BUILT BY SINGAPORE: FROM SLUMS TO A SUSTAINABLE BUILT ENVIRONMENT

From a rural town of overcrowded squatters to a modern cosmopolitan city with world-class urban infrastructure, Singapore has undergone tremendous transformation over the past five decades. The early years of our nation-building were largely focused on tackling the urgent housing shortage under the constraints of insufficient resources. In the late 1970s to early 1980s, as Singapore entered an era of intensive building activities of increased scale and complexity, the priority started to shift towards mechanisation and labour saving. Subsequently, as the city-state further prospered, greater emphasis was placed on ensuring the sustainability and inclusiveness of our built environment. This study reviews this development journey of Singapore's construction sector, charts the evolution of priorities along the way, and provides an analysis of how the built environment has played a crucial part in the making of a modern city-state with rapidly changing needs and challenges.

"Drawing upon past research and new interviews with our urban pioneers, Built by Singapore: From Slums to A Sustainable Built Environment *systematically documents the evolution of Singapore's built environment sector, and highlights some of the key lessons learnt along the way. For those of you who are tasked with developing solutions to tackle emerging challenges in this field, I hope that this publication will also serve as a useful and comprehensive body of knowledge."*

Quek See Tiat, Chairman, Building and Construction Authority

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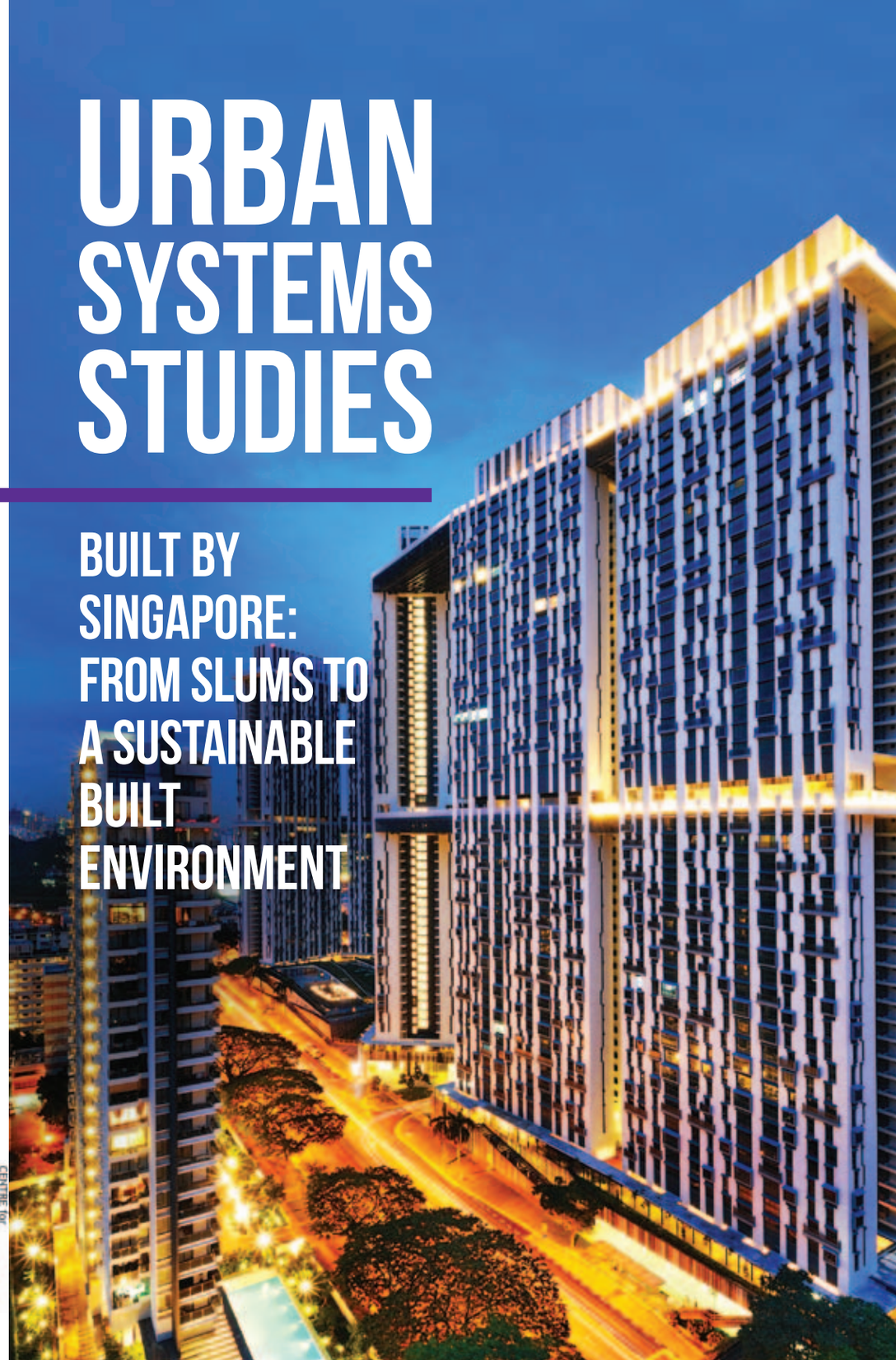

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URBAN SYSTEMS STUDIES

BUILT BY SINGAPORE: FROM SLUMS TO A SUSTAINABLE BUILT ENVIRONMENT

CENTRE for LiveableCities SINGAPORE

First Edition, Singapore, 2015

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Set up in 2008 by the Ministry of National Development and the Ministry of the Environment and Water Resources, the Centre for Liveable Cities (CLC) has as its mission "to distil, create and share knowledge on liveable and sustainable cities". CLC's work spans three main areas – Research, Capability Development and Knowledge Platforms. Through these activities, CLC hopes to provide urban leaders and practitioners with the knowledge and support needed to make our cities better. www.clc.gov.sg

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FOREWORD

Singapore has undergone tremendous transformation over the past five decades, from a largely rural town with squatter colonies to a cosmopolitan city today. The 50 years of post-independence nation-building that we celebrate today is a testament to the dedication and perseverance of our forefathers, who were committed to developing a resilient and forward-looking nation that Singaporeans can be proud of.

Creating a city that Singaporeans can call home is no mean feat. Post-independence, there was an urgent need to provide the basic necessities – homes for the people, and subsequently, infrastructure, schools and amenities – to support a fast-growing population. This had to be done quickly, without compromising safety and quality.

As a small, land-scarce nation with no natural resources, we needed to ensure that there was sufficient supply of materials to meet our construction needs. Over the years, alternative materials had to be explored to reduce our dependency on imported natural materials. For instance, the Building and Construction Authority (BCA) has been encouraging the use of recycled concrete aggregates as a form of sustainable construction so that our buildings can be constructed more responsibly.

To further cultivate this green building mindset, BCA introduced the Green Mark scheme 10 years ago, focusing on energy efficiency and the environmental impact of buildings, to encourage building owners to look at buildings from a whole life-cycle approach. To date, Singapore has made much progress in its green building journey, and is a more than a quarter of the way towards the national target of ‘greening’ 80% of all our buildings by 2030. To realise that target, we will need to continue focusing on ‘greening’ the large stock of existing buildings. Another integral initiative for a more sustainable living environment in Singapore is greater engagement with building occupants as they contribute up to 50% of a building’s total energy consumption.

As Singaporeans have become more affluent over the years, our built environment has also evolved to take more of the needs of different groups of people into consideration. Through promoting the concept of universal design, our pioneer generation, children, families and other

groups with special needs stand to benefit from better accessibility and connectivity between buildings and key infrastructure. Developers and government agencies, therefore, will have to consciously balance such needs in their plans and designs.

Today, despite having one of the most densely-built urban environments, Singaporeans live and work in modern buildings that have quality design and high safety standards. Such a world-class built environment did not happen by chance – it is the result of the collective efforts of our developers, architects, builders, engineers and property owners. However, to continue staying ahead of the game, there is still much to be done.

First, concerted engagement of all stakeholders will continue to be the key to ensuring that the formulation of plans for the way forward gives due consideration to the needs and concerns of the different groups. Second, it is vital that we attract new blood into the built environment industry to ensure future growth. By continuing to invest in local capability, and to rethink and revitalise the industry, we hope more young engineers will look forward to building a career in this sector. Last but not least, there is a critical need to re-examine and improve the way we build so that processes become more efficient and less labour-intensive. Measures such as enhancing the quality of the construction workforce, encouraging adoption of labour-saving technology, and supporting capability building and manpower development amongst local builders will all contribute towards building up the long-term sustainability and resilience of the built environment sector.

Drawing upon past research and new interviews with our urban pioneers, *Built by Singapore: From Slums to A Sustainable Built Environment* systematically documents the evolution of Singapore's built environment sector, and highlights some of the key lessons learnt along the way. For those of you who are tasked with developing solutions to tackle emerging challenges in this field, I hope that this publication will also serve as a useful and comprehensive body of knowledge.

Quek See Tiat
Chairman
Building and Construction Authority

PREFACE

The Centre for Liveable Cities' (CLC) research in urban systems tries to unpack the systematic components that make up the city of Singapore, capturing knowledge not only within each of these systems, but also the threads that link these systems and how they make sense as a whole. The studies are scoped to venture deep into the key domain areas the CLC has identified under the CLC Liveability Framework, attempting to answer two key questions: how Singapore has transformed itself to a highly liveable city within the last four to five decades, and how Singapore can build on our urban development experience to create knowledge and urban solutions for current and future challenges relevant to Singapore and other cities through applied research. *Built by Singapore: From Slums to a Sustainable Built Environment* is the latest publication from the Urban System Studies (USS) series.

The research process involves close and rigorous engagement of the CLC with our stakeholder agencies, and oral history interviews with Singapore's urban pioneers and leaders to gain insights into development processes and distil tacit knowledge that have been gleaned from planning and implementation, as well as governance of Singapore. As a body of knowledge, the Urban Systems Studies, which cover aspects such as water, transport, housing, industrial infrastructure and sustainable environment, reveal not only the visible outcomes of Singapore's development, but the complex support structures of our urban achievements.

CLC would like to thank the Building and Construction Authority, the Housing and Development Board and all those who have contributed their knowledge, expertise and time to make this publication possible. I wish you an enjoyable read.

Khoo Teng Chye
Executive Director
Centre for Liveable Cities

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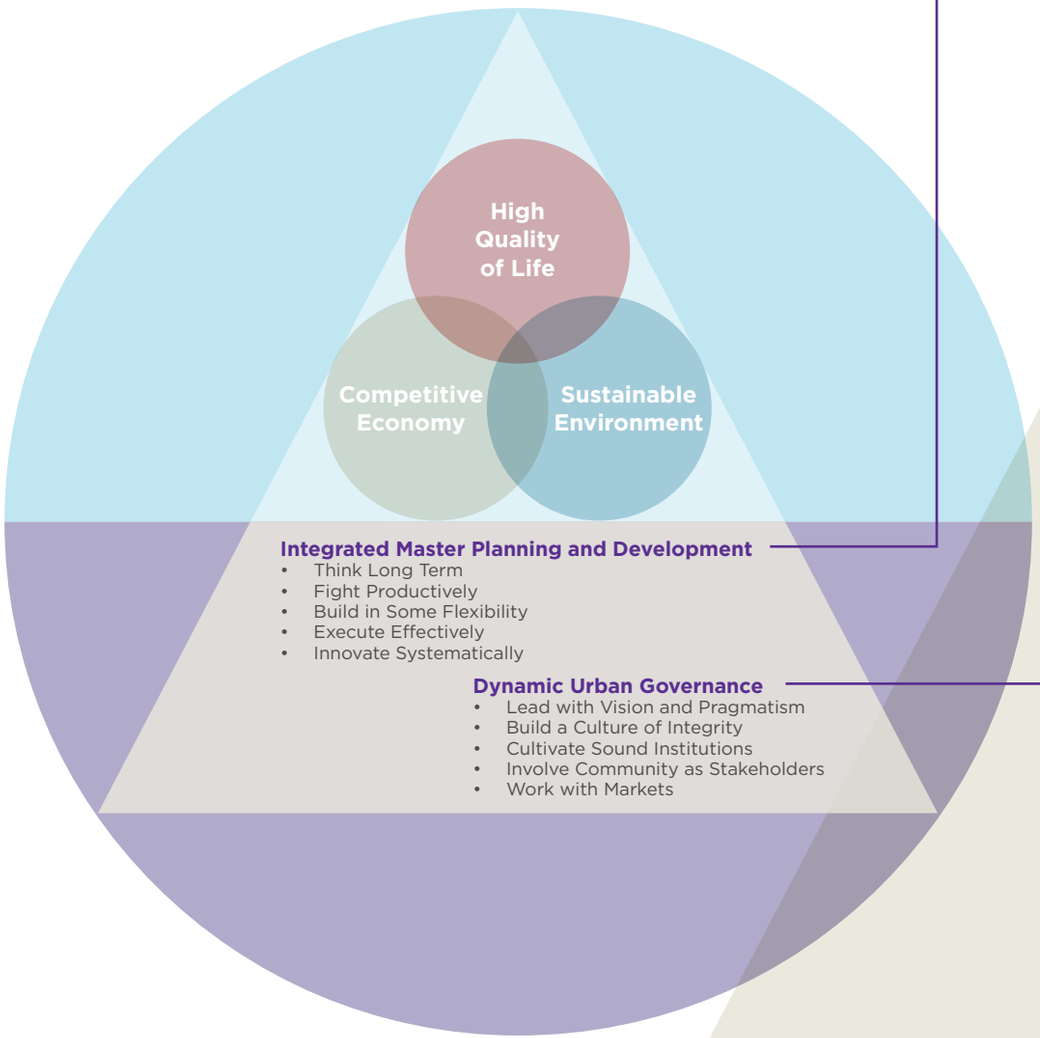
Michelle Kung, the researcher, would like to thank the following people who provided advice and encouragement throughout (in alphabetical order): Grace Cheok-Chan (BCA), Goh Thiam Lai (BCA), Jason Lau (CPG), Lee Siew Eang (NUS), George Ofori (NUS), Seah Muah Lock (BCA) and Tan Boon Kee (BCA).

THE CLC LIVEABILITY FRAMEWORK

The CLC Framework is derived from Singapore's urban development experience and is a useful guide for developing sustainable and liveable cities.

The general principles under **Integrated Master Planning and Development** and **Dynamic Urban Governance** are reflected in the themes found in *Built by Singapore: From Slums to a Sustainable Built*, detailed on the opposite page:



Integrated Master Planning and Development

Think Long Term

In anticipation of the growing demands for public housing and the need to mitigate supply disruptions and price fluctuations, the Housing and Development Board (HDB) began to look into stockpiling and in-house production of key construction materials to ensure both quality and reliability of the supply in the long run.

(see Towards Self-Sufficiency: In-House Construction Materials, p. 15)

Execute Effectively

Despite the high complexity of its construction process, Phase 1 of the Changi Airport development was completed within six years in 1981 – a speed that was considered fast even by international standards.

(see Case Study: A World-Class Airport in the Sea, p. 43)

Innovate Systematically

Singapore's built environment sector embarked on an industrialisation programme from the early 1980s to increase construction productivity through employment of key innovative construction methods such as modular design, precast and prefabrication technologies.

(see Precast and Prefabrication Construction Technologies, p. 35)

Dynamic Urban Governance

Lead with Vision and Pragmatism

To tackle the acute housing shortage in the early days of Singapore's development, the leaders then focused on getting things done and getting results. Wherever possible, red tape was cut to facilitate speedy procedures.

(see Pragmatism and the "Just Do" Mentality, p. 11)

Work with Markets

The government supported the development of local construction workforce through various schemes that incentivised local contractors to improve their skill levels, productivity and general workmanship.

(see Contract Management, Skills and Productivity, p. 13)

CHAPTER 1

INTRODUCTION

> The disease from which Singapore is suffering is Gigantism. A chaotic and unwieldy metropolis has been created, as in other countries, by haphazard and unplanned growth...
>
> British Housing Committee Report

Before Singapore was granted internal self-government in 1959, most Singaporeans had been living in overcrowded slums and squatter settlements without proper sanitation, lighting and ventilation. Some of these houses were ramshackle, built using attap leaves, old boxes and scrap metal.

In 1927, the British colonial government set up the Singapore Improvement Trust (SIT) to address the acute housing shortage and to implement a general improvement plan for Singapore's construction industry. However, after the end of the Pacific War, increased immigration rates accelerated population growth, and the SIT failed to provide adequate public housing to meet the needs of a fast-growing population. The difficulties faced included high land prices and other costs incurred in preparing sites for construction, shortages of materials and skilled construction operatives, inadequate supply of qualified professional personnel, and the non-availability of funds[1]. By 1947, building costs had reached four times their original levels in 1939[2].

20 years after the SIT was formed, the British Housing Committee reported that 72% of a total population of 938,000 were living within the 80 square kilometres that made up the central city area. There, urban slums proliferated, posing fire hazards and becoming breeding grounds for disease and crime. The situation was so bad that the committee referred to Singapore as "one of the world's worst slums" and a "disgrace to a civilised community"[3].

It was a challenging task to provide decent homes and basic infrastructure quickly and affordably. Singapore's transformation into a liveable city-state with a world-class built environment would not have been possible without the dedication of the local construction professionals and close collaboration amongst government agencies, industrial players and other key stakeholders.

This document captures the history of that transformation, specifically in the building sector[4], over four broad phases:

The Foundation Phase – 1960s to 1980s: captures the Singapore government's early efforts in construction development to tackle the urgent housing shortage crisis under the constraints of insufficient resources. Two key government institutions – the Housing and Development Board (HDB) and Public Works Department (PWD) – played decisive roles in successfully managing resource planning, and building the physical foundations for national development in the larger sense.

The Consolidation Phase – 1970s to 1980s: focuses on how the building regulatory system was set up to improve building maintenance and safety, and how various institutions nurtured a quality construction workforce.

The Innovation Phase – 1980s to 2000s: explores innovative technologies and policies to upgrade the construction sector, enhancing efficiency, productivity and quality.

The Vision Phase – 1990s to 2000s: emphasises construction quality, accessibility and sustainability for a greener urban future.

CHAPTER 2

FOUNDATION: BUILDING FOR BASIC NEEDS (1960s TO 1980s)

> The first phase was one of urgency, to house an overcrowded city...
>
> Lee Kuan Yew, founding Prime Minister

In the early years of Singapore's nation-building, the government had to focus obsessively on what was then often referred to by public servants as "breaking the back" of the housing problem. The primary aim was to build as many flats as quickly as possible to resettle slum dwellers and squatters, as well as to house an exponentially growing population. Two agencies played significant roles during this early period: the Housing and Development Board (HDB) as the housing authority, and the Public Works Department (PWD) as the engineering authority. Together, these two agencies laid a strong foundation in concrete terms, literally, to support Singaporeans' daily lives from cradle to grave.

THE HOUSING AUTHORITY: THE HOUSING AND DEVELOPMENT BOARD

To tackle the acute housing shortage, the HDB was formed in 1960 after the attainment of self-government, replacing the former British colonial agency Singapore Improvement Trust (SIT). The HDB got to work straightaway, but soon faced a stern test when a major fire broke out at Bukit Ho Swee on 25 May 1961. The fire left 16,000 people homeless and desperately in need of urgent resettlement. The day after the fire, then Prime Minister Lee Kuan Yew promised to re-house all the affected families into new homes within one year. Following a series of emergency Cabinet meetings and urgent consultations with the HDB, the government revealed plans to resettle the fire victims at the Bukit Ho Swee site itself, as well as at other upcoming or newly-completed public housing developments in Queenstown, Tiong Bahru, St Michael's Estate, Macpherson and Kallang[5]. In February 1962, three months ahead of the promised date, all affected families had been successfully re-housed[6].

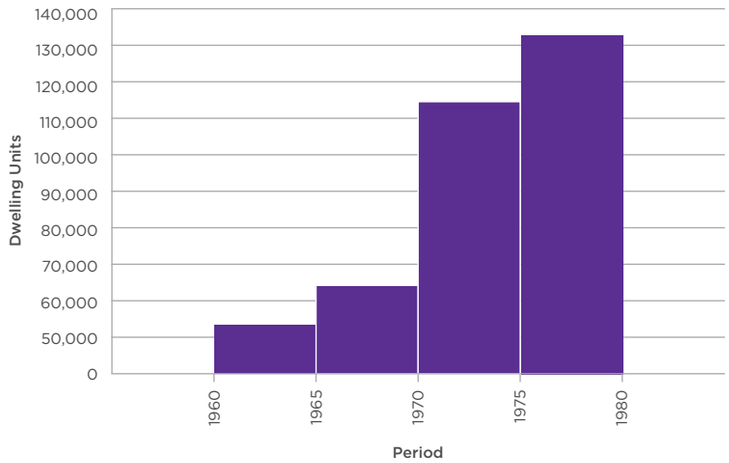
Lee Kuan Yew and the new residents of Bukit Ho Swee Estate.
Shortly after its establishment to tackle the housing shortage issue, the HDB was put to test with the need to urgently re-house the Bukit Ho Swee fire victims.

The flats constructed to house the fire victims constituted the first large-scale building project undertaken by the HDB, a young organisation that had been formed barely a year ago when the Bukit Ho Swee fire broke out. While these emergency housing flats had fittings and finishes that were in no way comparable to more modern HDB flats, they represented significant improvements in terms of safety and living conditions for the residents. Unlike the cramped and unhygienic living conditions in the slums, the HDB flats fulfilled people's basic housing needs through the provision of amenities such as electricity, piped water and proper sewage and waste disposal systems.

> *"The first phase was one of urgency, to house an overcrowded city... There were slums in the city and squatter huts around the city when we took office in 1959. The rate at which the SIT was building would never solve the problem... when the Bukit Ho Swee fire took place in 1961, we rehoused them quickly. And for them it was a great improvement, from their squatter huts to rooms with running water and electricity, and communal kitchens and communal toilets were better than what they had before. So it was an improved quality of life."*
>
> Lee Kuan Yew[7], founding Prime Minister

Over the next few years, the HDB continued to deliver high-rise, mass public housing to address the young nation's needs. Under the leadership of Mr Lim Kim San, the first Chairman of the HDB, more than 8,000 low-cost flats were built in four years. The Land Acquisition Act of 1967 gave the HDB legal powers to acquire land compulsorily, allowing them to undertake redevelopment of slums more swiftly[8]. By 1976, more than 50% of the population were living in HDB flats, compared to only 8.8% in SIT flats in 1959. Exhibit 1 below shows the rapid growth in the number of dwelling units built by the HDB during the first two decades of Singapore's development. Today, the HDB has grown even further as the "one-stop solution" for all public housing matters, and has provided affordable and quality homes for some 85% of the population.

Exhibit 1:
Growth of Public Housing Units in Singapore (1965–1980)



Source: HDB Annual Report 2008/2009[9]

THE ENGINEERING AUTHORITY: THE PUBLIC WORKS DEPARTMENT

Besides providing public housing units, basic infrastructure facilities such as roads and drainage networks had to be well-planned and implemented to serve the residents. The Public Works Department (PWD) played an important part here in terms of preparing all the land and public infrastructure required for development.

PWD was first formed as the Public Works and Convicts Department in 1833, during British colonial rule. In the early days, the construction of public works comprised mainly military establishments, such as barracks and camps[10]. In 1959, after the People's Action Party (PAP) came into power, the PWD was placed under the newly-formed Ministry of National Development. As shown in Exhibit 2 below, the PWD was responsible for the planning, design, implementation and maintenance of a wide range of public infrastructural development works. Some of the key public projects completed around this period included the Paya Lebar Airport (1955), Merdeka Bridge (1956) and the first multi-storey car park at Market Street (1964)[11].

Exhibit 2:
Branches of the Public Works Department

Architectural	Including the Health and Education, Defence and General Branches; constructed most government buildings.
Special Service	In charge of the construction of an increasing number of schools and geotechnical engineering.
Mechanical	All government vehicles, heavy machinery and plants.
Electrical	Maintenance of major electrical fittings and appliances.
Works and Buildings	Maintenance, general repairs and improvements to all government buildings.
Structural Design and Investigation	Conducted soil investigation for foundations; designed and maintained quality standards in materials used in PWD engineering projects.
Quantity Surveying	Produced bills of quantities for all public works projects; controlled tenders and contracts.
Sewerage	With the integration of the former City Council of Singapore in 1959, the PWD took over all sewerage sanitation, road and drainage projects.
Road	Looked after the construction, maintenance and improvement of all road projects including private streets.
Drainage and Marine	Responsible for the maintenance of jetties, sea-walls, river works and minor foreshore reclamation schemes.
Parks and Trees	Responsible for greenery and flowers in public spaces.

Source: Cheong, C. (1992). Framework and foundation: A history of the Public Works Department. Singapore: Times Editions for Public Works Department.

Between the 1970s and the 1990s, the PWD underwent further reorganisation, leading to the formation of a number of key public infrastructure planning and development statutory boards that we see today. For instance, in October 1972, both the Sewerage and Drainage Branches within the PWD were transferred to the newly-created Ministry of the Environment (ENV), and subsequently incorporated as part of the Public Utilities Board (PUB). The Parks and Trees Unit, which was tasked to spearhead the tree-planting programme that would beautify highways, open spaces and other public institutions, was merged with the Singapore Botanic Gardens in 1976 to become the Parks and Recreation Department (PRD), the predecessor of today's National Parks Board (NParks). In 1967, the Roads Branch absorbed the Bridges and Airports Branch, which was renamed Roads and Transportation Division in 1989. In 1995, the Roads and Transportation Division of the PWD merged with Mass Rapid Transit Corporation (MRTC), the Registry of Vehicles and the Land Transportation Division of the Ministry of Communications to form the Land Transport Authority (LTA). This re-structuring allowed the various organisations involved in the planning, development and management of land transport policies and infrastructure to be brought together under one roof.

FROM CENTRALISED TO DECENTRALISED GOVERNANCE

Over the years, both the HDB and PWD have undergone restructuring to respond to evolving needs and demands in the landscape of public housing and public works. For instance, the Housing and Urban Development Company (HUDC) was formed in 1974 to build estates for people whose incomes exceeded the ceiling imposed on buyers of HDB flats at that time. HUDC flats offered another housing option that was intermediate in terms of quality, between public and private housing. The HUDC scheme was discontinued in 1984 in response to its waning popularity, after 18 projects and over 7,000 units had been built.

In 2003, the Building and Development Division (BDD) of HDB was reorganised and HDB Corporation Pte Ltd (HDB Corp) was set up. The rationale of the corporatisation was to give the BDD more autonomy and flexibility, to leverage its strengths to venture into housing development projects overseas[12]. The hiving-off of these new roles allowed the HDB to refocus on its primary role in policy formulation and implementation as the public housing authority, to ensure that its policies and management approaches were in tune with the changing needs of society. These developments have also paved the way for greater private sector participation in the public housing sector.

In 1999, the consultancy arm of PWD was corporatised to form PWD Corporation while its regulatory arm, the Building Control Division, was merged with the former Construction Industry Development Board (CIDB) to form the Building and Construction Authority (BCA). The PWD's corporatisation was in line with the government's efforts to progressively devolve non-policy and non-regulatory functions from its various ministries and departments. The BCA plays both promotional and regulatory roles pertaining to the construction industry. Currently, the BCA has reinforced itself as a professional building regulator as well as a champion of the built environment sector to develop a technologically advanced construction industry and ensure that buildings and infrastructure in Singapore have high levels of safety, quality, sustainability and accessibility.

PRAGMATISM AND THE "JUST DO" MENTALITY

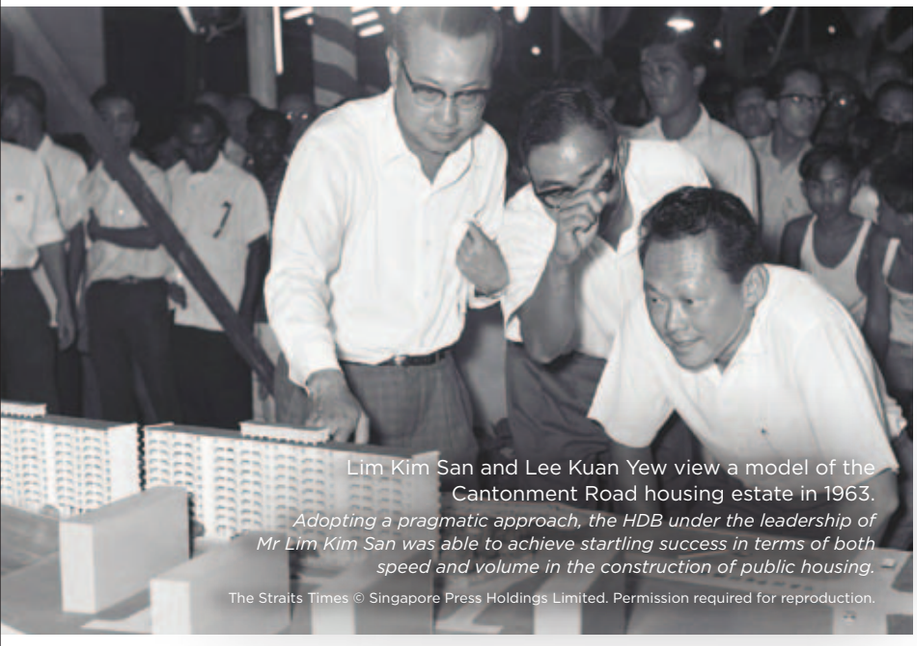
After the People's Action Party (PAP) came to power in 1959, the new government was soon made aware that if it did not improve the basic welfare of the citizens, it would not earn their support. Then Prime Minister Lee Kuan Yew went so far as to say, "We knew that failure would mean the end of the PAP government."[13] Tasked with a mission to ensure Singapore's survival and success, the leaders then adopted a pragmatic approach focusing on getting things done and getting results. Foremost amongst their many pressing concerns was to house a population clustered in shanty towns and slums.

In order to facilitate speedy procedures for public housing projects, the HDB dispensed with bureaucratic red tape wherever it could. At the same time, an uncompromising tone for integrity and zero tolerance for corruption were also set. Senior civil servants who demanded preferential treatment, as well as those who performed duties with vested interest were investigated and dismissed if found guilty. To ensure efficient delivery of housing units, the supply and prices of building materials were closely monitored. Brickworks and granite quarry owners were told that if they increased their prices indiscriminately, the HDB would enter the quarrying business. When the warning fell on deaf ears, the board took over some granite quarries to stabilise prices[14].

This kind of dedication, pragmatism and good discipline helped overcome the initial challenges faced by the young nation, and laid the foundation for the country's building sector. Mr Lim Kim San, the founding chairman of HDB from 1960 to 1963, illustrated this spirit when he recalls how he led the housing board in its earliest days:

> *"After having gone round with the HDB officers, I told them: 'You see how urgent it is.' The smell and the conditions were terrible, really terrible... I started interviewing heads of department one by one and assessed their capability. From then on, we started working. I told them: 'We have a job to do and we better get going. Do it well.' ... So, in the end, we got a very enthusiastic staff because they saw things were getting along. There was no such thing as having to wait for a committee to decide on anything which has got to be done. They will come up to me and I will just say yes or no. I would meet them almost every day [during] the first year or so, discussed the problems, made decisions there and then, cutting off all the red tape. And things were done quickly rather than having things on paper and having a formal meeting. We all just sat around and discussed, right up to 9pm, and then we would adjourn and have dinner."*

Lim Kim San[15], founding Chairman, HDB



Lim Kim San and Lee Kuan Yew view a model of the Cantonment Road housing estate in 1963.
Adopting a pragmatic approach, the HDB under the leadership of Mr Lim Kim San was able to achieve startling success in terms of both speed and volume in the construction of public housing.

CONTRACT MANAGEMENT, SKILLS AND PRODUCTIVITY

In the 1960s, the productivity of building contractors was low and overseas professionals spearheaded major projects in those early days. Besides getting help from experts despatched by the United Nations, the government also consulted the world's largest construction company then, Shimizu of Japan, requesting for their assistance in recommending improvements in our construction practices. It was not easy to find local contractors at that time. In order to increase the supply, Singapore adopted a pragmatic strategy of "getting them in first, upgrading their skills later" – anybody who was willing to be a contractor could be qualified. From there, the government helped improve the quality of inexperienced contractors' workmanship through training, and in doing so, gradually built up the capability of the local construction industry.

> *"Contractors were required to build into their contract sum the cost of deploying appropriate on-site building equipment and later engaging professional engineers to boost productivity and ensure timely completion. Not satisfied with that, HDB also conducted studies to find ways and means to improve productivity on a broader front and reap credible results. Workmanship, again, was an issue... To learn as much as we could, we invited Shimizu to oversee three contracts and stipulated that Shimizu's architects and engineers were not allowed to speak to HDB contractors of these three projects directly, but must convey their comments for improvements to the HDB architects and engineers. And HDB architects and engineers for these projects, aside from passing the comments to contractors, were required to compile Shimizu's suggestions into proper construction manuals for the reference of other architects, engineers and clerks of works in HDB. This was a key milestone in HDB's journey for a total quality construction control system which remains in use today."*

Liu Thai Ker[16], former CEO, HDB

To support the delivery of the massive number of low-cost flats needed, the HDB initiated a variety of schemes to develop contractors and enhance their skill levels. For instance, under the "Merit Star Scheme"[17] introduced in 1973, contractors were evaluated based on their construction efficiency, workmanship, site management, safety measures and levels of mechanisation. Merit stars were awarded to contractors who performed consistently well – for every merit star earned, the contractor would enjoy a 0.5% bidding preference when tenders were evaluated. On the contrary, contractors who performed badly would risk losing their merit stars. This system of checks and balances not only encouraged healthy competition among contractors, motivating them towards a higher standard of operational efficiency and workmanship, but also allowed HDB to build lasting relationships with reliable and skilled contractors over time.

The government also encouraged contractors to increase productivity by providing an "Interest-Free Financing Scheme", which enabled contractors to receive pre-financing loans from the HDB. The cost of deploying innovative equipment on site could be financed under this scheme and repayment could be made in instalments. This improved the cash-flow position of contractors while also providing an incentive for achieving greater efficiency and a reduced dependence on migrant labour.

In 1982, a "Core Contractor Scheme" was introduced after studies of similar schemes in Japan and South Korea were conducted. Under this scheme, contractors with a minimum paid-up capital of $500,000 and a minimum of five stars attained from the "Merit Star Scheme" would be offered a guaranteed annual workload for a fixed number of years. Contractors benefitted from the scheme by being able to plan ahead for their projects in terms of time, manpower and other types of resource investment, such as machinery and equipment. In 1988, these two schemes were replaced with a serial-tendering scheme, serving the same purposes. Essentially, contractors were given a large number of building projects to take advantage of economies of scale. In return, they were expected to abide by a set of requirements and also to maintain good standards of performance.

> *"We try to nurture local contractors by giving them some continuity in jobs, so we have a scheme called the 'Core Contractor Scheme'. We gave the contractor five or six projects over a few years. We also packaged the number of projects for a contract... In that way, local contractors then built up their capability by engaging more in-house engineers and qualified technical people."*
>
> Yao Chee Liew[18], former Manager (Building Development), HDB

Besides incentivising local contractors to do better, the government also tried to facilitate transfer of knowledge and technology from foreign to local contractors. For example, a foreign contractor was required to form a joint venture with a local contractor to tender for big construction projects.

Thanks to these schemes and initiatives, public agencies responsible for the implementation of major housing and infrastructure projects could access a reliable pool of qualified contractors and technical personnel on a continuous basis. The government was able to build up long-term partnerships with local contractors and improve the overall quality of the construction industry in Singapore over time.

> *"When we first started, our contractors were small. For example, a sanitary contractor, electrical contractor... there was no contractor who actually could be an overall building contractor. You started with that but we built them up into integrated contractors who could provide all these services and then they moved up to become developers themselves."*
>
> Tan Kim Chwee[19], former Director (Development & Procurement), HDB

TOWARDS SELF-SUFFICIENCY: IN-HOUSE CONSTRUCTION MATERIALS

Besides contract management, the government was also actively involved in the management of construction resources to ensure adequate and timely supply of essential construction materials at affordable prices. To keep up with the demands of the building programmes and to mitigate supply disruptions and price fluctuations, the HDB realised that it was necessary to produce its own building

materials. It started the "Direct Procurement and Supply Scheme", under which the HDB purchased materials in bulk, and supplied them directly to the HDB's construction sites at fixed prices. Bulk purchases, negotiated supply management, in-house production and stockpiling were some other strategies put in place to safeguard the reliability of the supply system and the quality of construction materials.

According to the former CEO, Dr Liu Thai Ker, the HDB had to operate plants to supply concrete aggregates and sand for quite a long time. The HDB set up a granite crushing plant on the offshore island of Pulau Ubin in 1963 and selected a long-term quarry site in Mandai in 1969 for its vast reserve of building materials. In 1972, the HDB even set up its own brick factory in the western region of Singapore. A total of 496 million bricks had been produced before the plant was shut down in 1998 due to the increasing use of precast concrete components as alternative materials. Later on, small, private, sand quarries still relying on conventional and inefficient processes were phased out by the government because of silting problems they created. The HDB then decided to set up a mechanised sand quarry in 1981. Through the development of all these local, in-house production channels of major construction materials, the HDB was able to sustain a high volume of local construction activities. Furthermore, laboratories were also set up within the production plants to carry out vigorous quality checks, to safeguard the quality and consistency of the construction materials.

Despite these measures, Singapore was still reliant on external sources for many key construction materials, and thus still had to prepare for unexpected situations such as sudden disruptions to the supply of materials from these exporting countries. National stockpiles of key construction materials were set up to help the industry tide over temporary disruptions. As a strategy for supply diversification, the BCA now requires all importers to maintain a small supply from distant regional sources, even when no supply disruptions are foreseen. At the same time, the government promotes the use of steel and recycled concrete aggregates to reduce reliance on the import of natural materials.

RECREATING THE "*KAMPUNG* SPIRIT"

To house the existing population and accommodate future population growth on an island with limited land, the government decided, with typical Singaporean pragmatism, to go for high-density, high-rise flats for public housing. This went against global trends at that time. Elsewhere in the world in the 1960s, public housing projects had run into problems, with the worst cases in other countries resulting in the creation of crime-ridden ghettos.

A few factors contributed to Singapore's success in creating "liveable" public housing. First and foremost, the HDB programme was intended to provide housing for the majority of the Singaporean population who would mostly come to own, rather than rent, their apartments. Second, much effort was invested to recreate the "*kampung* (Malay for 'village') spirit" in high-rise housing estates. This had been a strong community-binding element in the traditional low-rise settlements of the past. Planning and design interventions such as the creation of community gathering places in the "void decks" (vacant spaces on the ground levels of the HDB blocks) and common corridors (common linked spaces that provide access to individual units on the same floor) are all part of the overall effort to foster neighbourly interaction amongst public housing residents. In other words, the social dimension of creating homes for communities was just as important, if not more so, than the physical aspect of building houses.

INTEGRATED PLANNING AND INTER-AGENCY COORDINATION

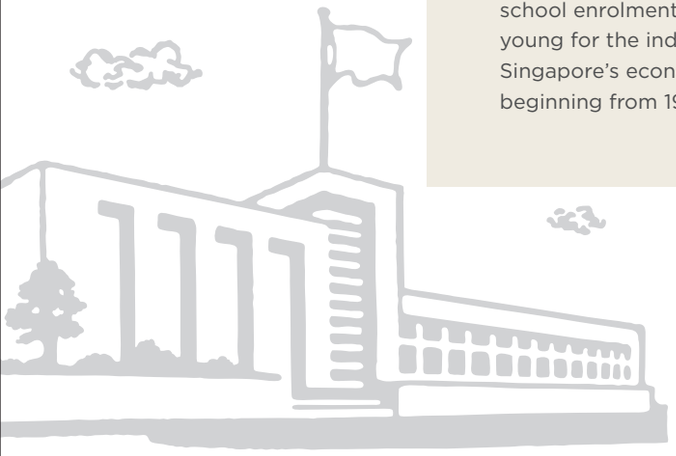
Just as building a "*kampung* community" must involve all members of a village, the work of the HDB required a lot of coordination among many agencies. Apart from the PWD, the other agencies that the HDB collaborated with closely for the provision of basic infrastructure included the Public Utilities Board (PUB), Ministry of National Development (MND) and Telecommunication Authority of Singapore (TAS). Besides clearing slums, the HDB was also in other areas of work including rebuilding obsolete properties, comprehensive planning for traffic and circulation systems in central areas, planning and designing other amenities such as shops, markets, hawker stalls, offices, car parks, open spaces, sewers, drains and water mains.

BUILDING SCHOOLS: FROM STANDARD DESIGN TO DISTINCT IDENTITY

> "*In the beginning, we 'mass-produced' schools. Then later, [we] moved to more diversity and variety. By the late 1980s, PWD architects were talking to principals about customised design for their schools because every school principal wanted to have a unique school. So it's moving from mass-production to customisation.*"
>
> Lim Peng Hong[20], former Senior Engineer, PWD

An important part of the HDB's township development is to ensure easy access to schools for the residents of new HDB housing towns.

Schools built in the late 1940s and the 1950s were simple structures with very few facilities. With self-government in 1959, education was accorded greater importance. In the early years of self-rule and independence, the government embarked on an accelerated school building programme to meet the needs of burgeoning school enrolment and prepare our young for the industrialisation of Singapore's economy. For eight years, beginning from 1959, schools were built at a rate of one per month to provide a place in school for every child of school-going age[21]. The priority then was to build schools fast and at minimum cost. The same layouts were often used for all projects in order to lower cost and facilitate faster construction. These facilities provided were simple, functional and economical.



With more households moving into the new HDB towns in the 1970s and the 1980s, the construction of new schools had to be significantly accelerated. The design of school buildings saw great transformation during this time. Not only were they bigger, greater variety in terms of design also emerged as the PWD organised design competitions for architects from the various government statutory boards.

The PWD's First School Building Programme to construct 66 schools was launched in 1973 and completed in 1978. The speed of implementation was in part due to the adoption of a standard design that came to be known as the "1974 Standard School Design". In 1979, the Second School Building Programme was introduced with the goal of building 57 new schools using new designs. In the 1980s, the PWD offered a selection of 12 school designs. At that time, there was an increase in the gross floor area of primary and secondary schools by 60% and 35% respectively, compared to those built in the 1970s. This generation of schools was upgraded and provided with a wider range of facilities. The Third School Building Programme involved 65 schools and had unique, customised designs and allowed for even more diversity.

In the 1990s, the school building programmes continued to shift its focus from quantitative to qualitative enhancements, incorporating designs that were more reflective and creative. Each school was conceptualised as a distinct building complex with its own unique identity.

To facilitate closer collaboration amongst agencies, a "service-coordinating meeting" was convened in the late 1970s. Every six months, heads of the relevant departments and agencies in areas such as road construction, bus services, civil defence, law enforcement and public health would meet to be updated on the HDB's one- to five-year building plans, and to discuss the implementation plans of basic infrastructure and amenities to support the proposed HDB housing development. Agencies had to speed up their works to match the HDB's building pace and to meet the required standards. Today, this spirit of public sector collaboration has evolved into what is known as a "Whole of Government" approach to the work of the civil service.

CHAPTER 3

CONSOLIDATION: REGULATING THE INDUSTRY AND DEVELOPING THE WORKFORCE (1970s TO 1980s)

> During CIDB's time, a number of areas relating to quality and productivity were developed. The buildability system, which assesses how much buildings at [the] design stage could enable site labour to be reduced, was developed; CONQUAS, the Construction Quality Assessment System, was developed; and the testing of foreign workers in their source countries before they came to work in Singapore was [also] developed and implemented ...

Lam Siew Wah, Deputy CEO, BCA

Having settled the pressing issue of acute housing shortage in the 1960s, the government was able to move on and focus more on enhancing the quality of the built environment and the capabilities of the construction industry. In particular, after the structural collapse of the Hotel New World (Lian Yak Building) in 1986, the government further tightened building regulations and set even higher safety standards for building design, construction and maintenance practices. This section discusses the two key enablers that were instrumental around this time, namely, sound building regulations and a more effective labour force.

BUILDING UPGRADING PROGRAMMES

Besides shaping a city's physical look, the built environment also makes up a significant part of a city's tangible assets. Singapore gives substantial attention to the management and upgrading of completed buildings to prevent physical deterioration – an important aspect that is often neglected by many other cities around the world. The key aims are to prolong the "lifespan" of the built environment and better maintain the value of the building assets in the longer term. Furthermore, a well-maintained built environment that appears new and tidy also helps foster stronger civic pride and a greater sense of ownership and belonging amongst citizens and residents.

Throughout the 1960s, the most pressing task of the Housing and Development Board (HDB) was to solve the problem of the nation's acute housing shortage, and improve the basic living conditions for the population as quickly and cost-effectively as possible. Having more or less addressed this issue by 1977, the number of public housing units in the pipeline outstripped actual demand[22]. The HDB decided to slow down the development of new flats and instead focus more on enhancing the quality of the existing built environment.

Some older flats constructed in the early days were demolished on a selective basis and replaced by newer public housing developments with a higher density. On a wider scale, a series of upgrading and estate renewal programmes was developed by the HDB to enhance the living environment and overall attractiveness of older estates.

"We repaint our old buildings on a compulsory basis. So, these are actions that you can do to, in a short time, change the feeling of a city, change the city and sense of pride of the city."

Lee Kuan Yew[23], founding Prime Minister

At the town, neighbourhood and precinct levels, such upgrading included the provision of additional services and amenities such as supermarkets, retail malls, sports facilities, parks, gardens, and children's playgrounds, to make community living more enjoyable and convenient. At the block level, architectural improvements such as facade treatment and lift upgrading were carried out to give older HDB blocks a new lease of life and identity. Within individual housing units, upgrading works often involved relatively hassle-free installations of prefabricated components, such as new toilets, which could be manufactured off-site and easily added onto existing units[24].

LEGISLATION FOR BUILDING MAINTENANCE

The number of private buildings in Singapore has also been increasing since the mid-1960s along with growing affluence. The maintenance of these private structures was largely regulated by the Building Control Division of the Public Works Department (PWD). Learning from the Australians, a strata-titled system was introduced into legislation in 1967. By enabling the subdivision and ownership of high-rise buildings, such legislation helped to create a system that could meet the social, economic, and psychological needs of a high-density urban landscape. Prior to 2005, the legislation governing the management and maintenance of strata-titled buildings were contained in the Land Titles (Strata) Act (LTSA) and the Buildings and Common Property (Maintenance and Management) Act (BCPA). In April 2005, relevant parts of the LTSA and the entire BCPA were combined into a single legislation known as the Building Maintenance and Strata Management Act (BMSMA)[25]. This provides a legal framework for the management and maintenance of strata properties and spells out the duties and obligations of different stakeholders such as subsidiary proprietors, management councils and managing agents.

The BMSMA is administered by the Commissioner of Buildings (COB). In the event of a dispute arising from strata living, the parties can apply to the Strata Titles Boards (STB), which is a quasi-judicial body set up under the BMSMA to hear disputes amongst stakeholders in strata-titled buildings. This further strengthens the self-regulatory system of strata ownership and living, which is crucial in a high-density urban environment.

LEGISLATION FOR BUILDING SAFETY

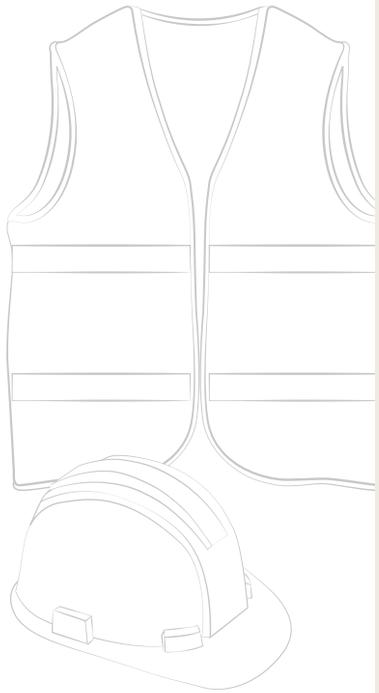
Before 1989, there was no requirement for an authority or independent checker to validate the structural design and safety of a building. The collapse of the Hotel New World (Lian Yak Building) in March 1986, which was the result of poor structural design and shoddy construction by unqualified personnel, led to major reforms in Singapore's construction industry. To prevent similar disasters, the government introduced stricter laws and building codes and the authorities began to conduct more frequent and more stringent checks on buildings.

"The Hotel New World tragedy was an objective lesson for Singaporeans... it demonstrates vividly and painfully the need for regular and proper inspection and maintenance to ensure safety."

S. Dhanabalan, former Minister, MND

Further refinements to the regulatory system were made after more recent incidents. The Nicoll Highway incident of 2004, where a stretch of the highway caved in due to underground subway tunnelling works, led to more stringent regulation of major underground building works, licensing of builders, provision of adequate site supervision, ensuring independence of parties in a construction project and raising of penalties for non-compliance with building control regulatory requirements[26].

HOTEL NEW WORLD COLLAPSE: A WAKE-UP CALL FOR THE INDUSTRY



The Collapse of Hotel New World.
After this incident, the government promptly tightened construction regulations and raised building safety standards.
Photo by MICA, courtesy of NAS

Built in 1971, Lian Yak Building was located in the Little India area. It consisted of six storeys and a basement garage. The Hotel New World was the main tenant occupying the top three floors of the building. Due to structural faults and poor construction quality, the building collapsed on 15 March 1986, killing 33 people.

Following the incident, President Wee Kim Wee appointed a Commission of Inquiry (COI) headed by Justice L P Thean to fully investigate the cause of the collapse. Based on the final inquiry report, a serious error had been made in the calculation of the building's structural load during the design stage – the weight of the building itself had been completely omitted. This major negligence meant that the building had been on the verge of collapse right from the day it was built. The building's columns were being stressed to their limit, and it was only a matter of time before it collapsed. Over the years, additional loads, such as air-conditioning installations, were added onto the building, exacerbating the already inadequate structure. These factors, along with the prolonged lack of proper maintenance, contributed to the building's eventual collapse.

Soon after the inquiry report was sent to President Wee Kim Wee, buildings across Singapore were rigorously checked for structural safety and those found to be unsafe were evacuated until the problems could be fixed. The disaster also prompted the government to tighten construction regulations and building safety standards. Before the Hotel New World collapse, the approval of structural plans was not a requirement during the design phase. After that incident, structural plans had to be prepared by qualified engineers, checked and certified by accredited checkers before submission for approval. Mandatory inspections of completed buildings now have to be carried out by structural engineers during the post-construction phase to ensure that the structures are maintained in good condition. Building owners are also expected to carry out structural inspections every five years for non-residential buildings and every 10 years for residential buildings.

CULTIVATING A HIGH QUALITY CONSTRUCTION WORKFORCE

The Construction Industry Development Board

In order to maintain quality standards within Singapore's built environment, the government made efforts to ensure a steady pipeline of skilled manpower in the construction sector. The Construction Industry Development Board (CIDB) was formed in 1984 as a statutory board under the Ministry of National Development to be the central body for coordinating, spearheading, promoting, developing and monitoring the industrialisation of the construction industry[27]. In addition to spearheading programmes that provide skilled construction labour as well as upgrading options, the CIDB worked with the ministries of Labour, Home Affairs and National Development to implement policies aimed at creating favourable conditions for the industry to attract and retain personnel at all levels. To attract adequate workers, the CIDB worked to improve the image of the local construction industry and encourage Singaporeans to consider pursuing careers in the industry.

> *"During CIDB's time, a number of areas relating to quality and productivity were developed. The buildability system, which assesses how much buildings at [the] design stage could enable site labour to be reduced, was developed; CONQUAS, the Construction Quality Assessment System, was developed; and the testing of foreign workers in their source countries before they came to work in Singapore was [also] developed and implemented ..."*
>
> Lam Siew Wah[28], Deputy CEO, BCA

The CIDB also centralised the public sector registry of contractors working for different agencies. The centralised registry enabled easy monitoring of the criteria for contractor selection, such as professional and technical personnel, track records, financial performance and paid-up capital, so that contractor evaluations could be standardised, and the required capabilities of contractors progressively raised. This provided recognition for the better, larger local firms and made them eligible to tender for larger government projects. The registry also became a de facto list for many private-sector developers to shortlist builders for their projects.

To ensure that basic quality standards are adhered to, trade tests were instituted in the country of origin for foreign construction workers (starting with China, then Thailand, India and Bangladesh), so that workers who came to Singapore would be more skilled. Test centres were set up by the private sector according to guidelines provided by the CIDB, but tests were conducted by CIDB testers. The trade tests consisted of a one-hour basic theory and a four- to five-hour practical on specific areas such as formwork, tiling or reinforcement work. The foreign construction labour levy was differentiated to benefit those who passed trade tests against those who had no trade certificates. Subsequently, passing trade tests became a mandatory requirement for any foreign worker who wished to come and work in Singapore. This requirement remains in effect today[29].

To control the number of foreign construction workers in Singapore, the CIDB introduced the Man-Year Entitlement Policy[30] to peg the number of man-years allowed in proportion to the value of the construction project. The main contractor would manage the allocated man-years and distribute them accordingly among his subcontractors, who together could convert the man-years into the number of foreign workers coming in on one- or two-year work permits.

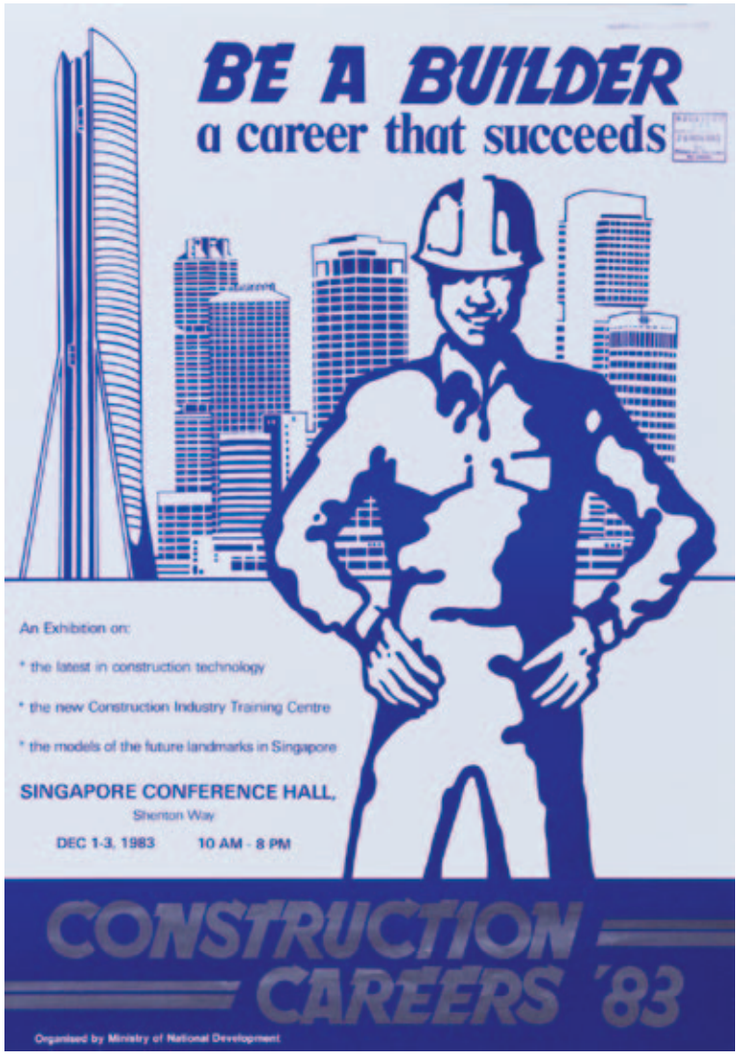
However, as a promotional agency, the CIDB did not have regulatory powers to mandate policies or measures for the industry. Instead, it relied on the government as a major buyer of construction services to implement its capability-building, quality- and productivity-improvement initiatives, and on the Ministry of Manpower to implement worker upgrading through its foreign worker policies.

Professional Development for the Industry

Construction Industry Training Centre

As the manpower development division under the CIDB, the Construction Industry Training Centre (CITC) conducted full-time courses on various construction trades at different skill levels to meet the industry's manpower needs. The CITC aimed to provide full-time skills training for new workers entering the built environment sector, as well as those already in the construction workforce who wished to further upgrade and expand their skills. In addition, the CITC also set standards, and provided testing and certification for construction skills in Singapore.

In 1990, the CITC set up the Construction Careers Centre to provide guidance to persons considering careers in construction, whether as professionals, technicians or tradespersons. The CITC had recruited several hundred apprentices, quite a number of whom completed their training and entered the industry. However, as more foreign workers entered the industry during the late 1980s and early 1990s, the apprenticeship programme was discontinued. The training priorities then moved towards technical and supervisory personnel.



Poster for Construction Careers Exhibition in 1983.

Much effort was put into promoting construction-related jobs. A new Construction Industry Training Centre was also set up to train and upgrade new and existing construction workers.

Poster from the MND Collection, courtesy of NAS

BCA Academy and Its Predecessor

As the construction sector expanded rapidly in the late 1980s, the training capacity of the CITC became overstretched. The need for a larger training centre became evident. A new centre at Braddell Road, the Construction Industry Training Institute (CITI), was opened in 1994. With its expanded capacity and facilities, the CITI conducted a full range of training programmes for workers, foremen and supervisors. In 2001, its first diploma programme in construction engineering was formally launched, providing school-leavers with alternative education and career options. Shortly thereafter, a series of new and specialist diploma programmes followed.

In 1999, when the BCA was formed through the merger of the former CIDB and the former Building Control Division of the PWD, CITI continued to play its role as the industry training centre under the management of the new BCA. By the mid-2000s, a rapidly expanding construction sector and new government initiatives aimed at transforming Singapore into a global city of excellence escalated the training needs of the industry. The demand for more and higher value-added training for practising professionals, as well as senior and middle management personnel in construction-related companies took on a new dimension. In response to this new challenge, the CITI was restructured and repositioned as the BCA Academy in 2007, to gear itself as a dedicated one-stop training, design and technology hub for the built environment with an expanded scope in professional education.

Professional Engineers Board

The rapid expansion of the construction industry in post-independence Singapore was placing an increasing amount of responsibility on engineers. In 1969, the government decided that it was time to legislate for the compulsory registration and control of practising engineers[31]. Shortly after the Professional Engineers Act was passed in 1970, the Professional Engineers Board (PEB) was formed in 1971. Its mission was to safeguard the lives, property and welfare of the public by setting and maintaining high standards for registering professional engineers, and by regulating and advancing the practice of professional engineering.

The Construction Industry Joint Committee

In the late 1990s, there was still a wide disparity in professional standards within the different groups that made up the industry, developers, architects, engineers, project managers and contractors. While some had designated institutes and associations that strove to maintain a level of professionalism, others were less focused. In fact, many lacked the capabilities to measure up to world-class standards.

In order to create a platform for different players in the construction industry to iron out issues of common interest, and to communicate differing views in a more coherent and coordinated manner, the Construction Industry Joint Committee (CIJC) was formed in 1997. Uniting key players from nine professional institutions and associations in the engineering, real estate, architecture, building, surveying, urban planning and project management, the CIJC provides a valuable forum to facilitate closer inter-disciplinary collaborations and forge collective efforts to develop the construction sector.

In 1999, the Construction 21 Committee, set up with representatives from the private, public and people sectors to upgrade all aspects of the construction industry, recommended institutionalising the partnering mechanism between the CIJC and the BCA. This and other recommendations formed the C21 blueprint to achieve the vision “to be a world class builder in the knowledge age”.

CHAPTER 4

INNOVATION: THE CITY AS A LIVING LAB FOR NEW BUILDING POLICIES AND TECHNOLOGIES (1980s TO 2000s)

> The building process has changed greatly over the years. In the old days, everything was done on-site. It was labour-intensive. Today, many things are done off-site, precast in factories, before being installed on-site. This makes it faster, more efficient and cost-effective.

Lau Joo Ming, former Deputy CEO and Senior Advisor, HDB

In the earlier years of Singapore's development, the construction industry was a key generator of employment opportunities. In the late 1970s and early 1980s, as Singapore entered an era of intensified building activities that increased in scale and complexity, priorities started to shift towards mechanisation and labour-saving initiatives. Such a shift was necessary to address the challenge of significant increases in the costs of land, manpower and construction materials as the nation prospered. The Housing and Development Board (HDB), the Public Works Department (PWD) and the Building and Construction Authority (BCA) played pivotal roles in promoting innovative technologies and policies to mechanise and upgrade the construction sector for greater efficiency, productivity and quality during this period.

PRECAST AND PREFABRICATION CONSTRUCTION TECHNOLOGIES

Singapore is the first country in the region to use precast and prefabrication technology in its construction sector. Precast is a method of casting concrete components in a controlled environment away from the construction site, while prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site before transporting the complete assemblies or sub-assemblies to the construction site. The traditional cast in-situ method of construction had been widely used to construct public housing in the 1960s. However, this low-productivity method required a sizeable pool of carpenters to do the formwork, and resulted in long construction periods. As the volume of construction projects surged significantly in the later part of the 1970s, contractors could not cope with the rising demand.

> *"In the interest of construction productivity and higher standardisation of materials supplied to our project sites, in the mid-1970s, the HDB devised its own Modular Coordination System according to international practice. This prepared us very well for the introduction of a precast and prefabricated system soon after. For prefabrication, the HDB is clearly one of the world leaders in the industry ..."*
>
> Liu Thai Ker[32], former CEO, HDB

To address the issue, Singapore began to embark on an industrialisation programme using innovative construction technologies that would enable the industry to significantly improve the ease and efficiency of construction. The HDB started incorporating modular coordination into its public housing designs, and initiated the use of prefabrication processes and the mechanisation of site operations.

At that time, Europe was at the tail end of its post-war reconstruction phase, having developed numerous prefabrication techniques to rebuild its cities. European countries were eager to share their technologies and sell them to other countries. Engineers in Singapore were sent to Europe to learn these skills and find ways of adapting the technologies for use back home. These technologies, which involved the production of building components off-site and assembling them on-site, proved indispensable to the HDB's building programme, as it greatly reduced dependence on manual labour and increased site productivity. By the 1980s, many turn-key builders had taken on prefabrication projects. The first prefabrication contract was awarded for the construction of three- and four-room flats in Hougang, Tampines and Yishun.

> *"The building process has changed greatly over the years. In the old days, everything was done on-site. It was labour-intensive. Today, many things are done off-site, precast in factories, before being installed on-site. This makes it faster, more efficient and cost-effective."*
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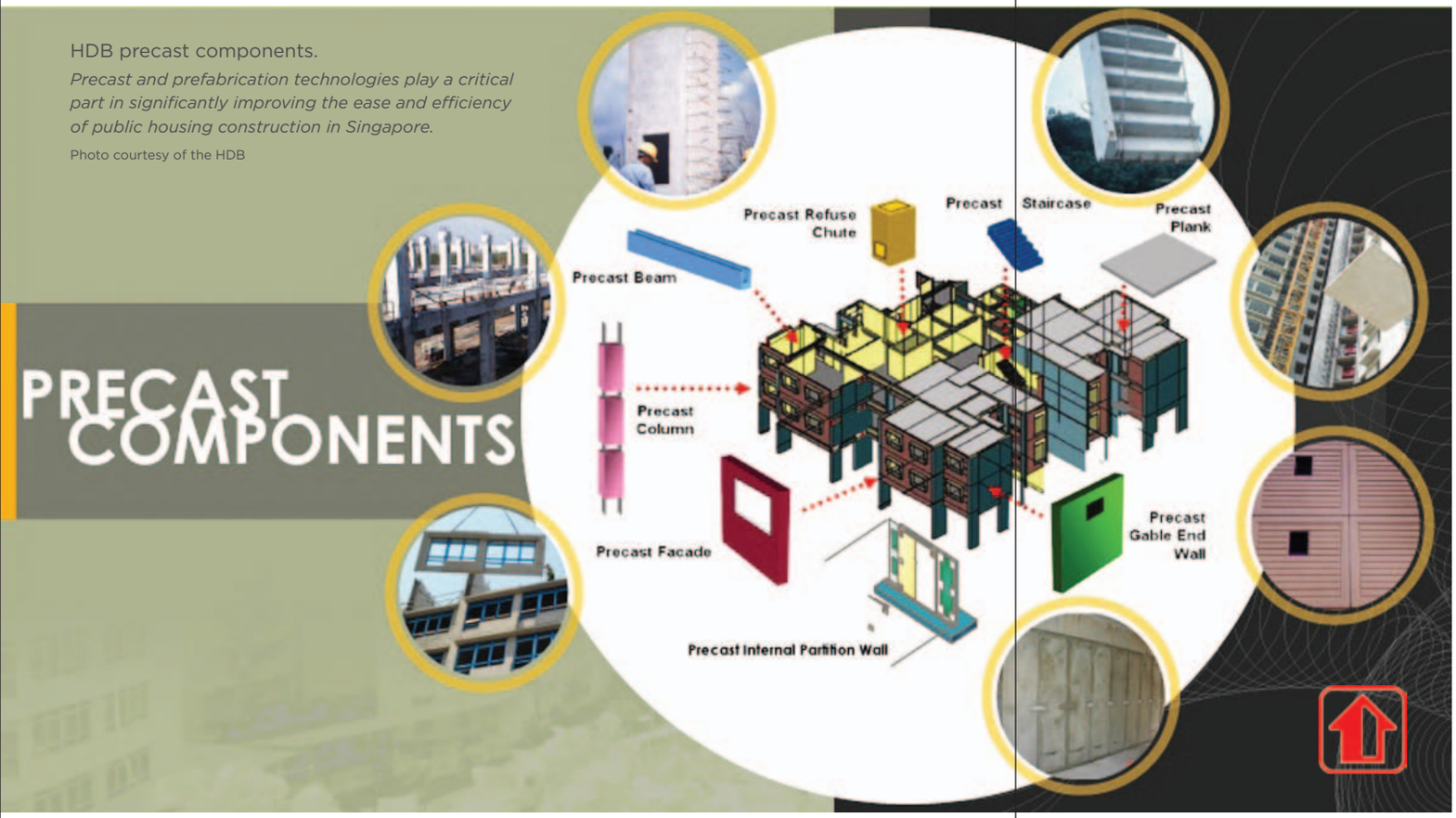


HDB precast components.
Precast and prefabrication technologies play a critical part in significantly improving the ease and efficiency of public housing construction in Singapore.
Photo courtesy of the HDB

The Prefabrication Technology Centre (PTC) was set up in 1995 to spearhead the development and use of prefabrication technologies. Later on, the PTC expanded its scope to include research and development, and became known as the Centre of Building Research under the HDB's Building Research Institute (BRI). This centre carries out prototyping and test-bedding to nurture the development of new building technologies for larger-scale application in future HDB housing projects. The "Pinnacle@ Duxton" development, for example, is an iconic project representing this major engineering breakthrough, with almost the entire building complex modularised and prefabricated off-site.

PINNACLE@ DUXTON: AN ENGINEERING BREAKTHROUGH

Pinnacle@Duxton is a landmark public housing development completed in 2009. It comprises seven blocks of 50-storey flats all linked by sky bridges at the 26th and 50th levels. An international design competition was held in 2001 and was keenly contested with over 200 design entries. Following the shortlisting of the winning design by a local architectural practice, HDB worked with the architects to further refine the concepts and details of the building design.

Prefabrication was applied extensively in the project. Majority of the concrete building components were prefabricated. As the development site was located in a tightly built-up work site in the heart of Singapore's historic Chinatown, the use of prefabrication for the building facade, columns, walls, slabs, household shelters, internal partitions and other key building components off-site helped to significantly improve the ease of construction works. This building method also increased productivity and reduced the impact on the surrounding living environment.

The Pinnacle@Duxton is visually dynamic and interesting. Yet surprisingly, the entire facade is primarily made of large-panel precast elements using an undifferentiated modular construction method. Put together innovatively through good design, this project is a stellar example of how creative designs allow buildings to remain buildable without compromising on the quality of architectural form.

Pinnacle@Duxton.

This award-winning public housing development was 90% prefabricated.

Photo courtesy of ARC Studio Architecture + Urbanism, Singapore

In line with the government's efforts to upgrade construction technology and minimise demand on construction labour, there are also plans for Integrated Construction and Prefabrication Hubs (ICPH) to be developed in Singapore. These high-tech multi-storey hubs are intended to bring all existing technologies together to provide a major capability upgrade for the construction industry. In 2013, BCA announced the development of the first ICPH at Kaki Bukit awarded under a public tender. Upon completion, the new ICPH is expected to be equipped with a state-of-the-art automated production line, which will have an annual production capacity of more than 100,000 cubic metres of precast components (three times more than a conventional, open precast yard). The high-tech multi-storey factory setting will not only speed up the production process but also provide better quality control of the precast concrete products. The ICPH will also be capable of producing structural, architectural as well as pre-finished, pre-assembled products for use in both public and private-sector projects.

> *"With our productivity drive towards off-site production, mechanisation and standardisation, the demand for precast components will increase significantly in the next few years. The concept of the Integrated Construction and Precast Hub is suitable for Singapore, as it allows us to intensify land use while ensuring production of high-quality precast components. Such facilities will be the next step forward for our local precasters towards automation, process integration, improved quality and significant productivity improvement."*
>
> John Keung[34], CEO, BCA

LEGISLATION ON BUILDABILITY

Another area where Singapore is a world pioneer is in quantifying buildability based on our Buildable Design Appraisal System (BDAS) and applying it at a national level. The Construction Industry Development Board developed the BDAS[35] to promote building designs that required less on-site construction labour to build. The scheme emphasises a set of "3S-design" principles: standardisation of building components, simplicity in construction and installation, and single integrated elements that can be prefabricated.

Projects which are more 'buildable' are those which use more standardised dimensions or components, and adopt a higher level of prefabrication. The BDAS was voluntary in the beginning. However, as the industry became more familiar with it, the Construction 21 Committee of 1999[36], set up under the Ministry of Manpower (MOM) and the Ministry of National Development (MND), recommended that this system be made a mandatory requirement for building-plan approval. This proposal was accepted and incorporated into the Building Control Act, which came into effect in 2001. Today, it remains a key driver in promoting buildable design through greater adoption of prefabricated, modular and standardised building components. Under the legislation, building designs are required to comply with a minimum buildable design standard.

While the industry has gained more experience with buildable designs, more can still be done to enhance buildability and further reduce labour usage. Buildable designs have to be complemented with the adoption of labour-efficient technologies and methods to improve productivity at the construction stage. To achieve this, BCA introduced the Constructability Appraisal System in 2011 where builders have to comply with a minimum constructability score, which requires the use of productive construction technologies, methods and processes that help reduce the industry's reliance on site workers. Positive correlations have been observed between higher buildable design scores and improvements in site productivity, construction quality and manpower consumption.

CORENET AND BUILDING INFORMATION MODELLING: KEY ENABLERS FOR PRODUCTIVITY

In addition to legislations, the government is leveraging information technology to enhance the performance and competitiveness of the construction industry. This comes in the form of two main IT platforms in Singapore: Construction and Real Estate Network (CORENET) and Building Information Modelling (BIM).

CORENET[37] is the flagship IT project initiated by MND, and driven by the BCA in collaboration with various other government agencies. Launched in 1995, it was introduced to re-engineer business processes used in the industry to achieve a quantum leap in turnaround time, productivity and quality. CORENET is an interactive platform, a one-stop shop for building professionals to make electronic submissions to the BCA or any of the other 15 government regulatory authorities from anywhere at any time (24/7). It has transformed a time-consuming and complex building plan and construction permit submission process into one which is highly efficient. Internationally, the CORENET system has contributed to Singapore being ranked the fastest in the world to issue construction permits and the world's most business-friendly economy in the World Bank's Doing Business Ranking for seven years, from 2006 to 2012.

"After the Asian financial crisis, the construction businesses went down from $27 billion in 1997 to $11 billion in 2001. All of us managed to survive that downturn. E-submission was certainly a major factor that helped us save manpower and cost... E-submission was a game-changer for the whole industry because it made the architects, consultants and engineers see that technology is something that can be used to minimise manpower."

Lee Chuan Seng[38], former Deputy Chairman, BCA

In recent years, BIM has also become one of the most exciting developments in the building and construction industry, significantly improving the design and construction process through more integrated project coordination. Fundamentally, it is a software application that enables the creation and modification of building plans in three dimensions (3D). Compared to the traditional two-dimensional plans, these 3D virtual models allow for more effective collaboration among architects, engineers, contractors and building owners because of the ease of visualisation and making design changes. Multiple systems within each building may also be thoroughly checked before construction even begins, reducing costs incurred due to change orders that crop up later in the project. Structured as a database, BIM systems are also able to represent the different construction phases over time, enabling stakeholders to better understand and plan the entire construction process.

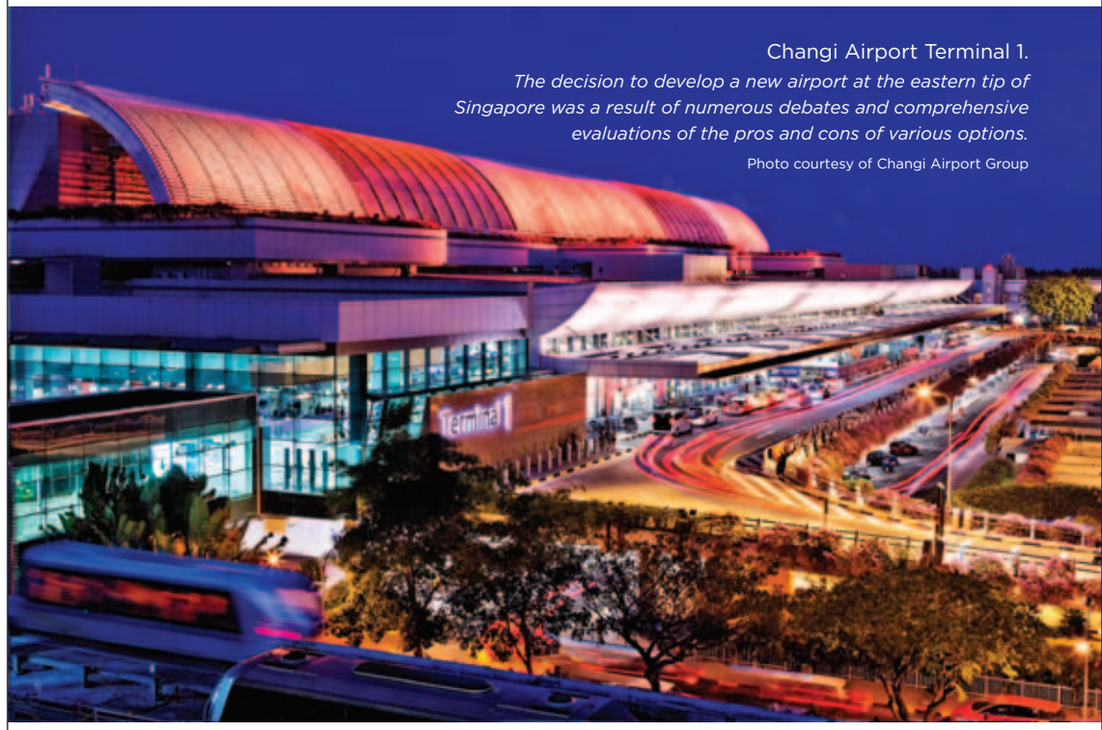
"BIM is the most critical. Because if you start from day one using BIM, it helps you to do many things. Detecting conflict in your engineering and your architect's design, plan your schedule, do your costing and even manage your building subsequently because there's a 3D model, so under our BIM roadmap, we have made it a mandatory requirement for them to submit for at least, to start with, regulatory approval by BCA. Today, we have dished out close to $20 million to help contractors, consultants, to buy software, to train their workers to use BIM. So that, to me, is an integrating element for the entire value chain. And we are not the only one doing it. The US, in their equivalent Construction and Productivity Road Map, are doing the same thing. So as in the UK, so as in Japan."

John Keung[39], CEO, BCA

To complement and encourage the increasing use of BIM, CORENET has included e-Submission capabilities as part of its web infrastructure since January 2010 for architectural BIM, and since April 2011 for engineering BIM.

CASE STUDY: A WORLD-CLASS AIRPORT IN THE SEA

Changi Airport is a pioneering project that shows what Singapore engineers, along with innovative technologies and policies, can do for infrastructure developments of unprecedented scale and complexity.



Changi Airport Terminal 1.
The decision to develop a new airport at the eastern tip of Singapore was a result of numerous debates and comprehensive evaluations of the pros and cons of various options.
Photo courtesy of Changi Airport Group

As a small island country, Singapore relies heavily on international transport infrastructure nodes to connect with the rest of the world. Prior to the development of Changi Airport, Paya Lebar Airport served as the main civil airport in Singapore. It was launched in 1955 with a single runway, and in the 1960s, around S$800-million[40] was invested for numerous improvements, including a runway extension and the addition of a new passenger terminal. By the mid-1970s, it became evident that the Paya Lebar Airport would not be able to cope with the growing air traffic for much longer, and a bigger airport was needed.

When Singapore wanted to expand its airport operations in the early 1970s, the government commissioned a number of airport studies.[41] In 1972, the cabinet accepted the British aviation consultant's recommendation to build a second runway and additional ground facilities at Paya Lebar by 1978. However, unsure about the long-term sustainability of the proposed option, then Prime Minister Lee Kuan Yew asked for a reassessment by American consultants, and a further study by a committee of senior officials, on the viability of transforming the Royal Air Force (RAF) airfield in Changi into a commercial airport. Both recommended staying with the Paya Lebar plan[42] because the alternative of moving to Changi would mean the loss of investments made on Paya Lebar and the high cost of relocation that would amount to about S$1.5 billion[43].

> *"I was not satisfied and wanted the option of moving to Changi reconsidered. I had flown over Boston's Logan Airport and been impressed that the noise footprint of planes landing and taking off was over water. A second runway at Paya Lebar would take aircraft right over the heart of Singapore city... Once built, we would be saddled with the noise pollution for many years."*
>
> Lee Kuan Yew[44], founding Prime Minister

The plan to expand Paya Lebar Airport would have proceeded if not for the global oil crisis that erupted in 1973. Oil prices quadrupled, slowing air traffic and delaying the need for a second runway. This presented a window of opportunity to reconsider the relocation of the airport, and Lee appointed Howe Yoon Chong, then Chairman of the Port of Singapore Authority, to chair a top-level committee for a final reappraisal to assess the feasibility of relocating the airport to Changi before a second runway was needed for Paya Lebar. The Special Committee on Airport Development headed by Howe concluded that it was possible for Changi Airport to be ready by 1981, and made the final recommendation of constructing a new airport there[45].

The committee cited a few key reasons for favouring the Changi site. Firstly, as the site was located at the eastern tip of Singapore, its flight path would be largely over the sea, hence posing fewer concerns over air pollution, noise pollution, as well as other types of risks and hazards. Secondly, unlike the Paya Lebar option which would entail sterilisation of large tracts of economically viable land in city areas due to height constraints, building a new airport at Changi would significantly minimise the constraints on the land-development potential around

the airport and along the flight path. Thirdly, given the need to ensure good local transportation connectivity between the airport and the rest of the city, the Changi site was preferred as it offered opportunities of providing better road access[46]. Last but not least, land was more readily available at Changi given that land acquisition was less of a problem, and that additional land required for the development could be reclaimed from the sea thanks to advancement in soil treatment, consolidation, engineering and mechanical construction technologies[47].

In April 1975, having taken into account the political situation in the region and its implications on the nation's growth, Lee made the executive decision to relocate the airport to Changi. The task of building Changi Airport fell on Sim Kee Boon, then Permanent Secretary of Communications.

The success of the Changi Airport project was highly dependent on the exceptionally high level of inter-agency collaboration and teamwork. To spearhead the project, an Airport Development Division (ADD) was formed within the PWD, comprising experts from a wide range of divisions, including architects as well as civil, structural, mechanical and electrical engineers. Outside the PWD, an interdisciplinary committee with representatives from more than 16 stakeholder organisations, such as the Ministry of Communications, Department of Civil Aviation, Public Utilities Board, Port of Singapore Authority, and Telecommunication Authority of Singapore, was formed to drive the project forward.

Site preparation at Changi officially commenced in June 1975. Working together with a Dutch consultant, the PWD drafted the Changi Airport Master Plan and started clearance works, which involved demolition of buildings, exhumation of graves and clearing of almost 200 hectares of swamp land. In the meantime, land reclamation works were carried out to enlarge the land needed to build the new airport. The whole site-preparation exercise was a massive challenge as a large portion of the airport pavement was situated on either existing land that was swampy or on newly-reclaimed land underlain by a thick layer of soft marine clay. As a result, extensive soil improvement works had to be carried out to improve the subsoil condition to minimise post-construction settlement, which would compromise the structure of the pavement.

> *"We used a lot of sand for the land reclamation. The whole reclaimed land was formed by depositing sand hydraulically. Initially, sea sand for reclamation was dredged from the nearby sea. However, when more land was to be reclaimed, alternative sources of materials had to be explored. Because construction was on*

reclaimed land and the ground was underlain by a thick layer of soft and compressible marine clay, it was necessary to pre-compress the soft marine clay and densify [sic] the loose hydraulic fill before building the airport pavement. It was the first time that we used the vertical sand drain system on a big scale to improve the soil. After that, the prefabricated vertical drain (PVD) system was also introduced, and is now commonly used for soil improvement work in Singapore and elsewhere... Extensive instrumentation was also carried out to monitor the soil improvement work. It was a time for pioneering work in geotechnical engineering in Singapore where different soil improvement and instrumentation methods were tried out on a large scale."

Tan Siong Leng[48], former Deputy CEO, URA

Beyond the development site, the PWD was responsible for building other public infrastructure in support of the airport project. For instance, plans for two expressways were laid out to link Changi Airport to the city: the Pan-Island Expressway (PIE) and East Coast Parkway (ECP). Both were completed in 1980, dovetailing the airport development timeline.

Phase 1 of the Changi Airport development was fully completed within six years in 1981, with Terminal 1 up and running on 1 July that year. Given the complexity of the construction process, this was considered an achievement even by international standards.

Over the years, the airport has continued to expand steadily with the opening of Terminal 2 in 1990 and Terminal 3 in 2008. Thanks to innovation and advancements in prefabrication construction technologies, precast structures made off-site in Tuas were delivered to the construction site at night to mitigate noise and traffic problems. This also allowed expansion works to be carried out efficiently on-site while the airport remained in full operation.

"The construction work was carried out 24 hours a day. Our engineers were required to be present day and night and they went on [in] two shifts. Sometimes engineers who worked through the night until morning might have to continue working into the late morning if replacements were not available... they worked very hard, and built very good relationships and working culture in the PWD... when the airport was opened, all of us were very proud. It was an achievement for PWD."

Kok King Min[49], former Director of Airport Development, PWD

CHAPTER 5

VISION: QUALITY, ACCESSIBILITY AND SUSTAINABILITY OF THE BUILT ENVIRONMENT (1990s – 2000s)

> Engineers could always try new things in HDB. There was no dedicated research centre back then, but one can say the whole HDB is a 'big research centre'...

Johny Wong, Group Director, HDB

Quality, accessibility and sustainability have become key focus areas in the more recent part of Singapore's building journey. Recognising the importance of quality in the built environment, the Singapore government has been guiding the industry towards better workmanship and the use of higher-standard finishing through a quality assessment programme for more than two decades. There has also been greater emphasis on the need to reduce the environmental impacts of buildings as well as to improve the accessibility of the built environment, to offer greater inclusiveness to a rapidly ageing population and to people with disabilities.

ENHANCING CONSTRUCTION QUALITY THROUGH ASSESSMENT PROGRAMMES

CONQUAS: A National Yardstick of Workmanship Quality

Initiated in 1989, the Construction Quality Assessment System (CONQUAS) is an objective quality assessment tool for construction workmanship. The scoring system assesses the quality of building projects by scrutinising random samples taken during various stages of the construction process. The appraisal is based on a combination of visual assessment and the use of measurement tools to measure against current standards. For instance, in the early days, water leakage was a major concern in many buildings, and waterproofing was therefore an important indicator of the construction quality. Following the implementation of CONQUAS, incidents of water leakage were significantly reduced. Thanks to the system, the overall quality of building developments in Singapore has experienced good improvements over the past two decades, with average CONQUAS scores rising from 67.9 in 1989 to 88.2 in 2014. This number underscores the efforts and improvements made by the building and construction industry to raise the quality of Singapore's living spaces.

The introduction of CONQUAS also facilitated a fairer incentive scheme to build up local capability. Under the previous Preferential Margin Scheme, local builders received an additional 5% tendering advantage over foreign builders when bidding for government projects. Up until the late 1980s, there were concerns from foreign builders regarding the fairness of the preferential scheme. In response, the government replaced the Preferential Margin Scheme with CONQUAS, in an effort to provide for improved accuracy in the assessment of performance quality. Further support for construction quality came in the form of a bonus given upon project completion for quality scores that were above the industry average. Correspondingly, poor quality would result in a deduction in payment. Contractors who consistently produced good quality work were given a tendering advantage when bidding for future government projects.

Since then, the contracting process in the construction industry has become more open. Based on quality scores, whoever scores higher, whether foreign or local contractors, will get an advantage when tendering. Although CONQUAS is not a mandatory requirement for private-sector projects, developers and builders have committed as much as 95% of private residential and commercial projects in Singapore for the assessment. CONQUAS provides the industry, especially builders and subcontractors, with a systematic way to measure and achieve a certain level of quality. The system has also evolved over the years to ensure its relevance to the industry and it is now in its 8th edition, which aims to improve quality through productive technologies, materials and systems.

The Quality Mark: Towards Even Higher Standards

To push for even higher standards of workmanship in residential developments, the Quality Mark (QM) was introduced in 2002. This voluntary scheme measures the quality of workmanship in every newly-completed residential unit and certifies the condition of the unit at the time of inspection. All toilets and bathrooms within each unit are also subjected to water tightness tests.

Homeowners of these certified units are reportedly more satisfied with their purchase, as less rectification work is required upon taking over the units. The QM is based on the same standards as CONQUAS. However, under the QM scheme, the BCA assesses every single unit of newly-completed residential projects. Over the past few years, the number of QM units has been steadily increasing, with more than half the units in private residential developments launched in Singapore being committed to the scheme[50].

> *"Our CONQUAS system is an open book to anyone who wishes to follow it. The scoring method is replicable. However, the critical factor to the success of implementing CONQUAS is the reliability of the scoring. Building a reliable assessor team – so that there is a high level of consistency among assessors and the final quality score is not dependent on only one or two assessors – cannot be replicated easily..."*
>
> Lam Siew Wah[51], Deputy CEO, BCA

The motivation for builders and developers to volunteer for a quality assessment scheme stems from a marketplace that has become much more sophisticated, as consumers' expectations continue to rise. The CONQUAS and QM schemes have been replicated in other countries, for example, in Malaysia.

In general, these accomplishments in raising standards represent significant steps towards a high-quality built environment in Singapore. To build on these successes, the government has created an ecosystem centred around the CONQUAS through the 2nd Quality Master Plan launched in 2013. This master plan detailed measures to promote the adoption of these quality schemes in a wider range of projects. It also aims to equip industry and practitioners with more skills and expertise in the areas of construction quality, productivity, and generate greater awareness among consumers of these quality systems.

TOWARDS SUSTAINABLE DEVELOPMENT VIA THE BCA GREEN MARK SCHEME

Singapore began to put more emphasis on the environmental sustainability of its buildings with the launch of the BCA Green Mark in 2005. The Green Mark is a leading green building rating system in the tropics and sub-tropics and serves as a benchmark for evaluating environmental sustainability in buildings. The system provides a comprehensive framework for assessing the overall environmental performance of new and existing buildings, thus promoting sustainable design, construction and operational practices in the built environment.

Under the assessment framework for new buildings, developers and design teams are encouraged to design and construct sustainable green buildings which can promote energy savings, water savings, healthier indoor environments as well as the adoption of more extensive greenery for their projects. As for existing buildings, building owners and operators are encouraged to set and meet sustainability goals in their operations, and to reduce adverse impact of their buildings on the environment and occupant health over the building's lifecycle. To advance the green building agenda in the region, the BCA has created a variety of schemes to promote Green Mark for different types of built environment. Exhibit 3 shows the various BCA Green Mark schemes available to date.

Exhibit 3:
Categories of Green Mark Schemes[52]

New Buildings	• BCA Green Mark for New Non-Residential Buildings • BCA Green Mark for New Residential Buildings • BCA Green Mark for Landed Houses • BCA Green Mark for Healthcare Facilities
Existing Buildings	• BCA Green Mark for Existing Non-Residential Buildings • BCA Green Mark for Existing Residential Buildings • BCA Green Mark for Existing Schools
Beyond Buildings	• BCA Green Mark for Infrastructure • BCA Green Mark for Districts • BCA-NParks Green Mark for Existing Parks • BCA-NParks Green Mark for New Parks • BCA-LTA Green Mark for Rapid Transit Systems
Occupant-Centric	• BCA Green Mark for Office Interior • BCA Green Mark for Restaurants • BCA Green Mark for Retail • BCA Green Mark for Supermarkets • BCA-IDA Green Mark for Data Centres

The assessment criteria cover a few key areas, including energy efficiency, water efficiency, environmental protection, indoor environmental quality, and other green features and innovation. The assessment identifies the specific energy-efficient and environment-friendly features and practices incorporated in the projects. Points are awarded for incorporating environment-friendly features that are better than those used in normal practice. The total number of points obtained provides an indication of the environmental friendliness of the building's design and operation. Depending on the overall assessment and points scored, the building may be certified to meet the BCA Green Mark rating of Platinum, Gold^{PLUS}, Gold or Certified.

As a whole, the Green Mark system in Singapore is similar to the Leadership in Energy and Environmental Design (LEED) system in the United States or the Building Research Establishment Environmental Assessment Methodology (BREEAM) in the United Kingdom. The key difference is that Singapore places more emphasis on energy efficiency in the certification system. For example, energy efficiency accounts for a quarter of the entire scoring system in the LEED system, whereas in Green Mark, this accounts for 50% or more of the score.

> *"Our green building rating system must have a strong emphasis on energy efficiency, energy conservation and energy security... the weightage and the criteria would be quite different from other similar systems in the US, Europe and Japan... We believe that we need to have our own green building standards that meet our own requirements in this region, in the tropics."*
>
> John Keung, CEO, BCA

Efficient energy usage is an important aspect of building sustainability. Worldwide, buildings use about 40%[53] of global energy. In Singapore, the percentage is even higher, with buildings accounting for around 50%[54] of the country's total energy consumption. This justifies the greater weightage on energy efficiency for the Green Mark assessment in Singapore.

To guide Singapore's green building strategy and to promote wider adoption of the BCA Green Mark scheme, the BCA launched three progressive green building master plans to systematically provide direction and targets for the built environment. Each master plan is a comprehensive suite of policies and measures aimed at accelerating the pace of green building development towards meeting the national target of having at least 80% of all buildings achieve the Green Mark Certified rating by 2030. The 1st Green Building Masterplan, launched in 2006, focused on greening new buildings. Funds were used to incentivise private developers to adopt environmentally-friendly building technologies and building design practices. This was followed by the 2nd Green Building Masterplan, launched in 2009, that emphasised the adoption of energy-efficient retrofitting designs, technologies and practices to achieve a significant improvement in the building energy efficiency. Launched in 2014, the user-centric 3rd Green Building Masterplan was formulated with a vision of making Singapore "a global leader in green buildings, with special expertise in the tropics and sub-tropics - enabling sustainable development and quality living." Guided by the national target and vision, there will be more engagement with the stakeholders and partners to progressively roll out economically sound, innovative and pragmatic measures to further green the large existing building stock, and engage tenants and occupants as well as the young to play a bigger role in Singapore's green building movement.

The implementation of these successive master plans requires extensive capability building in the industry. Since 2007, the BCA Academy has developed a full suite of courses ranging from certification-level Green Mark Managers and Green Mark Professional courses, to master degree courses jointly organised with the University College London and the University of Nottingham to ensure that professionals are well-equipped with the relevant skills and knowledge in green building design, construction, management and operation. Today, there are more than 6,000 green-collar professionals and technicians trained by the BCA Academy.

Overall, Singapore's Green Mark building projects have increased rapidly since the launch of the BCA Green Mark Scheme. The number of green building projects has grown from 17 in 2005 to close to 2,300 in 2014. In 2014, Singapore crossed a major milestone by greening around 27% of the entire building stock across the city-state. The government expects to cooperate more closely with the private sector and the community through multi-faceted building energy policies to attain the goal of greening 80% of all buildings by 2030. This will boost Singapore's position in playing a greater role in leading the region towards sustaining a more energy-efficient built environment.

On a wider scale, the BCA Green Mark Scheme has also gained regional recognition. From 2005 to 2014, projects that have applied for Green Mark certification in the region have increased to more than 250, covering 44 million square metres in 15 countries and 71 cities, making Singapore the green building hub of the region.

> *"Policies alone cannot achieve the social and economic changes that sustainability will require. Businesses and the community must work in partnership with government as the latter sets the tone, takes the lead and does its best to support their efforts... In Singapore, more can be done in terms of policy incentives, provision of accurate information as well as raising awareness of greenhouse-gas emissions to help building owners make more informed decisions and take the necessary action to improve the energy-efficiency performance of their buildings."*
>
> Lam Siew Wah[55], Deputy CEO, BCA

IMPROVING ACCESSIBILITY: AN INCLUSIVE BUILT ENVIRONMENT

The Code on Barrier-Free Accessibility in Buildings was first introduced in Singapore in 1990 by the Building Control Division (BCD) of the then Public Works Department (PWD). It was originally written to primarily address the needs of wheelchair users,[56] having a focus on enhancing accessibility to and within buildings. Through the years, following periodic reviews of the Code, its scope has been broadened extensively to accommodate a wider group with special needs, such as people with other forms of physical infirmities or limitations, who are not necessarily wheelchair-bound, as well as families with young children and the elderly.

To prepare for a rapidly ageing population, the government also started to place greater emphasis on making buildings and urban spaces in general, more elderly-friendly. Improved accessibility has been identified as a key enabler to support "ageing in place", whereby the elderly can live out their lives in the same neighbourhoods that they are familiar with.

While the Housing Development Board (HDB) had been proactive in promoting a barrier-free environment within HDB estates, a large number of pre-1990 private buildings remain "inaccessible". To encourage more private building owners to voluntarily provide basic accessibility within their existing buildings, the BCA introduced a $40-million Accessibility Fund in 2007, committing to co-pay up to 80% of the construction costs required to make old private buildings barrier-free.

To balance the different, and sometimes conflicting, needs of the interest groups that the Code seeks to serve, a Tripartite Review Committee was formed to facilitate a review of the Accessibility Code. Using this platform, representatives from relevant government agencies, industry associations and many voluntary welfare organisations were able to iron out issues of concern and achieve a balanced set of requirements that would best meet the needs of the community. Feedback and suggestions from the general public were also taken into consideration before finalisation of the Code.

> *"While BCA is not a statutory board in charge of community development, we do have an important role to play in fostering a cohesive and resilient society. The extensive provision of accessible facilities and features enables people of all ages and needs to lead a quality life and communicate with one another. These facilities help ensure that no one is left behind and everyone can contribute and participate to make a difference in the community."*
>
> John Keung[57], CEO, BCA

To create an environment that better addresses the needs of all age-groups and people of different abilities, the concept of Universal Design (UD) – which simply means "designing for people of all ages and abilities" – has gained importance over the years. Following a joint publication with the National University of Singapore entitled "Universal Design Guide for Commercial Buildings"[58] in 2006, the BCA introduced a new Universal Design Guide in 2007 that provides a more comprehensive set of guidelines and design recommendations that are applicable not only to commercial buildings but also residential buildings and public communal facilities. The Guide was meant to complement the requirements mandated by the Code on Accessibility, and to encourage building owners, developers and designers to go beyond barrier-free accessibility and UD as an integral part of the

building design and development process. To further encourage this, the BCA rolled out a UD Mark Certification Scheme in 2012 to recognise building developers and designers who apply UD in their developments.

The responsibility of improving accessibility in Singapore's built environment does not lie with the BCA alone. Other key public infrastructure provision agencies such as the HDB and Land Transport Authority (LTA) have an important role to play as well. In 2014, the BCA collaborated with National Parks Board to launch a new UD Mark Certification Scheme for parks and public spaces, with the intention of extending UD concepts beyond the confines of buildings. The BCA Academy, in anticipation of higher demand for UD expertise, has started running a certification course for UD Assessors since 2012 to ensure that professionals are well-equipped with the relevant skills and knowledge[60].

CASE STUDY: GREEN LIVING AT PUNGGOL ECO-TOWN

> *"Engineers could always try new things in HDB. There was no dedicated research centre back then, but one can say the whole HDB is a 'big research centre'. Whenever we get the opportunity, we will try to impress upon our bosses to try new ideas on a small-scale experimental basis. If you look at all the innovations in HDB, they all came from different parts of experimentation to form the whole story."*
>
> Johnny Wong[61], Group Director, HDB

The HDB, as the housing provider for more than 80% of Singapore's population, has a key role to play in supporting the nation's commitment to improve building and environmental sustainability of the built environment. While much has been done, there is a need to stretch the environmental targets and do more through new ideas and innovations. Punggol, located in the northeast region of Singapore, was identified as a town with potential for this purpose.

Promoting a sustainable lifestyle has been at the heart of the planning and design of Punggol eco-town. One key green initiative unique to Punggol was the introduction of a waterway traversing the town. The opportunity for a waterway arose from plans to dam up two rivers, Sungei Serangoon and Sungei Punggol, to form water reservoirs. The waterway and the new communal spaces along the promenade now provide an attractive waterfront living environment.

In 2007, the HDB launched its first demonstrative eco-friendly precinct in Punggol to showcase that innovation and sustainable development could be both practical and cost-effective[62]. Named Treelodge@Punggol, the demonstrative precinct introduced environmental features that embrace Singapore's tropical climatic conditions. It employed passive design strategies such as orientating buildings to maximise natural cross-ventilation and building in architectural features that minimise solar radiation. Green building technologies were also incorporated to facilitate efficient energy, water and waste management. Extensive greenery helps to cool down the ambient temperature, while beautifying and enhancing the living environment. Treelodge@Punggol was Singapore's first Green Mark Platinum Award public housing project. Although the upfront construction cost for the project was 5 to 8% higher compared to conventional public housing, it makes economic sense from the perspective of the buildings' whole life cycle, as the eco-features implemented help lower maintenance costs in the long run[63].

In 2010, the HDB announced plans to develop Punggol as Singapore's first eco-town. As a demonstration project, it presents an excellent opportunity to create "living laboratories" to test out new ideas and green technologies in sustainable development and integrated urban solutions. Urban solutions focusing on the five main areas of energy, urban mobility, water, resource and waste, and maintenance have been identified to help turn the eco-town vision for Punggol into reality. All in all, Punggol eco-town heralds a new generation of eco-living concepts and technologies which can be potentially replicated in other housing developments across Singapore.

> *"Punggol eco-town is a new estate that serves as a living laboratory to test new ideas and technologies. An example is the test-bed of energy-producing solar panels fitted to power lifts, pumps and lighting... At night, households can tap excess electricity generated by the panels. A waterway was created to run through Punggol eco-town to bring waterfront living to the residents. The Punggol Waterway project has won many international awards for its innovations and its adoption of green practices and novel technologies."*
>
> Khaw Boon Wan[64], Minister, MND

The Punggol Waterway.

Punggol is being developed as Singapore's first eco-town. One key green initiative is the creation of a waterway that transverses the town.

Photo courtesy of the HDB

BUILT BY SINGAPORE: FROM SLUMS TO A SUSTAINABLE BUILT ENVIRONMENT

1927
- Singapore Improvement Trust SIT was formed.

1946
- Public Works Department (PWD) was formed, and was subsequently placed under the newly set up Ministry of National Development in 1959.

1960
Housing and Development Board (HDB) was set up to replace SIT to tackle acute housing shortage.

1966
- Land Acquisition Act enacted, allowing acquisition of private land and slum resettlement to be undertaken more swiftly.

1969
- HDB completed 100,000 units of flats since its establishment.

1971
- Professional Engineers Board (PEB) was formed shortly after the enactment of Professional Engineers Act in 1970.

1973
- PWD launched the first School Building Programme.

1975
- Final decision was made to build a new airport at Changi.

1981
- Promotion of industrialised methods of construction with the key aims of reducing reliance on labour, increasing productivity and improving construction quality.
- Opening of Changi Airport Terminal 1.

1984
- Construction Industry Development Board (CIDB) was formed, responsible for setting guidelines for the construction sector.
- Construction Industry Training Centre (CITC) was formed, responsible for providing skills training to the local construction workforce. The centre was expanded to become Construction Industry Training Institute (CITI) in 1994 and later renamed the BCA Academy in 2006.

1985
- Slum-free milestone.

1986
- Hotel New World (Lian Yak Building) collapsed in March, triggering major reviews of construction regulations and tightening of building safety standards.

1988
- Town Council Act enacted to enable Town Councils to control, manage, maintain and improve the common property of public housing estates.

1989
- Building Control Act enacted, followed by the development of a series of Building Control Regulations to ensure compliance of building works with standards of safety, amenity and relevant public policies.
- Implementation of the Accredited Checker system to ensure structural safety of building designs.
- HDB Upgrading Programme (S$15 billion) announced, covering specific schemes such as SERS (Selective En-bloc Redevelopment Scheme), MUP (Main Upgrading Programme) and IUP (Interim Upgrading Programme).
- The Construction Quality Assessment System (CONQUAS) was launched as an objective quality assessment tool for construction workmanship.

1980

1990
- Introduction of the Code on Barrier-Free Accessibility in Buildings by PWD with the main intention of enhancing accessibility to and within buildings for wheelchair users. Over time, following periodic reviews of the Code, its scope has been broadened extensively to accommodate a wider group with other special needs.

1991
- Introduction of the Buildable Design Appraisal System (BDAS) as a means to measure the potential impact of a building design on labour usage, hence promoting less labour-intensive construction process.

1995
- Prefabrication Technology Centre was set up to spearhead extensive use of prefabrication and precast technologies.

1997
- The Construction Industry Joint Committee (CIJC) was formed to provide a common platform to facilitate closer inter-disciplinary collaborations and collective efforts to develop the construction sector.

1999
- PWD was corporatised to form PWD Corp.
- Building and Construction Authority (BCA) was formed.
- Construction 21 Committee was set up, under the Ministry of Manpower (MOM) and the Ministry of National Development (MND), with the key objective of reviewing Singapore's construction industry to enhance its productivity and reduce reliance on foreign workforce.

1990

2001
- Minimum buildability score under BDAS was legislated and made a mandatory requirement for building plan approvals.
- Implementation of CORENET as a one-stop e-Submission System for all planning and building plan approvals.

2002
- Introduction of Quality Mark to push for higher standards of workmanship in new private residential developments.
- PWD Corp was sold and privatised to form CPG Corporation.

2003
- The Building & Development Division of HDB was corporatised to form HDB Corp which was rebranded as Surbana in 2005.

2004
- Pinnacle@Duxton, HDB's 50-storey landmark public housing development, was launched. The project was completed in 2009.
- The Building Maintenance and Strata Management Act (BMSMA) enacted, providing a legal framework for the management and maintenance of strata properties.

2005
- Launch of the BCA Green Mark Scheme.

2006
- Launch of the 1st Green Building Masterplan.
- Introduction of the *Universal Design Guide for Commercial Buildings*. The Guide was superseded in 2007 by the Universal Design Guide which provides a more complete set of guidelines and recommendations on creating an inclusive built environment.

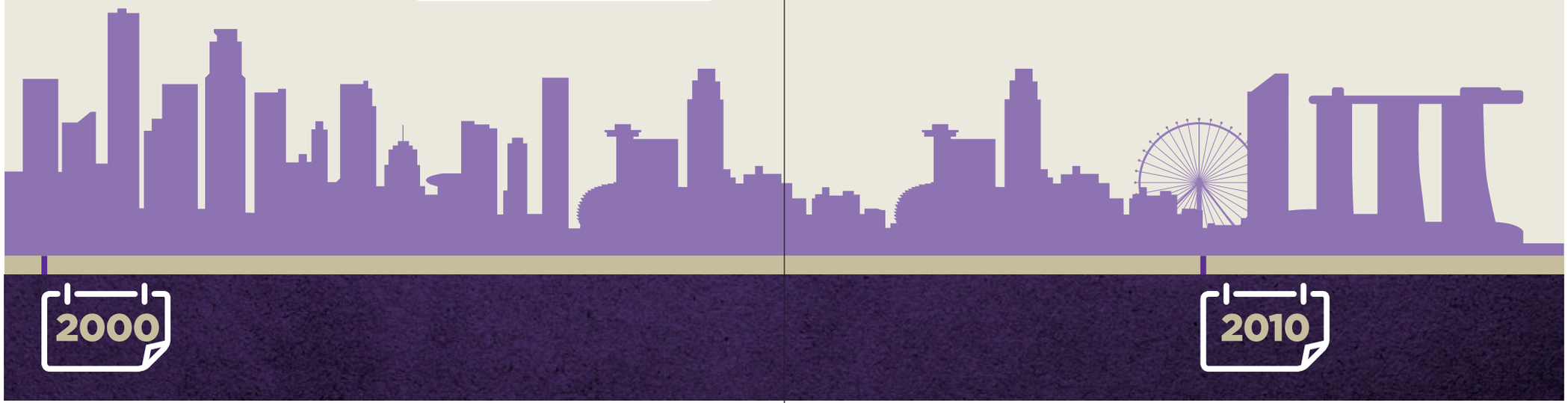
2007
- HDB launched Treelodge@Punggol, the first demonstration eco-precinct to test-bed and showcase the application of innovative design concepts and green technologies in public housing development.

2009
- Launch of the 2nd Green Building Masterplan.

2010
- Launch of the world's first BIM e-submission of architectural model through CORENET for regulatory approval in Jan. This was followed by acceptance of engineering BIM e-submission from April 2011 onwards.

2012
- Singapore celebrated the 1,000th BCA Green Mark Building project and the 100th BCA Green Mark Platinum Building project.

2014
- Launch of the 3rd Green Building Masterplan.
- As of July, BCA Green Mark Scheme has expanded beyond Singapore to 71 cities in 15 countries with more than 250 projects.



CHAPTER 6

CONCLUSION

> ...we cannot continue relying on cheap foreign workers in big numbers. We must act now before it is too late.
>
> Lee Yi Shyan, Senior Minister of State, MND and MTI

"The next three years will be a crucial transition period for the built environment sector. Construction firms will have to adapt to the tightened labour supply while seizing all opportunities to mechanise, automate and streamline workflow for higher productivity. In the longer term, the built environment sector will face increasing manpower supply constraints. Fewer workers from source countries like China and India are coming to Singapore because developments in these countries are catching up. Hence, we cannot continue relying on cheap foreign workers in big numbers. We must act now before it is too late."

Lee Yi Shyan[65], Senior Minister of State, MND and MTI

In response to key challenges faced in the different eras, Singapore's construction sector has undergone a series of evolutions in the past. Over the next few years, the government's efforts to slow the growth of the foreign workforce down to a more sustainable pace will present the construction sector with a major challenge of ensuring a much higher productivity level. To do so, there is an urgent need to change the way we build.

Firstly, there is scope to make prefabrication much more prevalent. Many local industry players have effectively adopted the use of precast and prefabrication methods in construction. Public agencies such as the Housing and Development Board (HDB) have also been key drivers of prefabrication technologies. However, a lot more can be done. To take it further, the Building and Construction Authority (BCA) has taken steps to promote an enhanced prefabrication concept commonly known as Design for Manufacturing and Assembly or DfMA for short. With DfMA, off-site production and assembly are maximised, resulting in minimum assembly work on site. Through automation and better quality control in a factory setting, much like in a manufacturing process, productivity off-site is also increased. In time to come, game-changing technologies such as Prefabricated Pre-finished Volumetric Construction[66] and Cross Laminated Timber[67] that support DfMA are expected to bring about a quantum leap in productivity, leading to significant savings in both manpower and time. It is nonetheless worth noting that the benefits of prefabrication would not be fully realised without good planning and understanding of the close relationships between design, construction, detailing, execution and manufacturing of prefabricated components. To this end, the BCA is stepping up its efforts to encourage wider adoption of powerful integrating tools such as Building Information Modelling (BIM) and Virtual Design and construction (VDC) in the built environment sector. In summary, close cooperation across the construction value chain – amongst architects, engineers, builders, precast manufacturers and suppliers of prefabrication components – is critical to the successful implementation of DfMA and productivity improvement.

Secondly, it is vital to build up in-house capabilities in Singapore, at both professional and working levels. In the early years, the public sector was the dominant player in the country's national development. A substantial body of knowledge was built up during that period. In addition to core technical expertise relating to building and construction, soft skills such as negotiation, project management, effective engagement with industry players and the public, had been accumulated. However, the corporatisation and divestment of segments of the public sector, especially the Public Works Department (PWD), resulted in the loss of strategic technical capabilities and tacit knowledge within the public service. As a result, the government has started looking into ways to rebuild in-house capabilities in recent years, with the help of relevant stakeholders including private firms, technical training institutes, and institutes of higher learning. Concurrently, much effort has also been put into improving the overall image of the building and construction industry and the job prospects it offers for key professionals, so that more local young engineers will look forward to building a career in this sector. The work environment will continue to improve with more off-site production and assembly as a result of wider adoption of prefabrication techniques. This can also help increase

the attractiveness of the industry as a whole. At the working level, skills training and upgrading will be equally important, as having a workforce that is higher-skilled and more experienced makes it easier to adopt new advanced construction technologies. With a core of competent and skilled workforce, wider adoption of Design for Manufacturing and Assembly (DfMA) and greater use of technology on site, Singapore can look forward to the development of a highly integrated and technologically advanced construction industry that creates a safe, high quality, sustainable and friendly built environment.

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APPENDIX A

Governance Tools of Singapore's Building and Construction System

(I) Legal Instruments

Acts
Housing and Development Act 1959
Housing Developers (Control and Licensing) Act 1965
Land Acquisition Act 1966
Land Titles (Strata) Act 1967 (revised 2009)
Buildings and Common Property (Maintenance and Management) Act 1973 (repealed 2005)
Town Council Act 1988
Building Control Act 1989 (Amended in 2007; a direct consequence of the Hotel New World collapse. It provides a blueprint to control building works and monitor existing structures for safety.)
Building and Construction Authority Act 1999
Building Maintenance and Strata Management Act 2004

(II) Executive Policies & Programmes

Tool	Description
Accredited Checker (AC) System, 1989	• Structural plans prepared by qualified engineers. • Plans checked and certified by AC before submission for approval.
Mandatory Inspection of Existing Buildings, 1989	• Periodic inspection of existing building. • Every ten years for residential buildings. • Every five years for other buildings.
Construction Quality Assessment System (CONQUAS), 1989	CONQUAS introduced in 1989 to measure quality achieved in completed. projects, now the national standard for quality workmanship. • Scoring system to assess contractors' workmanship standard. • Three components: structural; architectural; mechanical & electrical.
Buildable Design Appraisal System (BDAS), 1991	Assesses "structural system", "wall system" and "other buildable design features" in buildings, encourages designers and contractors to switch to more productive construction methods and technologies, such as modular and prefabricated building products.
Quality Mark Scheme, 2002	Assesses the workmanship of individual residential units.

Construction 21 Blueprint, 1999	Includes quality improvement as one of many initiatives to make the construction industry more competitive and efficient.
Construction and Real Estate Network (CORENET), 1999	Aims to re-engineer business processes of the construction industry to achieve a quantum leap in quality, productivity and turnaround time. Encourages use of IT included "e-Submission System", "Integrated Building Plan Checking System" and "Integrated Building Services Checking System".
BCA Green Mark Scheme, 2005	A building rating system that promotes use of green building designs and technologies, and aims to raise environmental sustainability and awareness among developers, designers and contractors.
1st Green Building Master Plan, 2006	Since 2008, all new buildings and existing buildings undergoing major retrofitting are required to meet the Green Mark Certified standard. • Incorporated a S$20-million Green Mark Incentive Scheme for New Buildings (GMIS-NB).
2nd Green Building Master Plan, 2009	Increased emphasis from new buildings to existing buildings and beyond building. • To green 80% of buildings by 2030, including a S$100-million Green Mark Incentive Scheme for Existing Buildings (GMIS-EB), Green Mark Gross Floor Area (GM GFA) Incentive Scheme and Building Retrofit Energy Efficiency Financing (BREEF). • New public sector buildings with more than 5,000m^2 of air-conditioned floor area to achieve Green Mark Platinum rating. • All existing public-sector buildings with more than 10,000m^2 air-conditioned floor area must meet GM Gold^{PLUS} rating by 2020. • Government land sales sites to require higher-tier Green Mark ratings (Platinum and Gold^{PLUS}).
Legislation on Environmental Sustainability Measures for Existing Buildings, 2012	• Achieve minimum environmental sustainability standard for existing buildings when installing or retrofitting a cooling system. • Carry out periodic energy efficiency audits on cooling system(s) and compliance with design system efficiency. • Submit building information and electricity consumption data annually through the BCA's Building Energy Submission System (BESS).
Sustainable Construction Master Plan (SCMP), 2012	Promotes the adoption of sustainable construction practices for all new building projects, reduces use of concrete as a key construction material by 30 to 50% over the next five years and encourages construction sector to use recycled materials.
3rd Green Building Master Plan, 2014	Emphasises the significance of the behaviour and practices of end-users, including building occupants and tenants. • All existing public sector buildings with more than 5,000m^2 gross floor area and less than 10,000m^2 air-conditioned area to achieve Green Mark Gold rating by 2020. • Rolled out a S$50-million Green Mark Incentive Scheme for Existing Buildings and Premises (GMIS-EBP).

(III) Institutions

Institutions	Description
Singapore Improvement Trust (SIT)	SIT formed following the recommendations of the housing commission and started functioning from 1927 to 1959. SIT was composed of professional architects and contractors to build affordable public housing in Singapore. However, SIT's building efforts were far from adequate to meet the needs of the fast-growing population and the housing situation worsened, especially after the Pacific War of the 1940s.
Chief Building Surveyor's Department (CBSD), Ministry of National Development	When Singapore was under the control of the British, the erection of private buildings in the city area was regulated by the City Architect and Building Surveyor under the City Council, whereas buildings in the rural areas fell under the charge of the Rural Board Building Surveyor. After self-government was attained, the Building Surveyor's section of the City Council and the Rural Board were merged to form the Chief Building Surveyor's Department under MND.
Public Buildings and Infrastructure Public Works Department (PWD)	PWD was formed in 1946 and placed under the Ministry of National Development in 1959. PWD was responsible for developing public buildings and infrastructure. In 1999, it was corporatised under Temasek Holdings before being renamed CPG Corporation in 2002.
Housing and Development Board (HDB)	The HDB was formed in 1960 to replace the SIT to plan and regulate the physical planning of Singapore. HDB is now the sole provider of public housing in Singapore.
Building Control Division (BCD)	In 1972, the Chief Building Surveyor's Department was abolished and a new Building Control Division was created under the PWD. BCD took over all the functions of CBSD. PWD was in charge of private buildings thereafter.
Construction Industry Development Board (CIDB)	The CIDB, a statutory body under the MND, was formed in 1984 and responsible for setting guidelines for the construction sector in Singapore. It is a central body to coordinate, spearhead, promote, develop, and monitor the industrialisation programme of the construction industry.
BCA Academy	Founded in 1984 as the Construction Industry Training Centre (CITC), its main role was the training of craft workers for the rapidly growing construction industry. The Centre expanded into the Construction Industry Training Institute in 1994 and was later renamed the BCA Academy in the mid-2000s.
Building and Construction Authority (BCA)	In 1999, the Building Control Division of the then Public Works Department (PWD) came together with the Construction and Industry Development Board (CIDB) to form the new statutory board: Building and Construction Authority (BCA). BCA is responsible for developing and regulating Singapore's building and construction industry as it strives towards an excellent built environment. Its role is to champion the development of an excellent built environment for Singapore. "Built environment" refers to buildings, structures and infrastructure in Singapore that provide the setting for the community's activities.
Inter-Ministerial Committee on Sustainable Development (IMCSD)	Set up in 2008, the Inter-Ministerial Committee on Sustainable Development (IMCSD) (led by the Minister for the Environment and Water Resources and the Minister for National Development) set a target to "green" at least 80% of the buildings in Singapore by having them BCA Green Mark Certified by 2030.
Strata Titles Board	Established under the Building Maintenance and Strata Management Act for matters related to the strata units or the strata development.


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