: **Construction Systems**
IT systems to facilitate the building process and project management.

Maintain Process: **Facility Management Systems**
IT systems to facilitate assets management, building performance and property maintenance.

Currently, the effort is focused at developing a set of infrastructure and industry projects in order to:

* Provide Information Services to allow businesses to speed up business planning and decision making processes;
* Provide Government to Business infrastructure to facilitate electronic building plans submission, checking and approval processes;
* Provide Business-to-Business enablers to facilitate building project collaborations and business transactions;
* Provide a set of standards to improve business communications;
* Provide a series promotional, training and incentive program to create awareness and encourage adoption.
5.3 Integrated Submission System

The Integrated Submission System consists of a series of ICT tools to assist to verify computer-generated plans for compliance to the requirements of all relevant authorities. These plans and documents can be submitted to all authorities electronically.

CORENET e-Submission System

The CORENET e-Submission System provides a network infrastructure that supports the electronic submission of building project documents to relevant authorities for processing and approval through a secured environment. Other than being an electronic channel for plan submissions and permit applications, e-Submission is also an industry-wide ICT infrastructure to promote e-commerce to the building industry.

The CORENET e-Submission System is a G2B (government to business) network infrastructure to facilitate electronic submissions and processing of project-related documents within a secured environment. The main objectives of e-Submission are to provide a one-stop, non-stop point for industry players to submit documents via the Internet to the various regulatory authorities for processing. The industry players would benefit through the need to make less frequent trips to agencies for submissions and minimizing multiple production of hardcopies of drawings. In addition, the industry players would be able to monitor and track the status of approval of submissions from the convenience of their desktop.

Key Participants to Full-scale e-Submission

- Ministry of National Development (MND):
- Building and Construction Authority (BCA)
- National Parks Board (NParks)
- Urban Redevelopment Authority (URA)
- Housing & Development Board (HDB)
- Ministry of the Environment (ENV):
- Central Building Plans Unit (CBPU)
Industry Representatives:

- Association of Consulting Engineers, Singapore (ACES)
- Institution of Engineers, Singapore (IES)
- Real Estate Developers Association, Singapore (REDAS)
- Singapore Contractors Association Limited (SCAL)
- Singapore Institute of Architects (SIA)

5.4 Integrated Plan Checking Systems

The Integrated Plan Checking Systems aim to automate the checking process for the various plan types. These are leading-edge systems that require the integration of expert knowledge in plan checking as well as Artificial Intelligence (AI) and Object Oriented Computer-Aided Design and Drafting (OCADD) technologies. With these systems, regulatory requirements can be captured more consistently and comprehensively. Any areas of non-compliance with regulations can be detected and amended during the design phase rather than during the approval phase. As a result, less re-submission needs to be done without compromising on the safety aspects of building.
Four integrated plan-checking systems are developed to cater to the needs of the four design functional areas:

5.4.1 Integrated Building Plan System (IBP)

An integrated system to check for compliance of building plans requirements of the various authorities.

BP-Expert

BP-Expert is a revolutionary building plan checking system developed by the Building Control Division of the Public Works Department. Formerly known as the Building Plans Processing System (BPPS), BP-Expert is an expert system that employs Artificial Intelligence (AI) and Computer-Aided Design (CAD) technologies to automate the checking of building plans for compliance with building control regulations.

BP-Expert, which is a precursor of IBP, was launched in October 1997 to serve as a "pace-setter" for the industry. Although BP-Expert only covers the Building Control Regulations, it is nonetheless useful to the Qualified Person (QP) as it relieves him of the responsibilities of checking and confirming that his Building Plan (BP) complies with the building regulations. Furthermore, BP-Expert also serves as an example of how advance ICT could help the industry. More importantly, the early release of BP-Expert would provide the much-needed impetus for the industry to plan ahead for feature-based CAD implementation.

Up till now, the use of BP-Expert by QP to check plans has not been made compulsory. The reasons are as follows:

- The industry is not ready for mass ICT conversion;
- BP-Expert is only for building regulations - other technical departments' requirements are still manually checked;
- Investment in feature-based CAD may pose additional financial burden to QP during this economic downturn;
• QP will have to decide if he wants to embrace this technology early so that in due course when the full suite of AI plan-checking systems is ready, he does not have to go through the learning curve from beginning. In short, he should look at BP-Expert implementation and hence feature-based CAD as a skills-upgrading program in the face of the fast emerging ICT-driven business environment.

The Integration
Several government agencies are currently working together on the IBP project to extend the scope of BP-Expert to include fire safety requirements, environmental health requirements, vehicle parking requirements, and so on. Once completed, a single AI plan-checking tool to check for compliance of building plans requirements of the various authorities will be made available. IBP will be developed using a new and more efficient platform. It will be less memory intensive compared to BP-Expert. Hence, current set up used to run BP-Expert would be able to run IBP.

Key Participants
• Building and Construction Authority (BCA)
• Central Building Plans Unit of The Ministry of Environment (CBPU)
• Civil Defense Shelter Bureau (CDSB)
• Fire Safety and Shelter Bureau (FSSB)
• Housing & Development board (HDB)
• Land Transport Authority (LTA)
• National Parks Board (NParks)

Project Schedule
Development work for IBP is targeted for completion in 2003.

Functions - From Design to Reality
The BP-Expert accepts as inputs building plans prepared with Computer-Aided Design (CAD) software. The system captures extensively the knowledge of
interpreting architectural designs as well as the expertise of applying building regulations to the designs. It automatically recognizes the layout of a floor plan, derives spatial relationships among the various building components and checks the design for compliance with the building code. Non-compliances will be highlighted, and with the feedback the architect can proceed to correct any design errors promptly. This process iterates until compliance of the building plans is satisfactorily met. The electronic files are then submitted to Building Control Division (BCD) of Public Works Department and the building is ready for construction.

**Artificial Intelligence Engine**

Building control regulations are built into the system as expert rules. To check for conformance, the artificial intelligence engine interprets the layout of the architectural plan through the use of semantic nets that derive the relationships among the building components.

**Online Browser of Objects**

Building objects are organized in different display layers, which can be viewed at the user's preference. Information associated with each entity can be retrieved through simple mouse clicks.

**Visual Feedback on Non-Compliance with Explanation**

Non-compliance with building control regulations is highlighted in red at their exact locations on the building plan. A simple explanation informs you of the nature of the violation.

**A Full Range of Annotation Tools**

Annotation tools that enable users to record comments directly onto the building plans are available.
Real Printing

Printing in BP-Expert is simple. The building plan can be previewed before printing. What you see on screen is exactly what you get on paper.

Operating Environment

- Unix Workstations or Pentium
- 200 MB HDD
- 32 MB RAM
- 17" Super VGA Monitor
- PostScript Printer (optional)

5.4.2 Integrated Building Services System (IBS)

IBS is an integrated system to check for compliance of building services requirements of the relevant authorities. IBS will be implemented after the IBP implementation is completed.

5.4.3 Integrated Structural Plan System (ISP)

ISP is an integrated system to check on key structural elements of the building for overall structural safety. ISP will be implemented after the IBS implementation is completed.

5.4.4 Integrated External Works System (IEW)

IEW is an integrated system to check on planning requirements external to the building line. IEW will be implemented after the ISP implementation is completed.

5.5 IT STANDARDS > CAD & Classification Standard

A Memorandum of Understanding ("MOU") was signed on 29th September 1998 to develop the National Standards for Information Exchange in the Construction Industry. The objective of the standards is to improve the exchange of building information amongst the building professionals during the building lifecycle. The standards will be developed in 2 phases to support information exchange based on
the current and emerging tools, respectively (Building Construction Authority). These standards were developed under the ambit of Construction Industry IT Technical Committee (CITC) - an industry-led committee comprising members from various professional bodies and leading firms in the industry.

5.5.1 Phase 1: CAD Standards

**Phase 1** aims to define the standards for current IT tools such as the geometry based CAD software used for drafting purposes by the industry today. Such CAD uses layering and symbols to represent building components such as doors. Phase 1 also look into classification of construction related information.

- CAD Standard for Drafting Convention - SS CP 83 Part 4: 2001
- CAD Standard for Color and Linetype - SS CP 83 Part 5: 2001

**CAD Standard for Layering - SS CP 83 Part 1: 2000**

In the construction industry, different consultant firms use CAD layer mechanism to structure their drawings differently. There is no standardized way of naming the layers across the industry. The CAD Layer Standard aims to standardize the naming format of CAD layer and to recommend a set of layers for different disciplines in preparing their CAD drawings. With the Standard, information will be grouped and separated by disciplines and construction objects. It will allow a particular discipline to access or retrieve the necessary information from its project partners’ CAD drawings easily. The target users of the Standard are designers, draftspersons and CAD Managers.

**CAD Standard for Symbols - SS CP 83: Part 2: 2000**

The purpose of the CAD Symbol Standard is to recommend a common set of symbols to be used in CAD drawings to represent real world building objects for the building industry. The Code of Practice for CAD Standards - Symbols aims to promote consistent use of symbols across disciplines to improve efficiency of the design and drafting processes. CAD vendors can then implement a common set of CAD symbol library that will minimize the need for individual firms to build up and maintain their library of CAD symbols. The target users of the Standard are designers, draftspersons and CAD Managers.


The File and Directory Naming Convention was developed to enhance uniformity in the naming of CAD files for the construction industry in Singapore. This is to facilitate identification of the contents of CAD files by capturing important attributes in filenames or other forms of documentation. A convention in naming the CAD files understood by different parties of a construction project will facilitate the exchange and management of the CAD files transferred between these parties. The list of important attributes covered in the convention include author, project identification, type-of-work, view plane, zone, version and user defined attributes. The target users of the Standard are designers, draftspersons and CAD Managers.

5.5.2 Phase 2: Classification Standards

Phase 2 aims to define the standards for emerging IT tools such as the model based CAD software. Such standards will be defined in conjunction with an international effort known as the International Alliance for Interoperability, IAI (S). Phase 2 also aims to develop an electronic measurement standard. The objective is to develop a Singapore Standard (SS) Code of Practice (CP) for the computerized measurement of construction works and in so defining, facilitate the development of compliant software to automate upstream resources quantification.
activities to enable seamless downstream online procurement of construction products and materials (Building Construction Authority).

- Standard for Construction Cost Information - SS CP 80: 1999
- Standard for Construction Resources Classification
- IT Standards for Construction Electronic Measurement

**Standard for Construction Cost Information - SS CP 80: 1999**

In the construction industry, different types of cost information are exchanged between the various parties, which come from a myriad of professions. However, there is no standardized system of classifying and presenting such information. Hence, to ensure that cost information is classified and presented in a consistent and reliable manner that is understood across the industry, a Standard Classification System for the construction industry was developed. Main users of the system are property developers, quantity surveyors, mechanical and electrical (M&E) engineers and contractors.

The Standard for Construction Cost Information was published as SS CP 80: 1999 Code of Practice for Classification of Construction Cost Information in October 1999. The Code of Practice comprises two classification systems - one based on building elements and the other on trades/work sections.

**Standard for Construction Resources Classification**

There is a need to classify the construction resources procured during the construction phase of a construction project. It is an essential component for organizing resources databases and implementation of electronic procurement. The list of construction resources covered in the standard includes products & materials, plants & equipment, services and aids. The target users of the Standard are contractors, construction resources procurers and suppliers. The Standard is in the early stage of preparation.
5.6 IT Tools – Building Information Modeling

It is often said that a picture speaks a thousand words. However, in the world of building designs, managing thousands of different drawings can often be a call of confusion and sometimes utter chaos. Typically the various players in a building project – architects, structural engineers, builders, contractors – require different sets of drawings to do their respective parts of the work. In such an environment, the various players often struggle to link seemingly unrelated information together to make sense of the big picture. It gets worse when one party makes a change to a small part of one drawing. Time will be spent locating the related drawings, then changing them and then communicating the changes to the other project members.

There have to be a better way to create and manage these building designs. One way is to use an IT tool called the Building Information Modeling, which is found in several AutoDesk’s products, like the Architectural Desktop 2004, AutoDesk Revit and AutoDesk Buzzaw. In this information model, rather than creating multiple unrelated drawings, users create a single data set—the building model—from which all project documents are generated, i.e.: scheduling information, plans, elevations, sections and more. A single consistent building model means creating the data only once and reusing throughout the building life cycle. Changes in the design data can also be incorporated quickly and to pin-point accuracy. Everyone from the project team is working from the same database, so it enhances productivity and project workflow and communications.

Building Information solutions have three characteristics:

1. They create and operate on digital databases instead of managing a set of seemingly unrelated drawing.
2. They manage change throughout those databases so that a change to any part of the database is coordinated in all other parts.
3. They capture and preserve information for reuse by additional industry specific applications.
Using Digital Databases

Building information modeling turns conventional wisdom around by starting with the capturing and managing of information around the building, and then presents that information back as traditional illustrators or in another appropriate format. The building information is stored in database instead of in a format, like a drawing file or spreadsheet. When the different project members call out for the drawings and information they require individually, the software then pulls up the relevant information from the database and presents them in formats that are appropriate and customary for each group of users. Users can then work independently on the local data sets simultaneously.

Change Management

With such parametric software, change made anywhere is a change made everywhere. In non-parametric software, extending the will does not automatically adjust the roof, floor and other related components. With parametric software, any change to any component is automatically applied to all other parts. With this model, finding out the amount of materials needed for the various parts of the building is no longer guesswork, but an accurate and automatic calculation done by the system.

Information Re-use

When a company wants to build a replica of an existing design, it can come up with an accurate estimate of the setting-up costs very quickly. This is because the information about the individual components, like the furniture, was already created for earlier expansions and the “library” of various objects can be re-used. This information can then be captured and reported back in a scheduled for inventory calculations, which in turn can be linked to a procurement system. The use of building information modeling solutions will result in higher quality of work, greater speed and productivity, and lower costs for the built environment professionals in the design, procure, build and management of buildings.
5.7 Benefits of CORENET and ICT

Since the late 1960’s there has been recognition that investments in IT are difficult to evaluate (Mcrea, 1970). Evaluation, which was considered as difficult in the data processing era, has become even more problematic in the “information age” as IT systems have grown from those designed to perform specific tasks (e.g. processing payroll) to those which extend across business processes and organizations. Viewed another way, the development of IT usage has moved from a purpose of aiming to “automate” to “informate” to “transformate” (Remenyi et al., 1995). The difficulty in evaluation centers on the fact that both costs (particularly intangible costs) and benefits are difficult to quantify. However, for the purpose of this thesis, we have briefly outlined some potential benefits of e-submission and a summary of the typical process-based benefits that arise from ICT investments in the design, procure, build and maintain process. These benefits are shown in table 5.
<table>
<thead>
<tr>
<th>Built Environment Business Process</th>
<th>Efficiency Benefits</th>
<th>Effectiveness Benefits</th>
<th>Performance Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td>Reduce lead times for design. &lt;br&gt;Reduce rework. &lt;br&gt;Increased information exchange</td>
<td>Improved quality of output. &lt;br&gt;Reduced technology risks. &lt;br&gt;More responsive ability to arrange meetings. &lt;br&gt;Increased speed of new design development</td>
<td>Improved idea sharing among project team members. &lt;br&gt;Improved integration.</td>
</tr>
<tr>
<td><strong>Procure</strong></td>
<td>Reduced storage requirements. &lt;br&gt;Reduced transaction costs and time. &lt;br&gt;Improved delivery scheduling.</td>
<td>Maintaining competitive capacity. &lt;br&gt;Faster response to supplier quotations. &lt;br&gt;Ability to provide instant price quotations to clients.</td>
<td>Improving external access to inventory and price information. &lt;br&gt;More effective identification and assessment of new suppliers.</td>
</tr>
<tr>
<td><strong>Build</strong></td>
<td>Reduced build times. &lt;br&gt;Improved productivity. &lt;br&gt;Reduced waste.</td>
<td>Improved quality of output. &lt;br&gt;Reduced technology risk. &lt;br&gt;Ability to exchange data.</td>
<td>Improve idea sharing among project team members. &lt;br&gt;Improved integration. &lt;br&gt;Improved project relationships with strategic partners.</td>
</tr>
<tr>
<td><strong>Maintain</strong></td>
<td>Reduced operating costs. &lt;br&gt;Faster access to operation and maintenance data.</td>
<td>Improved quality of output. &lt;br&gt;Ability to refer and reference to accurate data.</td>
<td>Improved captured of design and build decisions. &lt;br&gt;Improved life cycle information management.</td>
</tr>
</tbody>
</table>
Benefits of e-submission

With e-submission, there will not be anymore bulky stacks of paper. Instead, a convenient electronic media can be used to capture the plans for submission to BCA.

Easy Storage and Retrieval

In its electronic form, building plans can be archived and retrieved easily and efficiently. This allows public queries at BCA to be swiftly addressed.

Greater Productivity for Architects

While CAD technology allows architects to design and produce building plans at greater speed compared to the manual drafting board, BP-Expert's automated self-checking mechanism gives the architect an uninterrupted design and verification process, effectively reducing the overheads incurred in waiting for intermediate responses from the BCD.

Fast, Thorough, Consistent and Accurate Checking

BP-Expert guarantees consistent application of building control regulations in the checking of plans. The automated checking process ensures that all plans are checked thoroughly and accurately, and at a mere fraction of the time that it would take to check manually.

Shorter Turnover Time

A shorter turnaround time for plans checking means that manpower at BCA can be channeled from mundane checking tasks to providing more complex value-added services to the public, e.g. evaluation of waiver applications.
5.8 Findings

The application of ICT in the built environment is evolving at different paces, whether in the construction management, engineering, quantity surveying or the architectural field. Architecture, being a design and construct field, display a rising interests and needs in a wider range of activities; from design submission for approvals to the production of construction drawings; from communications with clients and consultants to client’s presentations throughout the different phases of building delivery. Most of the local built environment practices have been in business for many years, and have made the some changes to accommodate the new economy. Currently, there are a substantial number of companies that utilize ICT in different capacities. The majority of those who are not using them are definitely considering their use for the future. This translates into the expected awareness of ICT and its advantages in the built environment.

In areas where ICT is used, the highest usage was directed towards the administrative tasks in which the technology offers outstanding efficiency and flexibility in word processing and in spreadsheets and databases. Equally in extensive use was the instant communication capability that technology offers. The power of reaching many destinations and people instantly and efficiently presents itself as a cost effective tool.

The set of benefits in Table 5 may have some similarities with those to be found in other industries. In itself, this checklist of typical benefits does not provide a methodology for ICT benefits evaluation and realization. Future research can take this starting point in developing an actionable benefits measurement and realizable methodology for the built environment businesses.

Measuring the benefits of IT innovation has always proved difficult. There are at least 30 different methods of evaluation, some based on traditional investment appraisal techniques (primarily financial ratios), and others adopt subjective approaches (Andersen, 1999). No one technique predominates within the construction industry. There is neither a consistent approach within individual
organizations nor a consistent approach across organizations. The benefits of ICT are only fully realized when systems and available technology are applied to specific and relevant tasks and aligned with the organization business strategy. ICT benefits should also be considered as a portfolio of benefits distributed across several organizations.

In order to establish the scope of this portfolio and the best way to realize the benefits, a list of requirements for all relevant stakeholders should be produced. The ultimate criterion for success is an overall improvement in the business position of the organization. Therefore, the alignment of the business and technology strategy is of paramount importance. The nature of ICT is such that the development of ICT infrastructure cannot be regarded as another capital investment but as an inseparable part of business processes and design.
6.0 SINGAPORE’S BUILT ENVIRONMENT – BUILDING PERFORMANCE

6.1 Building Performance thru Intelligent Buildings as Intelligent Nodes

Utilizing Technology is not just about using computers for word processing and spreadsheets anymore. It is about living and the way we are transforming as a society in the way we learn, the way we play, the way we design, build and manage our physical environment. In most organizations today, individuals responsible for the management of the building facilities recognize that there is a strong relationship between architecture, interior design, the function, and the operation of a building. Similarly, there is recognition that when the relationship is merged effectively, it can have a tremendous effect on the overall or total building and human performance. A very productive and cost effective environment is possible when the basic elements of a building are merged and optimized (Duffy 1990).

Today’s buildings must provide a healthy, safe, secure, and highly productive environment that can be operated at peak efficiency and minimal cost. This is because nobody can totally or accurately predict what kind of technology will be available in five to ten years from now. Buildings, just like cities, must be flexible enough to accommodate tomorrow’s systems, utilize it, and change according to the global community’s business needs.

Everyday, information technology demonstrates the power to fundamentally change how we as individuals and organizations can work together. The globalization of business continues to demand us to respond to rapid communication of management information and control. The productivity of an intelligent environment is a necessary requirement to compete in this new economy. While we will continue to see and comprehend the information displacing the physical, we will continue to have a need for a highly efficient and productive environment that can support our business objectives.
With this in mind, this chapter will discuss how the concept of an intelligent building, total building performance and the diagnostic tools can be used in measuring and assessing this performance to support the business objectives. It emphasized the need to fully address the fundamental building performance mandates of thermal comfort, acoustic comfort, air quality, lighting comfort, spatial comfort, and building integrity.

6.2 What is an Intelligent Building?
A modern building is a vital and dynamic asset for the organization which accretes or owns it. It has both symbolic and functional value. Various groups of people who are connected with a building tend to attach importance to quite different features and benefits of the building. Some different views of an intelligent building are likely to be:

- To the Public: An exciting and familiar icon representing the place.
- To the Employees: An inspiring, efficient, comfortable and secure workplace.
- To the Owners: A statement of the owners’ stature, and sound investment.
- To the Tenants: An attractive, prestigious, cost effective business location.
- To the Project Team: A building, which is energy-efficient and easily managed.

There is, even now, no generally accepted definition of an intelligent building. A public visitor who sees multimedia information displays provided for his or her information in the foyer of the building may experience a certain kind of intelligence. A customer whose access to the banking chamber and use of services is pleasant and efficient is experiencing intelligent building architecture. The tenant whose costs are reduced through comprehensive automated energy management and low building operation and maintenance costs is benefiting from intelligent building systems.
The Intelligent Building Institute has proposed that, "an intelligent building is one that provides a productive and cost-effective environment through optimization of its four basic elements - structure, systems, services and management - and the interrelationships between them."

The Evolving Concept of Building Intelligence
There are recognizable stages that can be identified in the continuing development of intelligent buildings since the 1980’s, when computers become universally available and began to be used in buildings for various purposes.

The First Generation – Early 1980’s
From the early 1980’s computers were utilized in building systems both in automating the control of various electrical and mechanical systems such as air conditioning and lift systems. Significant improvements were achieved in the efficiency of operation of various systems, and some control and supervision functions were successfully automated, releasing people for other activities. This could be called the “Technology-Centric approach to Intelligent Building”.

It achieved some of its benefits by using individual computers to provide system control functions and take the routine supervision of some low-level building management functions from human beings. However, it eventually became clear that these systems lacked flexibility which people and organizations required, and were generally unable to grow, change and reconfigure with the organizations they served, particularly the tenants. Therefore, despite their usefulness and regardless of the high level of investment involved, they tended to have a short economic life compared with the building structure.

The Second Generation – Early 1990’s
Further technological development led to the availability of PCs (personal computers) with a range of small software packages and better programming languages, and LANs (Local Area Networks) for flexible interconnection and communication. AT the same time, various groups of BMS (Building
Management Systems), which supervised and controlled the variety of electrical and mechanical building systems, were now able to be interconnected or integrated, including access control with intruder alarm systems, air-conditioning with power, and various mechanical systems. This made it possible to achieve limited reconfiguration and redeployment to adapt building space and services to the movement of people and functions which take place continuously in modern organizations. This could be called the “Organization-Centric approach to Intelligent Building”. The flexibility to adapt to the changing needs of organizations conferred on building management systems a longer economic life compared with the life of the building structure.

Even in this period, however, the usual approach to designing, selecting and installing communications and building management systems was to do it independently of, and usually after the building design process. It has been quite usual, especially with speculative developments, to let the purchaser or principal tenant to install cabling, computers and telecommunications systems after the building has been completed. This often leads to compromise, and make the integration extremely difficult to achieve.

The Third Generation – Late 1990’s and Beyond

The dominant trend in IT and Telecommunications in recent years has been the rapid growth of computer networking, both in local area networking of desktop PCs and mainframe computers, and wide area networking, involving interconnection over large distances. Improvements in systems interaction techniques associated with software development methods and standardization of interfaces had further facilitated the integration of Building Management System (BMS), which in turn provided an opportunity for the control of electrical, mechanical and hydraulic systems to be achieved in an integrated fashion. Improvements in cabling systems, particularly the advent of structured cabling systems using unshielded twisted-pair cable interchangeably for both voice and data communication greatly assisted the process of integration. As a result of these improvements, useful interaction between user systems and building
systems became possible. This now provides an opportunity for the first time for the building occupants to directly control some aspects of the office environment. This new trend could be deemed as the “People-Centric approach to Intelligent Building”.

It is now usual for the building management, computer and communications systems to be designed as part of the overall building design process. As a result, maximum integration, higher security and other associated benefits can be achieved. Through their centralized control, adaptability, and great functionality, building management and communications systems now play a fundamentally important role in providing a stimulating, efficient, responsive, comfortable and secure environment for building occupants. For both the building owners and tenants, this environment is one-business objectives and which motivated users can be at their most creative and successful in helping to fulfill the organizations corporate.

6.3 An Intelligent Building System

An Intelligent Building System (IBS) is a system of technical infrastructure, which provides the functions, facilities and services to co-ordinate and optimizes the management of the mechanical, electrical and hydraulic building services. The IBS works in harmony with the vital primary contribution to building intelligence made during the architectural design process, and also with information and telecommunications systems, which support internal and external communications, to create the special environment of the intelligent building.

Objectives of the Intelligent building System

A range of benefits can flow from the implementation of the IBS, reflecting the different priorities of the various stakeholders in building and intelligent building. These benefits can be clearly seen in the relationship to the four objectives of the IBS.
1. Building Management
2. Space Management
3. Business Management
4. User Management of the Environment

**Building Management**

Through the creation of an integrated means of management, the task of managing building systems is made easier and therefore more efficient, easing staffing requirements. An intelligent building system is capable of monitoring the periods of energy consumption as well as the location in the building of that use of energy. Practice has shown that where both types of information are available, alternative management strategies can be introduced and the effectiveness of the strategies can be objectively evaluated.

The stepwise refinement of energy management strategies has been proven to reduce energy consumption patterns of up to 40%. Case studies of existing intelligent building systems have shown that energy savings of 20% to 40% achievable over previous best practice methodologies (Hartkopf, et.al. 1986).

The intelligent building system is also able to record sufficient parameters to compute the efficiency of plant and to be bale to establish the trend of the performance over a period of time. Decreases in efficiency are detected earlier and remedial action can be implemented much earlier, and in many cases before serious breakdowns occur.

The benefits of planned maintenance and close monitoring of equipment have been proven in a number of studies in the mining and manufacturing industries. The recording of detailed energy consumption also facilitates the introduction of a wider range of tenant billing options, and also enables tenants to receive information to enable them to adopt more energy efficient practices.
Fig: 8 Building Management Benefits

Maintenance engineering practices have shown that if equipment is maintained regularly after specified operating cycles, the life and efficiency of the plant can be enhanced. The best-documented results of this approach are in the airline industry. The cost of recording and monitoring plan to obtain this information has been too high in the past and therefore only limited attempts at monitoring have been made.

An intelligent building system has the infrastructure to monitor wide range parameters and to more accurately record the amount of usage of any one item of the plant. In addition, the ability to trend the performance conditions enables new alarms conditions to be monitored, many of which give an earlier warning of problems. The earlier detection of problems means that overall efficiency of the plant is raised and costly unplanned breakdowns are reduced.

Space Management
IBS can provide a focus for co-ordinate faculty management. Through increased flexibility of building resources allocation, the tasks of re-assigning and optimizing floor spaces usage is made easier. The building services can then be specified to include a high degree of remote control. This will enable groups of lights to be re-arranged without any new wires having to be installed. Telephone and data lines will be bale to be re-allocated using programming techniques instead of re-wiring or replacing existing cables with higher capacity cables.
In the past, the high cost of changing workplace resources meant that sub-optimal conditions had to be endured, with a consequent loss of business efficiency. The benefits of structured cabling and high cost of re-allocating building resources through non-programmable techniques has been proven in many buildings.

The communication industry has proven the cost benefits of using common or structured cabling approach, even down to small companies of 30 people.

**Business Management**

Through the application and more effective management of advanced information and telecommunication systems, an organization’s business effectiveness can be enhanced.
**User Management of the Environment**

In an intelligent building, the tenants can have access to selected IBS control functions by the means of a PC and an application program. The range of control functions will depend on the specific characteristic of the mechanical, electrical and computer systems chosen for the building and the range of features that the building manager will allow a user to have the ability to control. The design of the corresponding IBS user interface software will be governed accordingly to the requirements of security, safety and prudence. It may, for example, allow the staff to adjust the air conditioning in their zones, control lighting, interact with automatic energy management functions, report faults or request changes to environmental parameters to meet health needs, book shred facilities such as meeting rooms, control incoming telephones, and make private International Direct Dial (IDD) calls using a smart card or direct charge to the payroll.
6.4 Total Building Performance

Although technology is a primary agent in the emergence of the intelligent building concept, intelligence in buildings cannot be solely achieved by the application of advanced building technologies. Ultimately, the level of building intelligence must be measured by how well a building is designed to meet the building user’s needs, rather than by the extent of the telecommunications and building automation technologies incorporated (Loftness et al. 1995).

Nevertheless both the “hardware” and the “software” are critical to ensure that the building can provide the maximum conducive and productive environment for the users (Mahdavi, et al. 1991). All members of the professional team have an important role to play in achieving this goal. How then can the professional proceed to achieve this goal?

6.4.1 The Project Brief

Every building project starts with a brief. This is a very important document as it sets the framework and performance benchmark for the entire process. The quality of the end result will be affected by the comprehensiveness and clarity of the brief. We are more likely to get what we want if we know what we want. Therefore it is worthwhile spending some time and resources in formulating this
upfront. Here cost is usually a major consideration in the project brief. The cost of a project may be roughly be categorized as follows: 1/3 for a 50-year-old building shell, 1/3 for the services items (which typically last 15 years), and 1/3 for the finishes and decorations, which usually changes very 5 years. Therefore, over the lifespan of the building, we will be spending 3 to 4 times of the original investment on service items and 10 times on decorations.

Given this perspective, isn’t it prudent to invest more on the initial design process and derive an integrated and responsive solution to the building shell and systems? If we factor in people cost over the occupancy period and the potential benefits to be gained, the numbers will even be more persuasive. There are numerous reports of success stories in the literature where owners have adopted such an attitude and approach to holistic design. But, unfortunately, these still represent “a drop in the ocean of ignorance and indifference” (Duffy, 1900).

As Singapore competes in the global arena for top talents to sustain its economic activities and growth, ensuring a certain quality of life is of paramount importance. This will include providing a conducive and healthy working environment that will support creative and productive work. The built environment has a direct role in this matter.

Current Approach – Prescriptive Based
So how is the cost factor measured in the project brief? The current approach in most countries tends to be very prescriptive and usually is in terms of static quantities. We usually measure from the ground up with specifications for the following: gross floor areas, accommodation types and schedule and regulatory and statutory requirements. Examples of these regulatory and statutory requirements would include: plot ratio, height control, overall thermal transmittance value (OTTV) and, most recently in Singapore, the buildability score. (a recent score established by the Building Construction Authority in Singapore) In the environmental design domain, we take numbers for granted and hardly stop to question their continued relevance in the present day context.
Future Approach – Performance Based

In the past, we accept static singular indices that purportedly represent the common average conditions because it was not possible to perform in-depth dynamic design analysis, due either to the lack of local data and knowledge, technically prohibitive and costly in time. With rapid advances in computer technology and reduction in cost, coupled with ongoing data acquisition on local climatic and environmental conditions, we are in a better position to embark on relatively more detailed and accurate design analyses based on a performance approach. This will help in defining our design decision to create an environmentally responsive building.

The performance-based approach to design is gaining some recognition in the building industry. We can find many different models in the literature but they share certain common aspirations. For example, questions are raised on the traditional theories concerning the relationship between building design and productivity of occupants. As a result, many long accepted standards pertaining to interior environmental (e.g. lighting, acoustics, thermal etc…) are no longer of sufficient quality for occupants. The aspired design objectives should be to seek solutions, which give high priority to human needs (in terms of an appropriate and stimulating environment) and job performance while obtaining minimal overall costs with the greatest possible energy savings (Ruck, 1989).

Undoubtedly, any specification of optimal conditions for human health, comfort and productivity will remain somewhat controversial, but we should nonetheless proceed to grapple with the issues and let rigorous and persistent yield its insight to educate all of us.
6.4.2 Mandates and Limits

In order to address these issues, we will need to have a set of mandates and limits of accountability. In this case, the Total Building Performance model (Hartkopf, et.al.1986) established by the team at Carnegie Mellon University will be discussed. In their model there are 2 major aspects to the concept.

1. Design Performance Mandates
2. Limits of Acceptability

*Design Performance Mandates*

The way they assess the performance of the proposed building is by looking at the design performance mandates. An example of the building performance mandates is shown in table 6.

<table>
<thead>
<tr>
<th>Mandates</th>
<th>Environment Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>Air temp, humidity, air velocity, radiant temp</td>
</tr>
<tr>
<td>Visual</td>
<td>Lighting levels, contrast, color rendition, glare index, comfort</td>
</tr>
<tr>
<td>Acoustical</td>
<td>Reverberation time, sound pressure level, audibility</td>
</tr>
<tr>
<td>Air Quality</td>
<td>Ventilation rate, pollutant types and levels</td>
</tr>
<tr>
<td>Spatial</td>
<td>Adjacencies, accessibility, way-finding, efficiency, ergonomics</td>
</tr>
<tr>
<td>Bldg. Integrity</td>
<td>Degradation, movement, chemical &amp; biological attack, fire safety</td>
</tr>
</tbody>
</table>

(source: Hartkopf, et.al.1986)

These mandates encapsulate the comprehensive range of environmental factors, which we should consider and assess in the design process. And you would have noticed, the table laid out a broad spectrum of factors that goes beyond just materials and form. It includes very important factors, that advancement in building technologies can be used to help the team to design buildings that can achieve these mandates.
Limits of Acceptability

Here the limits of acceptability were established depending on type of occupancy and the requirements for four major human and society conditions. These society conditions include: physiological, psychological, sociological and economical. There are close inter-relationships between the design mandates and the limits of acceptability. The performance indices in this regard that are assessed can be both quantitative and qualitative. Table 7 shows the inter-relationships between the design mandates and limits of acceptability.

Table 7: Inter-relationship of Design Mandates and Limits of Acceptability

<table>
<thead>
<tr>
<th>Physiological</th>
<th>Psychological</th>
<th>Sociological</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial</td>
<td>Ergonomic, Access</td>
<td>Habitability, Beauty</td>
<td>Way finding, Adjacency</td>
</tr>
<tr>
<td>Thermal</td>
<td>Cool, Refreshing</td>
<td>Adaptable, Control</td>
<td>Flexible dress code</td>
</tr>
<tr>
<td>AirQuality</td>
<td>No health, Hazard</td>
<td>Openness, Not stuffy</td>
<td>No irritant from neighbors</td>
</tr>
<tr>
<td>Acoustical</td>
<td>Speech clarity</td>
<td>Quiet, Soothing</td>
<td>Privacy, Communication</td>
</tr>
<tr>
<td>Visual</td>
<td>Gd.illumination, No glare</td>
<td>Orientation, Spacious</td>
<td>Occupant status, Territoriality</td>
</tr>
<tr>
<td>Building Integrity</td>
<td>Fire safety, Weather-tightness</td>
<td>Durability, Image</td>
<td>Status, Aesthetics</td>
</tr>
</tbody>
</table>

As seen from the above table, the inter-relationship between the designs mandates and the human & social conditions are very important and all these factors need to be assessed in totality. We can clearly see from this table that most of the factors would include, not only design considerations, but also a combination of building technology expertise, in order to address these relationships.

6.5 Findings

This chapter introduces the concept of an intelligent building, the total building performance and the building diagnostic tools for measuring and assessing this performance. Integrated with the present building delivery process, these tools
offer new quality assurance procedures for providing suitable, reliable, and sustainable conditions for occupancy comfort.

The term “intelligent Building” is a misnomer. A building is not intelligent but the people who design and build it are. Similarly, a building does not consume energy but the people who occupy it do. One definitive characteristic of human intelligence is the inherent drive to sustain and enhance the quality of life in all respects. That is why we innovate and produce all kinds of paraphernalia to imbue our lifestyles. If we begin to indulge in the means and regard them as the end, then we defeat the very purpose of our action in the first place.

I submit that the lack of acceptance and pervasive implementation if the intelligent building concept is to a large extent due to the imbalance focus on the “end-product” rather than the larger environmental context in which such products exist and operate. The IT industry thrives on that and we are all caught up with every new release – a faster CPU, a bigger and better storage device, the newest software version, etc… We are willing to pay for them, regardless of whether we really understand or need all those enhanced functionalities. But in the building environment industry, when it comes to investing in providing a responsive environment and infrastructure to accommodate and support all these end products, owners are often wary and hesitant as it is perceived to be costly and when push comes to shove, these features get omitted from the specifications.

As Singapore competes in the global arena for top talents to sustain its economic activities and growth, ensuring a certain quality of life is of paramount importance. This will include providing a conducive and healthy working environment that will support creative and productive work. The built environment industry has a direct role to play in this matter. In this new economy, cost will have to be secondary and knowledge based design needs to be primary.

A knowledge-based approach to design must first establish a clear set of performance criteria to be achieved. Specification of the building elements and
systems are only the means to mediate between the external “uncontrollable” environment and the internal “controllable” environment to achieve the desired conditions and functionality in an intelligent building. Proposed design solutions should be evaluated using the most appropriate techniques or tools that will take into account the specific macro and microclimate and environment conditions on site. This will at least help to surface any potential problem before it becomes a costly remedial exercise after the building is constructed.

In order for Singapore to move from a third world built environment practice to a first world built environment practice, the built environment industry needs to recognize the need for a paradigm shift in the image, processes and purposes of the industry. Knowledge and integrated teamwork are clearly essential ingredients within the strategic framework for success in developing future intelligent buildings.
7.0 CASE EXAMPLES OF OTHER CITIES UTILISING TECHNOLOGY

The Intelligent Community Forum has defined five critical success factors of the Intelligent Community, whatever its size or location. They are:

- Broadband Infrastructure;
- Knowledge Workers;
- Risk Capital;
- Digital Democracy;
- Marketing Prowess.

_Broadband Infrastructure._

The term "broadband" identifies communications circuits, which offer greater capacity than the conventional "narrowband" telephone circuit. As the Internet becomes the common platform for the internal and external operations of companies and institutions – which are themselves increasingly communications-dependent and data-dependent – broadband is fast becoming a determiner of competitiveness. Like seaports and airports before them, broadband infrastructure will be one of the key enablers of economy growth. An Intelligent Community is not content to leave its broadband destiny in the hands of the market.

Intelligent Communities:

- Express a clear vision of their broadband future
- Craft public policies that encourage the development of broadband services
- Promote equitable access to them by organizations and individuals at all rungs of the economic ladder

_Knowledge Workforce._

Intelligent Communities exhibit the determination and demonstrated ability to develop a workforce qualified to perform knowledge work. This is not simply a matter of
possessing universities able to crank out post-grads with science and engineering degrees. Effective development of knowledge workers extends from the factory floor to the research lab, and from the loading dock to the call center or Web design studio. The creation of knowledge workers is one of the primary means by which Intelligent Communities ensure that the majority of citizens benefit from the Digital Age economy.

**Risk Capital.**
To be competitive, a community must provide the resources needed to start and grow new businesses. Principal among those resources is capital. Intelligent Communities recognize this fact and make every effort to attract and promote the growth of venture, strategic and public-market capital.

**Digital Democracy.**
Success in the Digital Age demands a social and political culture that welcomes change. The challenge facing communities is to convert change-resistant cultures into ones that welcome innovation, without losing the values and sense of identity that make them communities in the first place. Intelligent Communities confront this challenge by creating a compelling vision of the benefits that innovation can bring, managing the negative consequences of change for segments of their population, and striving to bring the benefits of innovation to citizens who might otherwise be left behind.

**Marketing Prowess.**
Globalization of markets, capital flows and business operations puts a premium on the ability of communities to market their "intelligence." Intelligent Communities market themselves effectively, based on a knowledge of the competitive offerings of other cities and regions, clear understanding of what leading-edge businesses require, and a determination to deliver it.

### 7.1 Calgary Technologies, Calgary, Alberta, Canada

Calgary Technologies, Inc is in the business of economic development, focused exclusively the Advanced Technology sector of the City of Calgary, Alberta, Canada. Calgary Technologies provides technology incubation and
commercialization, business network and cluster development services, external
attraction and promotion services, advocacy and government relations services,
and manages Calgary's Connect Calgary program. Calgary is a diverse, multi-
cultural city of over 900,000 people that is one of fastest growing cities in
Canada. Canada's second-largest municipality, Calgary boasts a workforce with
the highest education level in Canada, and the nation’s highest per-capita
concentration of engineers and scientists. In 2000, Calgary received one of twelve
grants from Industry Canada to support development of its Connect Calgary
program, a Digital Divide initiative that focuses on improving delivery of
community services to individuals at risk using the Internet. Calgary was named
the 2002 Intelligent Community of the Year by the Intelligent Community Forum.

7.2 City of LaGrange, Georgia, USA
A rural city of 26,000 people 60 miles southwest of Atlanta, LaGrange has
pioneered in developing public-private ventures for broadband based economic
development. Set in the rural Georgia countryside, LaGrange is an enterprise-
based community that levies no local taxes but instead earns revenue from
services including utilities and telecommunications. Through partnerships with
companies including ITC Holding and Charter Communications, the city has
funded and constructed a total of four broadband networks, serving businesses,
institutions and residents within and beyond the city limits. Using this
infrastructure, the city introduced in 2000 a free high-speed Internet access
service for all residents, with free installation and training, delivered via a World
gate set-top system and the cable TV network. In the same year, LaGrange was
named the Intelligent Community of the Year by the Intelligent Community Forum.

7.3 City of Osaka, Japan
In 1999, Osaka City was listed as 3rd in FORTUNE magazine’s ranking of best
cities for business in Asia and in January 2000 was ranked 1st in the "e-Cities
listing". In order to develop Osaka as a vigorous and attractive international
information city for the 21st Century, high level, ultramodern municipal functions
will be integrated in advance in the wide coastal area of the South and North ports. It will lead the development of not only the Bay Area but also the Kansai-Osaka Region. When the new downtown is completed, it will have a daytime population of 200,000 people. Osaka is also home to Osaka Media Port (OMP), a public-private organization that operates a broadband network serving the Kansai region and satellite facilities. OMP was founded as part of a larger Model Cities development called Osaka Technoport.

7.4 City of Sunderland, United Kingdom

In 1991, this depressed former shipbuilding and mining center in the north of England launched a multi-pronged initiative to create a knowledge-based economy. Based on a comprehensive Telematics Strategy, the initiative included a new office park called Doxford International, training programs, network development and infrastructure projects funded by the European Commission. By 2000, Doxford had created over 8,500 jobs and had expanded to over 37,000 square meters (407,000 square feet) of commercial space. More importantly, an original focus on call centers had expanded to include the Internet industry. Among Doxford tenants was DomainNames.com, an authorized registrar of Internet addresses, which selected Sunderland primarily for the connectivity it could provide; and Leighton, an Internet company which started with 13 people and, within a year, had expanded to 180 and moved into a new 28,000 square-foot facility. Though Sunderland – with an aging population and facing the ever-present lure of London only 3 hours away by train – has seen its population slowly decrease with time, the city has successfully built a diversified economy, with communications-dependent businesses matched by Nissan’s European automotive assembly plant and other more traditional industries.

7.5 City of Vaughan, Ontario, Canada

Vaughan, "The City Above Toronto," is situated on the northern boundary of Canada's largest city (Toronto population of 2.4 million, 1998 est) and is at the geographical hub of the Greater Toronto Area (population of over 4.8 million, 1998 est). Two-thirds of the Canadian market (20 million people) and half of the
U.S. market (135 million people) are within one day's drive of Vaughan. Vaughan has a resident labor force of more than 90,000 and is home to some 7,000 companies. These businesses also can draw from the Greater Toronto Area labor market of more than 2.5 million. More than half of Vaughan's residents have some post-secondary education, with 18.7 percent holding a university degree compared to a national average of 10 percent. Vaughan's telecommunications network is composed of state-of-the-art fiber optics and 100 percent digital switching. In addition, the City is pursuing the implementation of a Smart Community Network (SCN) that will link education, health, business and government agencies into a powerful network.

7.6 Dubai Internet City, United Arab Emirates

Dubai Internet City (DIC) provides a Knowledge Economy Ecosystem that is designed to support the business development of Information and Communications Technology (ICT) companies. It is the Middle East's biggest IT infrastructure, built inside a free trade zone, and has the largest commercial Internet Protocol Telephony system in the world. In line with Dubai's liberal economic policies and regulations, DIC offers foreign companies 100% tax-free ownership, 100% repatriation of capital and profits, no currency restrictions, easy registration and licensing, stringent cyber regulations and protection of intellectual property. Within a short span of time, a dynamic international community of ICT companies has established itself in Dubai Internet City, including Microsoft, Oracle, HP, IBM, Compaq, Dell, Siemens, Canon, Logica, Sony Ericsson and Cisco, to name just a few. These companies represent a formidable community of over 5,500 knowledge workers. DIC provides a scalable state-of-the-art technology platform which allows companies looking to provide cost effective business process outsourcing (BPO) services such as call center operations.

7.7 Florida High Tech Corridor Council

Florida High Tech Corridor Council was created in 1996 and is co-chaired by University of Central Florida President John Hitt and University of South Florida
President Judy Genshaft. The Council is comprised of the two universities and twenty high tech companies that work in partnership with 11 local community colleges and a dozen economic development organizations to achieve the mission to attract, retain and grow high tech industry to Florida's High Tech Corridor. The Corridor includes the 21 counties that make up the service areas of the University of Central Florida and the University of South Florida. Current studies have revealed thousands of high tech companies reside along the Corridor. The six sectors targeted by the Council include: Aviation & Aerospace, Information Technology, Medical Technologies, Microelectronics, Modeling, Simulation and Training, and Optics & Photonics. The Council has sponsored a variety of projects geared at accomplishing its mission. These projects focus on three distinct strategies: 1) Provide matching funds for university and business research & development projects 2) Encourage the development of workforce development initiatives 3) Conduct collaborative marketing projects with the local business, educational and economic development organizations that raise awareness of the region.

7.8 Greater Toronto Marketing Alliance, Toronto, Ontario, Canada

The Greater Toronto Area (GTA) comprises 29 regions and municipalities covering slightly more than 7,000 square kilometers (2,700 square miles). The Greater Toronto Marketing Alliance (GTMA) is the key point for contact to exploring business opportunities in this vibrant region. With the resources of its public and private sector partners, the GTMA provides essential business information and site selection services to help businesses invest in the GTA. North America’s fifth largest and second fastest growing urban area, the GTA is the leading Canadian city for corporate headquarters, with nearly 430 of them in 1998. Home to 15% of all Canada’s businesses, the GTA also hosts offices of many of the largest foreign companies, including General Motors, IBM, Ford, Imperial Oil and Mitsui. The GTA ranks as one of the top Information Technology & Telecommunications (IT&T) clusters in North America, with more than 3,100 IT&T companies responsible for about Can$38 billion in revenues and Can$10 billion in exports annually. The GTA is also one of the top five R&D
centers in North America, with projects involving more than 15,000 employees, constituting an estimated 25% of all R&D in the North American IT&T industry. In addition to telecommunications, major GTA clusters include business services, biotechnology and medical equipment, and new media.

7.9 Seoul Metropolitan Government, Seoul, South Korea
With a population of over 10 million, Seoul has become world’s leader in broadband deployment, with a penetration rate of 60% of Internet users by year-end 2001, according to Frost & Sullivan. More important than basic penetration has been the rapid growth of a "broadband lifestyle," which finds citizens of Seoul spending an average of 13 hours per week on the Internet. An investment of US $400 million by the national government led to a further $3.5 billion investment by the private sector. The city has a 2.5 Gigabit backbone network as a foundation for service delivery and has made major e-government investments in what it calls the OPEN system. OPEN represents a unique effort to improve the transparency of government and drastically curb the potential for corruption in the delivery of services. All routine applications for regulatory approval, from business registration to construction permits, are processed in a paperless, online environment.

7.10 Taipei City Government, Taipei, Taiwan, R.O.C.
In order to realize the vision of building Taipei into a CyberCity, Taipei City Government created the CyberCity Plan. The outcome of these initiatives is increased access to Internet for citizens, enabling on-line public transactions, enhancing the effectiveness of small to medium-sized enterprises and to ensure that Taipei is a highly efficient, digitized metropolitan area. Over almost four years, the achievement of the CyberCity vision has progressed satisfactorily and has essentially achieved important milestone goals. Embracing the technological requirements of recently developed, innovative, broadband, wireless and mobile devices, Taipei City Government is formulating the next steps of the Cyber City four-year plan (2003-2006). Future e-policy is based upon these six initiatives: 1) Developing wireless and optical fiber internetworking infrastructure 2) Promoting
a “virtual city hall” 3) Eliminating the digital divide 4) Promoting digitized learning 5) enhancing the “citizen’s life” website 6) Enabling information exchange between cities.

7.11 Teleport Brussels, Belgium
Teleport Brussels is playing a substantial role in the economic development of the Brussels Region. Brussels is the administrative, commercial, and financial heart of Belgium, as well as home to the European Commission. Its population of slightly less than one million makes up 10% of Belgium’s population but 17% of its workforce. The leading industries are the financial and service industries, which provide 2/3 of all employment, plus food processing and the manufacture of machinery, electrical products, chemicals, and textiles. Teleport Brussels works in collaboration with its members: the Brussels Regional Development Agency, Technopol Brussels, the universities and the business world. Its mission is to promote access to advanced telematics applications for SME’s, to train multilingual call center operators, and to act as a brainstorming group and study platform on telematics applications and telecommunication infrastructures.

7.12 Findings
The Intelligent Community views communications bandwidth as the new essential utility, as vital to economic growth and public welfare as clean water and dependable electricity. Intelligent Communities work to position their citizens, businesses and public sector to prosper in the Digital Age. Rather than trying to prop up dying industries, they eagerly embrace the growth industries of tomorrow. They work to create the advanced ICT infrastructures needed to gain a competitive edge in attracting and growing the leading-edge industries that create jobs in the economy of the 21st Century. They train their citizens to take advantage of those jobs and work to deliver government services in electronic form more cost-effectively and efficiently than ever before.

Given Singapore’s small domestic market, an inward looking strategy focusing on building a robust domestic ICT ecosystem for organic growth will not allow
Singapore to sustain its economic competitiveness. If the built environment stays out of the global market, it not only loses additional business but risks being marginalized due to the limited growth potential. Global companies are already collaborating with the best-in-class companies in their segments all over the world. For example, a built environment MNC may utilize ICT to coordinate the prelim designs of a project with their designers in Japan, design and develop the mechanical and electrical systems in India, outsource production of building components in China and develop software applications for the project in US. Singapore built environment companies must target the world as their market. They must be globally competitive contributor in areas that are becoming or will become important in the future.

One area that Singapore should consider is to capitalize Singapore’s position as thought leader in being among the first in the world to deploy and use ICT pervasively. There is currently a concern that Singapore is gradually losing its ICT leadership in Asia. Asian countries like Japan are known for its consumer devices and innovations in mobile technologies and applications, while Korea is starting to creates waves as a major broadband player. As other cities like Dubai, Florida, Taipei, Brussels and many other cities ramp up their efforts to aggressively develop their ICT sectors, Singapore needs to regain its competitive advantage by differentiating itself and branding itself as a thought leader in ICT.

One way that Singapore can maintain this global leadership position is by exhibiting thought leadership in specific areas such as standards development. In the area of developing standards, Singapore could be a host to cities and organization for standards and trade to encourage standards development to happen in Singapore, and to drive the development of such standards in Asia. Singapore could provide a repository of information on standardization to Asian countries and facilitate cooperation and the development of international standards within Asia. Singapore could drive the adoption of these standards in regional forums such as APEC and ASEAN and thru the many FTAs that Singapore have signed.
In addition, Singapore could also establish leading edge certification programmes for ICT manpower and skills development for the overseas built environment industry. This is critical for establishing Singapore as a leading ICT Hub with world-class manpower who is competent in emerging technology areas.
8.0 CONCLUSION

To compete successfully in the new global economy, providing a world-class ICT centric built environment, intelligent buildings, and high performance space, to accommodate and support the various economic activities is no longer an option. In the face of rapid changes and advances in technologies, sustainability is a key issue to contend with. The ICT centric built environment and intelligent buildings must be adaptable to changing requirements and consideration of life cycle cost competitiveness will become more important than mere concerns of first cost.

Due to the influence of many factors, especially external ones, the domestic built environment market in Singapore will be in for another lean year. Local firms will have to upgrade their competence in utilizing ICT tools and be more cost vigilant to stay competitive. Firms that have gained expertise and experience in various projects, utilizing ICT tools, over the years should be bold to venture overseas to seize the business opportunities out there and work with industry partners to look beyond the domestic market. The Singapore government has built up a strong technology infrastructure and backbone. The built environment industry players should utilize these resources to succeed in the external market and to move from a third world built environment towards first world built environment practices.

In order for Singapore to progress towards a globally competitive knowledge economy, every sector must play its part. The built environment industry is no exception. It cannot be left behind as the rest of the economy moves ahead. One way, which can help transform Singapore into a "World Class Builder in the Knowledge Age", is through a total systems approach in upgrading all aspects of the industry. Two macro recommendations, which can address these issues across the built environment value chain, have been identified as key recommendations in chapter 4. These recommendations include, ways to enhance the professionalism of the industry, and ways to Adopt an Integrated Approach to Construction. This total systems approach in re-inventing Singapore’s construction industry will align it with the rest of the economy in
Singapore’s transition to the knowledge-based economy, achieve the vision of being a World Class Builder in the Knowledge Age and sustain our competitiveness for the next decade and beyond.

The CORENET process epitomizes the collaborative ICT effort needed to transform the built environment industry. Many government agencies, industry players and members of the public were deeply involved in the formulation of the comprehensive blueprint. The various committees and working groups have more than 100 members from the entire spectrum of the built environment value chain. They include developers, architects, engineers, consultants, academics, contractors, regulatory bodies and consumers. CORENET is an industry effort and represents the collective views and interests of all players.

The performance strategies outlined are not just for the industry to look at what it is doing and to do it better. We need to look at a totally new approach to the built environment. What is proposed by the CORENET initiatives and the building performance mandates is a radical change from the current way we design, procure, build and manage projects. To achieve productivity breakthroughs and quantum leaps in the performance and image of the industry, we need to re-invent the built environment industry and to work with the industry to realize this new vision of a world-class built environment capable of meeting the needs of a knowledge-driven built environment.

Built environments are living entities. They embody cultural, historical, economic, political and social progress. As civilizations evolved over the centuries from an agrarian society to an industrial society and to the present knowledge-driven society, the roles of the built environment have similarly changed with the times. In today’s information age, electronic transactions and interactions are made in real-time in cyberspace, thus transcending the physical boundaries and limits of the built environment. Governments, which recognize this development will need to utilize ICT technologies to expand their outreach, connect with people and tap into the global market for new opportunities.

A built environment in the new millennium must have the hardware and technological infrastructure to support an information economy. Also important is the software (the IT
solutions) and the human-ware (the ideas and knowledge of people). A built environment that is able to process information efficiently will be able to generate new knowledge effectively.
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