

SOARING TO NEW HEIGHTS



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Sunlight casting the floral design of the skylight into the Botanic Gardens station on 27 December 2015, when the station and 11 others on the Downtown Line 2 were opened to the public. Picture: Singapore Press Holdings

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SOARING **TO NEW** HEIGHTS

FENG ZENGKUN

Land Transport \bigcirc Authority We Keep Your World Moving

Straits Times Press

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The view of the tunnel from a Downtown Line train travelling from Tan Kah Kee station towards Bukit Panjang station. Picture: Alphonsus Chern for the Land Transport Authority

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FOREWORD

Building an underground MRT line takes a long time as tunnelling is involved.

Downtown Line, for instance, has taken 16 years from its conceptualisation to its opening. Over this period, the project was shaped and nurtured by four Ministers for Transport. It was first mooted by former Minister Yeo Cheow Tong in 2001, to essentially serve the Bukit Timah area. Later, under former Minister Raymond Lim, it evolved into a larger project, to not just link Bukit Timah to the city, but also further to the east. Then-Minister Lui Tuck Yew oversaw many of its construction marvels, including the diversion of the Singapore River. Given the scale of the project, we decided to open it in three stages. I had the fortune to see Stage 2 open for passenger service in December 2015 and to see through its Stage 3 construction.

The Downtown Line is our fifth MRT line, but for many residents along its 42 km corridor, it is their first line that links them to the rest of our rail network. Now, residents in Bukit Panjang, Bukit Timah, Bedok Reservoir and Ubi have a fast, direct rail connection to our city centre, and an alternative means to the North-South and East-West Lines. Singaporeans and tourists will also have another travel option to get to and from Changi Airport. It has enhanced the resilience of our rail network.

The Downtown Line is a significant achievement as it is our longest, fully underground and automated rail line. It also marks a milestone as it is the first line to come under the New Rail Financing Framework. Under this framework, the Land Transport Authority owns all operating assets, enabling the train operator to focus on providing quality train service.

These achievements would not have been possible without the hard work, ingenuity and perseverance of the Land Transport Authority staff and the contractors. They worked tirelessly through the years to overcome the many engineering complexities and construction challenges. It is a labour of love.

Singaporeans — commuters, motorists, affected residents and businesses — contributed too. Thank you for your patience, understanding and unwavering support throughout this journey. You suffered noise, dust, inconvenience and disruptions. You have been a great inspiration to us!

The completion of the Downtown Line marks a giant step towards our 2030 car-lite vision: to double our rail network to 360 km, to enable 8 in 10 homes to be within a 10-minute walk of a train station. Many more Singaporeans can now make "Walk, Cycle, Ride" their way of life and collectively raise the quality of life in Singapore. Let's walk-the-talk together!

KHAW BOON WAN

COORDINATING MINISTER FOR INFRASTRUCTURE AND MINISTER FOR TRANSPORT

DIER



MESSAGE

Forty-two-km-long, 34 stations and 12 interchanges. Sixteen years in the making.

This is the Downtown Line, the latest addition to Singapore's rail network.

Building the Downtown Line has been no easy feat. It has been one of the most challenging infrastructure projects in Singapore. Engineers and crew have had to excavate the deepest MRT station in the country, divert the Singapore River, blast through extremely hard granite and handle many other complexities, all the while keeping commuters moving.

There have also been unprecedented circumstances beyond what most of us can ordinarily imagine. News of the insolvency of Alpine Bau, the contractor who was to build three stations along a stretch of the Downtown Line, hit the Land Transport Authority like a bolt from the blue. In addition, the strong sentiments expressed by residents of the Maplewoods condominium due to the construction of a nearby station also caught us by surprise. In response, the Land Transport Authority swiftly stepped up its engagement efforts and proposed creative solutions to tackle the multitude of concerns.

While the issues were intense and seemed insurmountable, our staff banded together and never once gave up. With unyielding perseverance, they soldiered on, determined to open the Downtown Line as scheduled.

And they did, overcoming all of these obstacles and emerging the stronger for them.

I would like to thank our staff, partners and contractors for pulling together, against all odds, to make the Downtown Line a reality.

But most of all, thank you too, the citizens and residents of Singapore, for your steadfast support during the construction of the Downtown Line. We could not have done it without you.

This book chronicles the Downtown Line's journey from conception to completion, and the highs and hurdles along the way.

I hope you will enjoy reading it.

CHAN HENG LOON ALAN

CHAIRMAN, LAND TRANSPORT AUTHORITY

Welding work being carried out at the Tampines West station on the Downtown Line 3. Picture: Land Transport Authority



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The first MRT train breaking through the rice-paper shield in a 'tunnel' frame at Bishan station on 7 November 1987. Picture: Singapore Press Holdings

Then-Second Deputy Prime Minister Ong Teng Cheong (right) and then-Minister for Communications Yeo Ning Hong (left) going through the fare gates at Toa Payoh station on 7 November 1987, when the stretch between Toa Payoh and Yio Chu Kang stations began operations. Picture: Singapore Press Holdings

n 7 November 1987, a train with six carriages left the newly built Bishan station on the North-South Line to pick up passengers. That was the first service run of Singapore's new Mass Rapid Transit (MRT) system.

As early as 1967, Singapore's planners had predicted that the country would need a rail-based transport system within a few decades to cater to the growing population. The journey to that first train trip in 1987, however, was far from smooth.

Even in the late 1970s, the Singapore government was divided over whether to build a train system at all. While some supported the idea, others believed that the resources would be better spent on expanding the existing bus network.

To determine the way forward, the government embarked on a four-year study, which found that a combination of buses and trains would serve the country best in the long run.

In 1982, then-Minister for Communications Ong Teng Cheong announced that the government had "taken

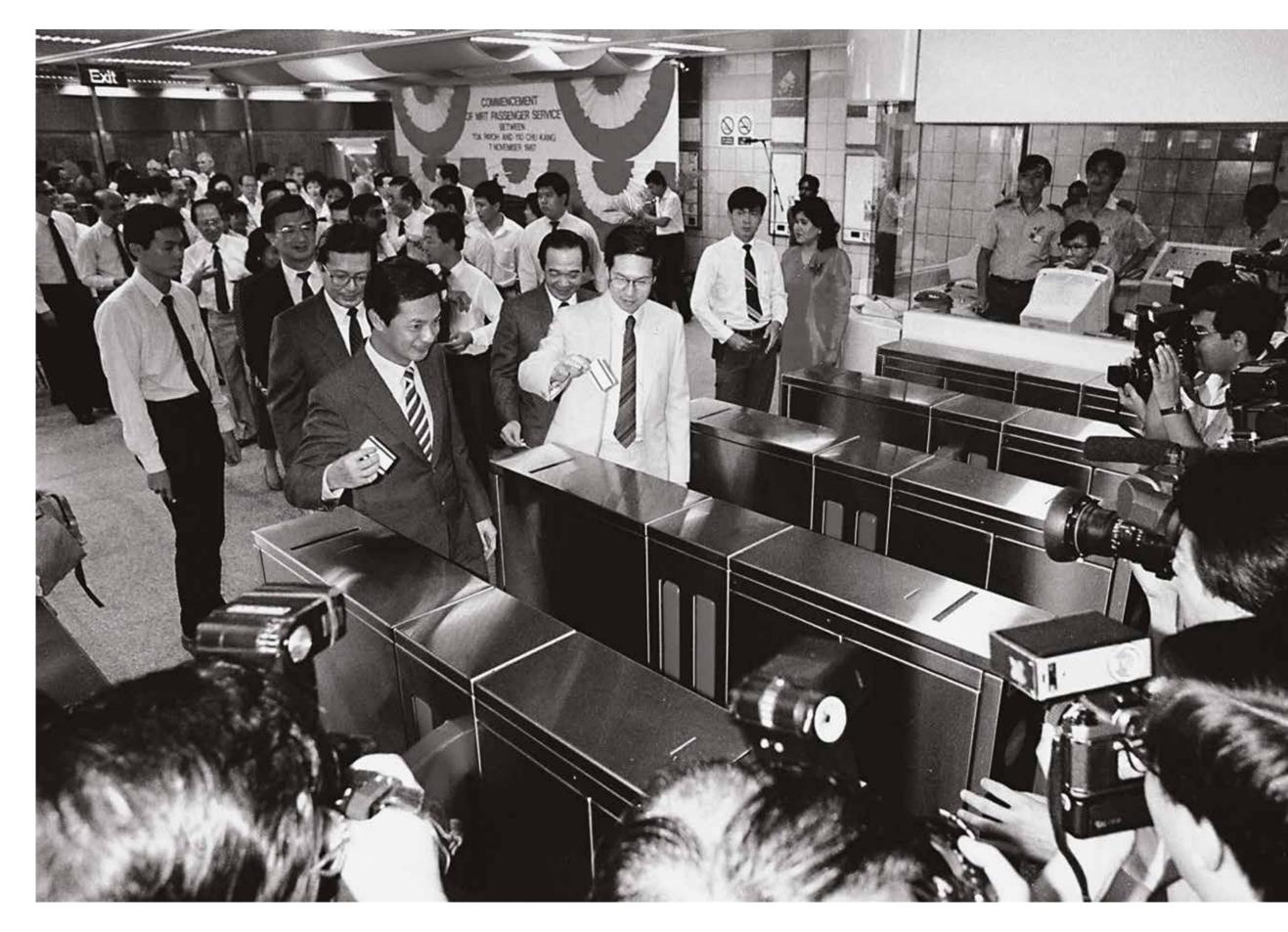
a firm decision to build the MRT". He explained: "The MRT is much more than a transport investment, and must be viewed in its wider economic perspective. The boost it will provide to long-term investors' confidence, the multiplier effect and how the MRT will lead to the enhancement of the intrinsic value of Singapore's real estate are spin-offs that cannot be ignored."

> THE STARTING LINES

On 22 October 1983, construction on the MRT system began at Shan Road, off Balestier Road, with a tunnel shaft located between the planned Toa Payoh and Novena stations on the North-South Line.

About five years later, then-Prime Minister Lee Kuan Yew officially launched the MRT system on 12 March 1988.

The original network consisted of the North-South Line and the East-West Line. Since then, commuters have been able to travel more easily and quickly to more places in Singapore on both these lines, as well as the North East Line and Circle Line, built later by the Land Transport Authority (LTA).







> HELPING YOU TO GET AROUND

Now, in 2017, 30 years after that first train left the Bishan station, the Downtown Line (DTL) is ready to join its sister rail lines.

The 42 km, 34-station train line is not just Singapore's fifth MRT line. It is also Singapore's longest MRT line that is both underground and fully automated — which will become even longer with the completion of its 2.2 km extension by 2024 — and a game changer for Singapore's public transport network.

Constructed over 10 years from 2008 to 2017, the DTL spans the length of Singapore, from Bukit Panjang in the northwest to the Singapore Expo in the east.

It extends the rail network to the schools, homes and businesses along the Bukit Timah corridor for the first time, and provides people across Singapore with a new and quick way to travel to the city centre, whether they are meeting friends for dim sum in Chinatown, going shopping in Bugis or working in Marina Bay.

Employees at the industrial estates in Jalan Besar, Ubi and Kaki Bukit can also shorten their commute by using the nearby DTL stations.

"Companies operating at the industrial estates, that have to hire buses to ferry workers to and from nearby MRT stations, will save on the cost of hiring private transport," said then-Minister for Transport Raymond Lim in 2010.

With some 500,000 commuters projected to use the DTL each day on average, the train line is already a fixture in many people's lives.

It is also critical to keeping Singapore moving towards a 'car-lite' future.

Mirroring its butterfly-like alignment was its development — the DTL underwent several changes in its early life, beginning as not one, and not two, but three separate infrastructure projects.

> HOW THE DOWNTOWN LINE BEGAN

On 23 October 2001, then-Minister for Communications and Information Technology Yeo Cheow Tong was at the official opening of the Dover station on the East-West Line when he announced three new MRT lines, two of which would later be connected to form part of the DTL: the Bukit Timah Line and the Eastern Region Line.

"As a small island, we have very limited land for road expansion. The most efficient way of meeting the transport needs of a growing population is to develop a comprehensive Rapid Transit System network, which will enable large numbers of people to move quickly along heavily populated corridors," he said.

Timah Expressway.

DTE were on the cards. Region Line. to the Marina Bay."



Then-Minister for Communications and Information Technology Yeo Cheow Tong waving to commuters at the Dover station on 23 October 2001. Looking on were then-Senior Parliamentary Secretary for Communications and Information Technology Yaacob Ibrahim (rightmost) and then-Member of Parliament for West Coast GRC S Iswaran (second from right). Picture: Singapore Press Holdings

"Such a network will also provide Singaporeans with an attractive, convenient and affordable alternative to cars."

The Bukit Timah Line was envisioned to stretch from Singapore's downtown to Bukit Panjang, and run almost parallel to a route traced by the Pan-Island Expressway and Bukit

"This line is likely to be fully underground and will alleviate the heavy traffic in the Upper Bukit Timah, Bukit Timah and Dunearn Road corridor.

"It will also provide the areas around Choa Chu Kang and Bukit Panjang with a more direct link to the city centre," MrYeo explained.

The Eastern Region Line, on the other hand, was slated to loop around the often-congested East-West Line and help to relieve the latter's heavy passenger load.

"It will also be largely underground, and benefit residents in Tampines, Bedok, Marine Parade, MacPherson and Kaki Bukit," MrYeo added.

> A FIRST LOOK AT THE DOWNTOWN LINE

Four years later, in 2005, the government laid out plans to ease travel in the Marina Bay area by building a new 3.4 km-long Downtown Extension (DTE) MRT line with five stations.

Several developments had been in the works in the area, including Gardens By The Bay, and large commercial and residential complexes.

Even then, there was a glimmer of the future DTL.

Mr Yam Ah Mee, the LTA's Chief Executive at the time, mentioned that expansions of the

He explained that the LTA's goal was to eventually extend the DTE eastwards to link it to the Kim Chuan MRT Depot in Paya Lebar, and westwards to connect it to the Bukit Timah Line — a configuration that prefigures the existing DTL.

Just one year later, in 2006, then-Minister for Transport Raymond Lim revealed that the LTA would complete feasibility studies within a few years for a new line — the DTL — that would be made up of the proposed DTE, Bukit Timah Line and northern section of the Eastern

He said: "We continue to strive to provide Singaporeans with a high quality and affordable transport system. A critical pillar of such a system must be a world-class public transport system, because the vast majority of Singaporeans will use this as their principal mode of travel... The Downtown Line will enhance connectivity across the island

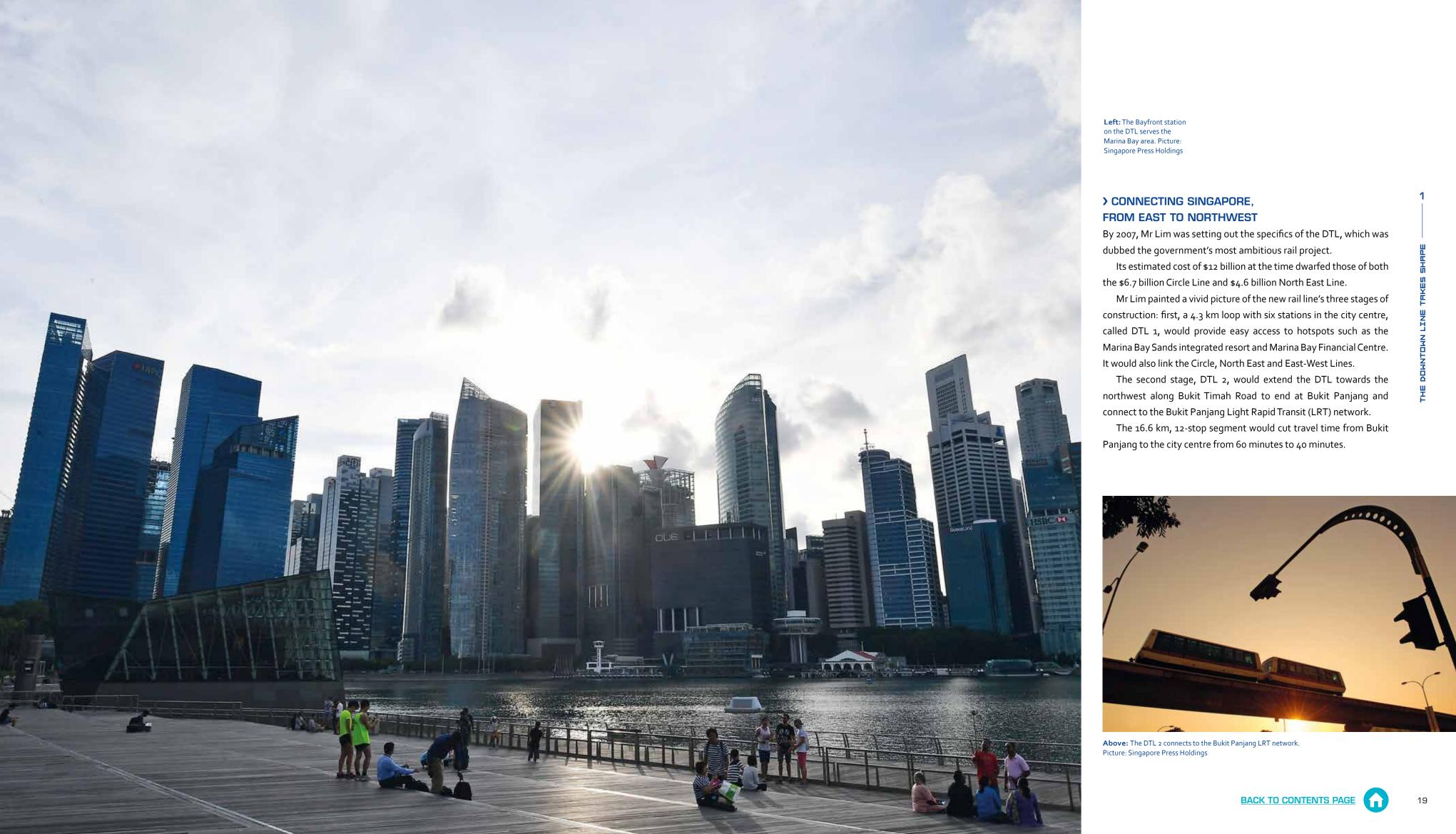




Top: Then-Minister for Transport Raymond Lim inspecting a train at the Kim Chuan MRT Depot, used for trains plying both the Circle and Downtown Lines, on 25 January 2008. Picture: Singapore Press Holdings

Above: The Kim Chuan MRT Depot, opened on 4 March 2009, has the capacity to stable 77 trains. Picture: Singapore Press Holdings







The terminal point for the DTL 3 is the East-West Line's Expo station. Picture: LTA

The DTL 3, the third and longest leg, would swing eastwards. Fifteen stations were planned along its 19.1 km length, including stops in the MacPherson, Bedok Reservoir and Tampines areas.

Its terminal point would be the East-West Line's Expo station.

The alignment for the DTL 3 was later extended to 21 km, and an additional station added in Jalan Besar to cater to people commuting to and from nearby industrial estates and future developments in the area.

Mr Khaw Boon Wan, Coordinating Minister for Infrastructure and Minister for Transport, said: "The 42 km-long DTL has overtaken the Circle Line to become Singapore's longest underground and fully automated MRT line.

"Besides enhancing resilience for our train network, the DTL will bring the MRT within walking distance of many households."



The Downtown Line edges out the Circle Line as Singapore's longest Mass Rapid Transit (MRT) line that is both underground and fully automated. It will become even longer when its 2.2 km extension is ready by 2024.



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Above: The Tampines West station on the DTL 3 brings train services within walking distance of National Servicemen recreation club SAFRA Tampines, schools such as East View Primary School and Junyuan Primary School, and Temasek Polytechnic. Picture: LTA

Right: The Bencoolen station on the DTL 3 is Singapore's deepest MRT station, at 43 m below ground. Picture: Alphonsus Chern for the LTA

> WAITING FOR THE DOWNTOWN LINE

For Singaporeans living in neighbourhoods across the length of the planned DTL, its completion could not come sooner.

Ms Joan Ang told The Straits Times in 2007 that she had to switch train lines thrice to get from Bukit Panjang to Bugis. "It's a pity the new line can't be up sooner!" the student said, adding that she often travelled to the east for her fencing lessons.

Bukit Timah housewife Jennifer Woodward looked forward to taking the MRT to town instead of a taxi, while Ms Brenda Lee, a dental nurse who lived near Bedok Reservoir, said that she would give up her car if the DTL had a station near her home.

Tampines resident Francis Tan summed up the proposed DTL's appeal: "This is great. I can go almost anywhere in Singapore."

> SETTING NEW RECORDS

"The DTL is much more than just Singapore's fifth MRT line. Its construction broke many records in the country, and set the standard for future train lines in many ways," said Mr Sim Wee Meng, LTA's Senior Group Director, Rail.









Above: Then-Minister for Transport Lui Tuck Yew (fourth from left) visiting the DTL's Gali Batu MRT Depot on 6 August 2015, with then-Minister for the Environment and Water Resources Vivian Balakrishnan (second from left) and other Members of Parliament (from left to right) Alex Yam, Liang Eng Hwa, Sim Ann and Christopher de Souza. Picture: LTA

Right: Visitors touring the area in the depot where DTL trains dock at the end of the day for maintenance. Picture: LTA The Bencoolen station on the DTL 3 is Singapore's deepest MRT station, at 43 m below ground. The station had to be constructed at such depth because of existing infrastructure such as the buildings at street level and the tunnels for the North-South and Circle Lines.

Another herculean achievement was the rerouting of the Singapore River to allow for the boring of two tunnels under it to connect the DTL 1 Chinatown station and the DTL 3 Fort Canning station. Although the LTA had diverted smaller waterways before, that was the first time it had changed the course of a river for an MRT project.

Even when one of the major contractors for the DTL 2 filed for bankruptcy out of the blue in 2013, jeopardising the planned timeline for the segment, the LTA rallied and worked around the clock to get the project back on track.

"The LTA and the replacement contractors worked tirelessly and doggedly, and pulled long hours over many nights and weekends," remembered then-Minister for Transport Lui Tuck Yew, during a visit









Picture: Singapore Press Holdings

to the DTL's Gali Batu MRT Depot on 6 August 2015. "Looking back now, there were so many obstacles that we had to overcome to build the entire DTL, from very soft soil to incredibly narrow spaces for some of the tunnels and stations," said Mr Ngien Hoon Ping, LTA's Chief Executive. "We couldn't have done it without the dedication and resilience of the whole team."

part of Singapore.

This commemorative book chronicles the journey of the DTL from inception to completion, and beyond. It captures the construction challenges, the outreach to residents, the highs and lows of the decade-long labour to bring the train line to fruition and the efforts of the men and women who worked tirelessly to make it a success. This book is also about you, and how the DTL is both for you, and could not have been realised without you. Please enjoy it.

Left: The Bukit Timah area where trains used to trundle through on railways — including that across this steel truss bridge spanning Bukit Timah Road and Dunearn Road, beside King Albert Park station — is now served by the DTL.

> CHANGING THE WAY YOU TRAVEL

Beyond the technical and construction accomplishments, the DTL is also a milestone in Singapore's public transport system, and the first step in the government's plan to double the length of the national train network to 360 km by 2030, enabling a 'car-lite' future.

For the first time, residents in the extensive Bukit Timah corridor can now hop onto the MRT network easily and travel to every other

Students from across the island who are enrolled in schools in Bukit Timah can also take the train to and from home instead of relying on buses or their parents to drive them.

Singaporeans going on vacation overseas can take the DTL and transfer at the Expo station to get to Changi Airport. Tourists visiting Singapore can also take this route in the reverse direction to the city, giving them an alternative to the East-West Line.

The DTL has changed the way many people travel for work and play. Ms Joanne Khaw, a teacher living near the Beauty World station when it opened in December 2015, told The Straits Times: "My family goes to the Botanic Gardens quite often during the weekends. With the DTL, we can now leave the car at home."



ceremony held on 21 December 2013. Accompanying him is Mr Sim Wee Meng, LTA's Senior Group Director, Rail. Picture: Singapore Press Holdings

Bugis

"The Downtown Line is our fifth major MRT line, and the beginning of our plans to double our MRT network to 360 km by the year 2030... Every day it will move more than 500,000 riders, and it will make it faster and easier for families in the eastern and north-western parts of Singapore to travel to the city centre and to the rest of Singapore. This is the first step in that journey."

Prime Minister Lee Hsien Loong, at the official opening of the DTL 1 on 21 December 2013



THE DOWNTOWN LINE, **FTR GLANCE**

23 OC TOBER 2001

Plans for two new Mass Rapid Transit (MRT) lines — the Bukit Timah and Eastern Region Lines — were announced.

21 APRIL 2007

Then-Minister for Transport Raymond Lim outlined the new DTL and its three stages of construction.

3 JULY 2009

Groundbreaking began on the DTL 2 at the Beauty World station. The 16.6 km length stretches to the northwest from the city centre and across the Bukit Timah corridor to end at Bukit Panjang. It has 12 stations.

 \bigcirc

29 AUGUST 2011

SBS Transit was appointed as the operator of the DTL.

12 FEBRUARY 2008

Groundbreaking began on the DTL 1, a 4.3 km loop in the city centre with six stations, at the Chinatown station.

MID-JULY 2011

Work resumed on the King Albert Park station and its tunnels after being suspended for close to two months. The LTA had taken steps to reduce *inconvenience to residents* of the nearby Maplewoods condominium.

28 NOVEMBER 2011

Groundbreaking began on the DTL 3 at the Expo station. The DTL 3, which spans 21 *km eastwards from the city* centre to the Singapore Expo, comprises 16 stations.

14 JUNE 2005

Plans for a Downtown Extension (DTE) line, an MRT line with five stations in the city centre, were announced.

 \bigcirc

19 JUNE 2013

One of the major contractors for the DTL 2, Alpine Bau, declared insolvency, threatening a considerable delay of at least six months to the completion of the train line.

> 22 DECEMBER 2013 The DTL 1 was opened.

29 RUGUST 2013

Contractors McConnell Dowell South East Asia and SK E&C (Singapore) were appointed to complete the work at the three stations that were being built by Alpine Bau — King Albert Park, Sixth Avenue and Tan Kah Kee stations.

15 RUGUST 2014

Plans for the DTL 3 to be extended to join the existing East-West Line and future Thomson-East Coast Line were announced. The 2.2 km DTL 3 Extension is scheduled to be completed in 2024.

> 21 OCTOBER 2017 The DTL 3 was opened.

21 DECEMBER 2015

The DTL 2 was opened

schedule. The project team

and contractors managed to

- keeping to its initial

make up for lost time.





FORGING NEW FRONTIERS



ook into the history of the DTL and you'll find a series of new records and trailblazing milestones.

From its design and construction to its operation, the rail line has rewritten the rules on what is possible in Singapore's rail sector.

To create the DTL, the LTA and its contractors diverted a river and canals, built a viaduct to redirect traffic over a construction site, negotiated Singapore's dense network of buildings and infrastructure and built the country's deepest MRT station at a depth of 43 m, the equivalent of a 14-storey building underground.

The engineers and workers also contended with soil that was as soft as toothpaste, and with rocks that were so large and extraordinarily hard that explosives and special tunnelling machines were needed to clear a way through them for construction.

Even the way the rail line is operated is unprecedented. The DTL is the first train line in Singapore to be managed under a new framework, introduced by the LTA in 2010 to boost rail service, efficiency and maintenance.

The DTL has raised the bar for Singapore's future train lines. In fact, it is a game changer in the way that the rail line has broken new ground and advanced the frontiers of the rail industry in the country.



An SMRT train on a train track at Tanah Merah station in November 2002. In 1998, the transport firm won the licence to run the North-South Line and East-West Line for the 30 years between April 1998 and March 2028. Picture: Singapore Press Holdings

> CHANGING THE RAIL INDUSTRY FOR THE BETTER

Eagle-eyed observers would have noticed that the DTL trains are the first in Singapore to sport the LTA's logo and signature blue and green colours.

This milestone is not merely a cosmetic one: it represents a fundamental change in the way that rail lines in Singapore are financed and operated.

In the past, transport companies bid for licences to operate rail lines in Singapore. Each of these licences was valid for a period of 30 to 40 years.

In 1998, for example, transport firm SMRT won the licence to run the North-South Line and East-West Line for the 30 years between April 1998 and March 2028.

Several responsibilities came with such a licence to manage a rail line and earn revenue from it.

The firm with the operand upgrade the assets n communications systems. Given this, the operator expansion, replacement an implementing any changes

> IMPROVING RAIL SERVICE FOR YOU

In 2008, the New Rail Find Master Plan. Two years later, the Ray implemented for the DTL. Under the framework, and the LTA would also tak and lease them to the oper The shorter licensing



The firm with the operating licence for a rail line was obligated to build, repair, replace and upgrade the assets needed to operate the line, such as its trains and signalling and communications systems.

Given this, the operator of a rail line might be too cautious to carry out expensive capacity expansion, replacement and upgrading works, as it bore the full financial cost and risk of implementing any changes to the line's assets.

In 2008, the New Rail Financing Framework (NRFF) was introduced in the Land Transport

Two years later, the Rapid Transit Act was amended and in 2011, this new framework was plemented for the DTL.

Under the framework, new rail operating licenses would be valid for only about 15 years, and the LTA would also take over ownership of new rail lines' operating assets, such as trains, and lease them to the operators.

The shorter licensing periods would boost competition in the rail industry, compel

The DTL trains are the first in Singapore to sport the LTA's logo, such as this one that was unveiled to the public in September 2012. Picture: Singapore Press Holdings



incumbents to improve their efficiency and service, and allow LTA to change the licences' conditions more quickly to adapt to developments in the sector.

By taking on the assets' ownership, the LTA would also free operators from heavy capital expenditures and enable them to focus on providing reliable rail service. The LTA could also undertake integrated and long-term planning for the whole rail network.

> PROVIDING FOR THE FUTURE

For their part, the companies that were appointed to manage rail lines under the new regime would have to maintain the operating assets according to a new set of requirements, or be penalised.

The firms would also have to pay an annual licence fee for the right and responsibility to operate and maintain the lines and earn revenue from them.

The money from the fees would go into a new Railway Sinking Fund, managed by the LTA and set up specifically to pay for expenditure related to the building, replacing and upgrading of the lines' operating assets.

> THE FIRST OF ITS KIND

The DTL is the first rail line to be tendered out under this new framework that will improve train service and reliability in the long run. Signalling its groundbreaking status, its trains are the first in Singapore to have the LTA's logo and colours, since the LTA owns the assets.

In August 2011, public transport operator SBS Transit successfully won the award and the first licence to operate the DTL under the new framework. In accordance with the new framework, its licence will last for 15 years from 2017.

"The NRFF is a better framework. The operator can concentrate on making sure that its train services are reliable and on time, and commuters will reap the benefits of that," said Mr Jeremy Yap, LTA's Deputy Chief Executive, Public Transport, Policy & Planning.

> BRINGING BUKIT TIMAH ON BOARD

Besides ushering in a new age in rail management in Singapore, the DTL also brings the rail network to residents and businesses in the heavily populated Bukit Timah corridor for the first time.

Residents in Bukit Panjang and Bukit Timah can now take a direct train to the city centre.



and Jacob Ball Furthermo 10 minutes' wa and save their "Ultimately get around the DTL 2 is one n at the official o



Families and nature lovers can also go to the Bukit Timah Nature Reserve, Botanic Gardens and Jacob Ballas Children's Garden more easily.

Furthermore, about 30 schools are located along the route of the DTL 2 and within five to 10 minutes' walk of a station. Students can enjoy a comfortable train ride to and from school and save their parents the drives.

"Ultimately, we aim to make Singapore a safe, green and 'car-lite' city, where all of us can get around the island conveniently, and connect with our friends and family seamlessly... The DTL 2 is one more step towards becoming such a city," said Prime Minister Lee Hsien Loong at the official opening of the DTL 2 on 26 December 2015. About 30 schools, including Nanyang Girls' High School in Bukit Timah, are located along the route of the DTL 2. Picture: Singapore Press Holdings







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> GIVE YOUR CAR A BREAK

To encourage people living and working along the Bukit Timah corridor to use the DTL, the LTA embarked on a public education campaign to help them learn about the rail line and Singapore's train system at large.

The MRT system might be unfamiliar to residents in the area, many of whom drive, explained Ms Helen Lim, LTA's Group Director, Corporate Communications.

"We wanted to acquaint these residents with the DTL and encourage them to leave their cars at home and take the train."

The message was emblazoned across banners and posters that were put up throughout the corridor, including at places where motorists would see them, such as on roadside lampposts and car-park boom gates. The LTA also organised roadshows in hotspots such as shopping centres to promote the DTL.

The LTA even created and distributed brochures which included a step-by-step guide to buying and using a travel card, a map of the MRT system, and information on the malls, schools and other attractions located near DTL 2 stations.

By engaging the schools, condominiums and businesses along the route of the rail segment, LTA officers could also address the community's questions about the line and encourage people to try it and experience its benefits for themselves.



In the months before the launch of the DTL 2 on 27 December 2015, the LTA embarked on a public education effort to encourage residents in the Bukit Timah area, many of whom own cars, to take the DTL instead of driving. Picture: LTA



As part of the public education efforts to encourage more people to take the DTL, LTA organised school talks, road shows and put up banners, such as this one outside Methodist Girls' School, to encourage more commuters to try out the DTL 2. Picture: Singapore Press Holdings





DTL stations have been equipped with bicycle parking spaces, such as this one at Stevens station, to encourage more people to ride to the stations and take the MRT, instead of driving. Picture: LTA

> BRINGING MRT BUILDING TO NEW HEIGHTS

From excavating Singapore's deepest MRT station at Bencoolen to encountering a boulder the size of a double-decker bus while digging at the site of the Little India station, the LTA and its contractors faced challenges both expected and unforeseeable during the decade that it took to build the DTL.

The LTA also recruited companies both local and overseas with relevant expertise to help build the rail line. The institutional knowledge, technical skill, and experience of LTA staff have allowed for challenging construction that had never been done in Singapore but was necessary for the DTL. Here's how the LTA and its contractors expanded the country's boundaries of construction.

Methodist Girls' School students on their way to taking the DTL 2 at King Albert Park station in April 2016. Picture: Singapore Press Holdings

UP TO

Time saved by about 65 per cent of commuters each day after the opening of the DTL 2

MORE THAN

Time saved by about 15 per cent of commuters each day after the opening of the DTL 2





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> MOVING THE SINGAPORE RIVER

"All of the research and studies had pointed to the same conclusion. To complete the DTL, the tunnels connecting the Fort Canning station and Chinatown station would have to pass under the Singapore River," said Ms Choo Chai Fong, LTA's Deputy Group Director, Infrastructure Design Engineering.

Furthermore, to build the tunnels safely, the LTA would have to do something it had never done before: it would have to temporarily redirect part of the river and fill in the original section with soil.

The LTA had considered 20 other alignments for the tunnels but rejected them all because they were either unsafe or would hurt the environment more, or both.

It also could not tunnel directly under the river, as the risk of ground subsidence or, worse, the tunnels flooding during the construction process, was too high.

In addition, the area surrounding the Singapore River had been home to the country's earliest settlements as well as a boat-building trade. Its banks had also housed warehouses. All manner of rubbish, including timber beams, reinforced concrete debris, cables and even boat anchors, had been thrown into the waterway.

While it had been largely cleaned up by 1987, chances were that some of these objects remained wedged in the riverbed.

"We couldn't tunnel directly under the river because there would have been no safe way of removing any obstruction in front of the tunnel boring machine. The risk of water rushing in would have been too high," remembered Mr Chang Kin Boon, LTA's Director, DTL 3, Civil Construction Team 2.

By rerouting the river and packing the section above the planned route of the tunnels with soil, the LTA and its contractor could safely excavate across it and clear the way of obstacles.

There was also the matter of people's livelihoods. The LTA had considered, and then decided against, damming the river entirely. Tour boats that would have had to stop operating were able to keep doing so on the diverted river throughout the three years of DTL construction, Mr Chang added.



> A HERCULEAN TASK

Right from the beginning, the complex process of rerouting the river was fraught with difficulties.

"The LTA had diverted smaller waterways before, but it had never attempted to change the course of a river for an MRT project," said Mr Indran Ratnam, who was LTA's Deputy Director, DTL 3, Civil Construction Team 2, and is now Director, Thomson-East Coast Line Civil Team 5. Furthermore, the Singapore River was part of the Marina Reservoir, he noted.

The heavy land use in the area also meant that the redirected portion of the river would come within half a car's length of the ceiling of the nearby underground Central Expressway (CTE) tunnel.

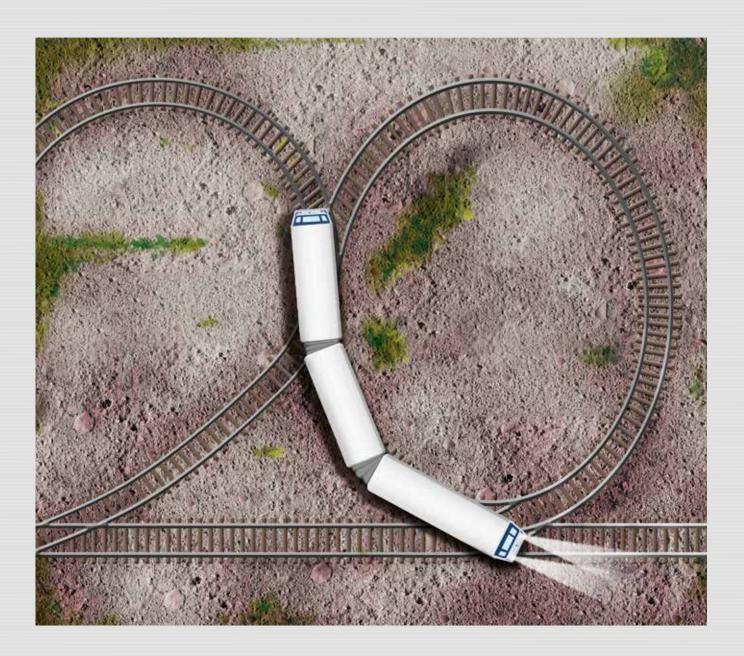
The site of the diversion was also close to the historically significant Ord Bridge, which was completed in 1886 and named after Sir Harry St. George Ord, Singapore's first governor after the territory became a British crown colony in 1867.

Additionally, work on the project could be carried out only within specific hours to avoid inconveniencing people who lived near the construction site.



Above: The site of the diversion of the Singapore River was close to the historically significant Ord Bridge, completed in 1886. Picture: Singapore Press Holdings Left: Tour boats continued plying the Singapore River during the three years that it was diverted. Picture: Singapore Press Holdings





P I Number of alignments that the LTA considered for the train tunnels between the Fort Canning and Chinatown stations, before deciding to route them under the Singapore River

completed successfully.



"The tunnels from the Fort Canning station to the Chinatown station were close to the river bed and the CTE, and right in the middle of a heavily built-up area that is a tourist belt," said Mr Frank Lai, who was LTA's Senior Project Engineer, DTL 3, Construction Team 2, and is now Deputy Project Manager, Thomson-East Coast Line, Civil Team 4. Asked if these challenges caused any sleepless nights, Mr Chang replied that they were part and parcel of the engineer's profession. "We have to factor in all the risks and do our best," he said.

> THE RIVER RESTORED

During the river diversion, the LTA also maintained adequate hydraulic flows to keep the river's water clean as it is connected to the Marina Reservoir. "That was one of our top priorities - making sure that the construction works didn't pollute the precious raw water supply to the Marina Barrage. We also didn't want to mar Clarke Quay, which is visited by many tourists," said Mr Egwin Law, LTA's Senior Project Manager, DTL 3, Civil Construction Team 3. After the tunnels were completed, the LTA restored the river to its original course as the diversion canal site was slated for redevelopment. This part of the project, too, was

During the diversion of the Singapore River, the LTA kept the river clean as it is connected to the Marina Reservoir. Picture: Singapore Press Holdings

> EAST TUNNELS' CHALLENGES

Beyond the rerouting of the Singapore River, the boring of the Fort Canning station's tunnels was also a nerve-wracking and exacting task.

Due to space constraints, part of the tunnels connecting the Fort Canning station to the Bencoolen station were built just 1 m above the North East Line tunnels, 3 m below the Circle Line tunnels and 8 m below the North-South Line tunnels.

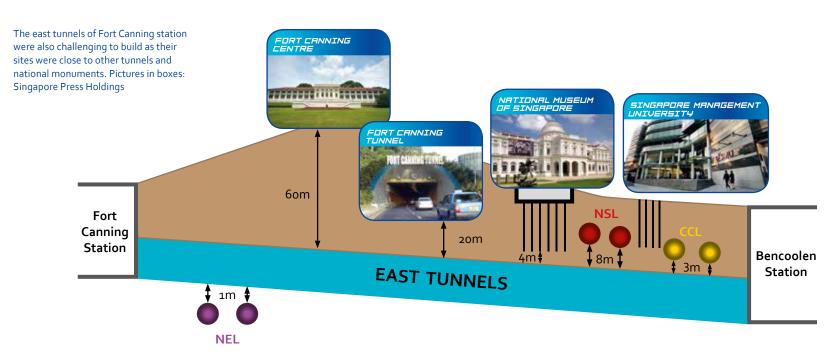
Typically, it is very risky to tunnel within 6 m of an existing train tunnel, as excessive movement of the ground could cause the train tracks in the existing tunnel to misalign and affect train service.

To cross the 'live' train tunnels safely, the LTA and its contractor studied the geology along the planned DTL tunnels' route and changed the tunnel boring machines' cutter heads in strategic locations to maximise efficiency and minimise the risk of problems.

The LTA also worked together with the Building and Construction Authority and the two public transport operators to develop risk assessment and emergency procedures.

"We used sensors and monitors to keep an eye on the 'live' train tunnels around the clock, and set a stringent movement limit of 15 mm for them," said Mr Esen Sze, LTA's Deputy Project Manager, 2 Tunnelling,

"We also checked the tracks between 1 am and 5 am to ensure that trains could continue to run on them safely at the usual speed."



The LTA also introduced safety protocols to reduce the speed of trains or even halt train service within the existing tunnels if necessary.

it continued.

> AN AWARD-WINNING PROJECT

The planning and flawless execution of the diversion, construction and restoration works impressed engineers across the world.

In 2016, the project to build the Fort Canning station and its tunnels was named the "Tunnelling Project of the Year" by the International Tunnelling and Underground Space Association.

The LTA beat world-class challengers from China and Portugal in the category of projects that cost between 50 million euros (S\$80.4 million) and 500 million euros (S\$804 million).

"As Singapore's underground space becomes more congested, the construction of its new underground metro lines has become more challenging and complex, often pushing the boundaries of engineering," read the citation for the award.

"The tunnelling project encountered and successfully overcame a host of challenges, such as cutterhead interventions required to remove building foundations, and tunnelling within close proximity to national monuments and in-service metro lines, with only 1 m separation at times,"

The design and building of the tunnels also won numerous other honours, such as the 2015 Hulme Prize from the Tunnelling and Underground Construction Society Singapore, given for the best technical paper by young engineers or students, and an Excellence Award from the Singapore Concrete Institute.

The Institution of Engineers Singapore included the project in Singapore's Top 50 Engineering Feats when it drew up the list to mark the nation's 50th year of independence in 2015.

"The entire process of diverting the river and building the tunnels was a real learning experience for us," said Mr Chua Chong Kheng, LTA's Deputy Chief Executive, Infrastructure & Development.

"The recognition for the work aside, it was really amazing that we accomplished it in the first place."

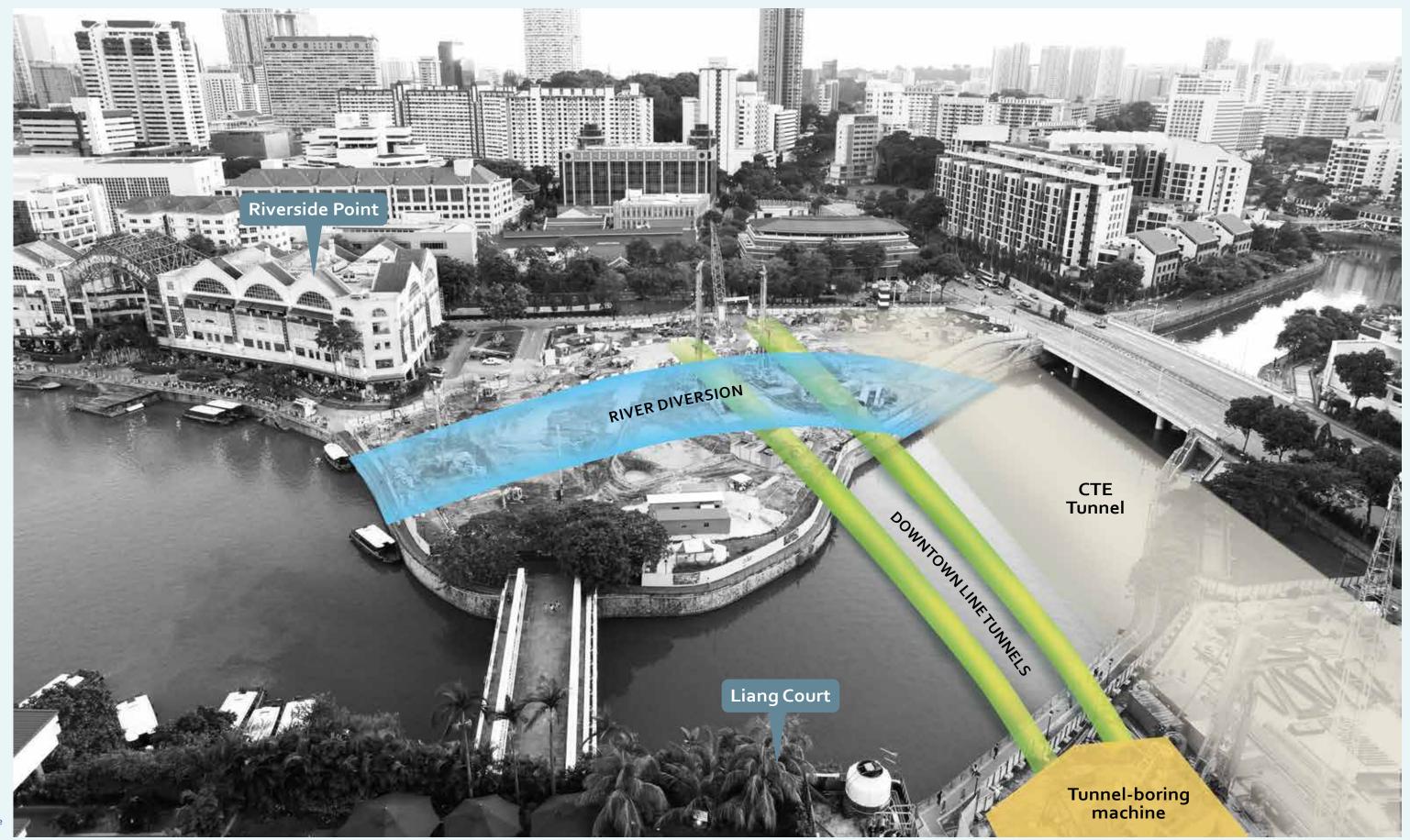
"As Singapore's underground space becomes more congested, the construction of its new underground metro lines has become more challenging and complex, often pushing the boundaries of engineering. The tunnelling project encountered and successfully overcame a host of challenges, such as cutterhead interventions required to remove building foundations, and tunnelling within close proximity to national monuments and in-service metro lines, with only 1 m separation at times."

Citation for the Tunnelling Project of the Year Award 2016



REROUTING THE SINGAPORE **RIVER**

The LTA had to divert the Singapore River to build the tunnels connecting the Chinatown station and Fort Canning station on the DTL. Here is how it accomplished the extraordinary task.



The site of the diversion for the Singapore River in April 2012. Picture: Singapore Press Holdings







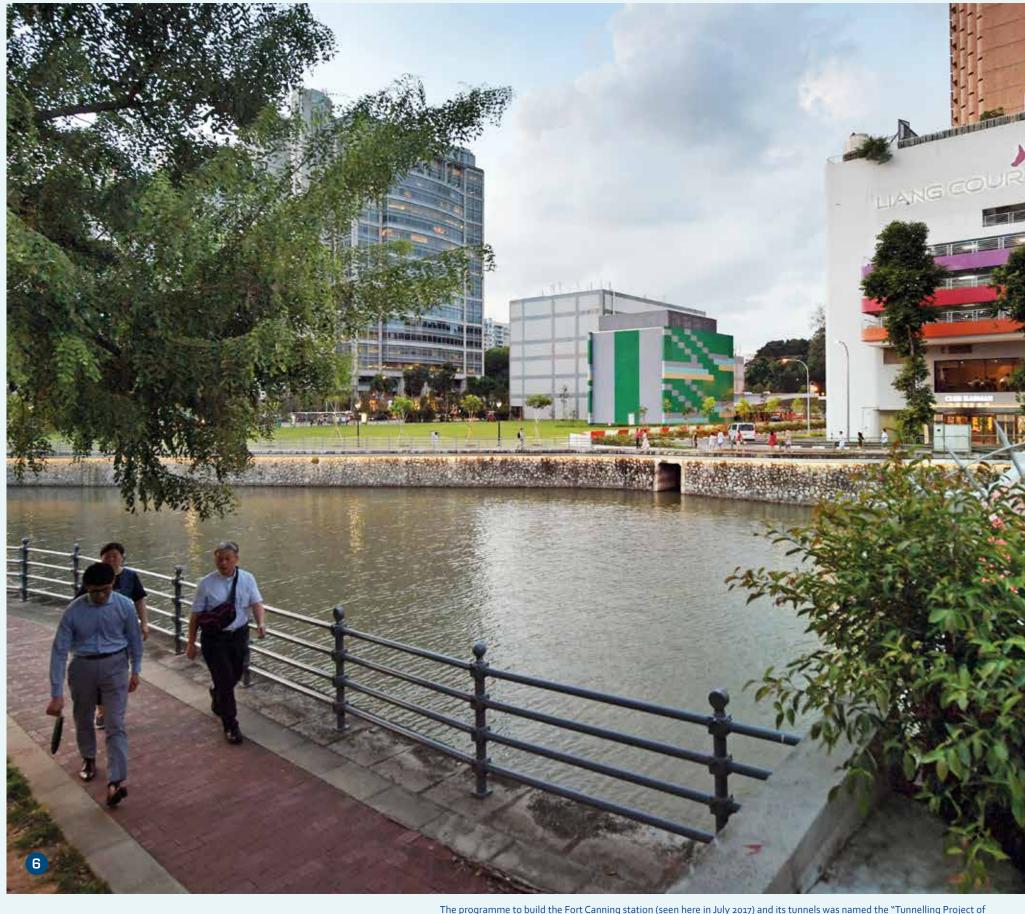


Pictures: LTA





- **1** The Singapore River before the diversion.
- 2 A diversion canal measuring 8 m deep, 42 m wide and about 150 m long was built along the river's west bank. A temporary bridge was also erected across the canal.
- **3** The existing river walls at both ends of the diversion canal were demolished to create the river's new route.
- 4 An embankment was constructed across the river's original course, by draining the site of water and then filling it with soil.
- 5 Piling rigs were used to remove obstructions such as timber beams, cables and reinforced concrete debris along the planned tunnels' route. The site was then pumped with a stabilising material before the tunnels were constructed.
- 6 After the tunnels were completed, the embankment and the temporary bridge were removed. The diversion canal was filled in, restoring the river to its original route.



The programme to build the Fort Canning station (seen here in July 2017) and its tunnels was named the "Tunnelling Project of the Year" in 2016 by the International Tunnelling and Underground Space Association. Picture: Alphonsus Chern for the LTA



The LTA had to build a two-lane viaduct

to divert traffic from the DTL site at

Picture: Singapore Press Holdings

Telok Ayer as there was limited space.

> PUTTING TRAFFIC LANES IN THE SKY

In another first for Singapore, the LTA and its contractor built a viaduct in the heart of the central business district to direct traffic over the construction site of the Telok Ayer station.

"We usually divert traffic sideways temporarily to build MRT stations and tunnels under the road, but at the Telok Ayer site, because of the tall buildings on either side of the street, we had to be more creative," said Mr Markus Ruddock, who was LTA's Senior Project Engineer, DTL 1, and is now Senior Project Manager, Thomson-East Coast Line, Civil Team 2.

To build the groundbreaking two-lane viaduct, which stretched about 500 m over part of Cross Street, the LTA temporarily closed the two centre lanes of the street.

Work on the viaduct began in February 2008 and was completed by the end of the year. Three up-ramps onto the viaduct were constructed at Central Boulevard, Raffles Quay



Line, Civil Team 3.

of the results.

and Robinson Road, and motorists could use it to bypass four busy traffic junctions at Raffles Quay, Robinson Road, Cecil Street and Telok Ayer Street.

"Taxi drivers loved the viaduct! They used it to move around the central business district and take bookings from farther away," said Mr Simon Wee, who was LTA's Senior Project Engineer, DTL 1, Telok Ayer station, and is now Senior Project Manager, Thomson-East Coast

After the Telok Ayer station and tunnels were completed in late 2010, the LTA hired a specialist contractor to cut the viaduct into chunks and remove these at night and during weekends to minimise inconvenience to motorists and other stakeholders. The LTA then restored the section of Cross Street that had been under the viaduct to its original state.

> MAKING TRAIN TUNNELS STRONGER

In fact, one of the DTL construction achievements was not just a milestone for Singapore, but a breakthrough for Southeast Asia too.

The combined 4.5 km of tunnels between the Jalan Besar, Bendemeer and Geylang Bahru stations on the DTL were the first in the region to be lined with steel fibre reinforced concrete, a type of material that makes tunnels more durable.

Steel fibres are mixed into concrete to create the reinforced version.

A large trial was conducted in Singapore to find the best way to do this, so that the resultant reinforced concrete would not only deliver the required performance values but also have good workability, flow and fibre dispersion.

Many different mixes were tested. The most promising candidate was then put through three more consecutive trials, with the mixture cast on different days to ensure the consistency

The workers involved in the trials also received special training on how to prepare the specimens to minimise their variability.

"Eventually, the LTA and its contractor were able to achieve a perfect dispersion and orientation of steel fibres within the concrete segments, and the reinforced concrete also met internationally recognised European standards," said Mr Ng Choon Yeang, LTA's Principal Project Manager, DTL 3, Civil Construction Team 2.

The achievement won the Singapore Concrete Institute's Excellence Award and the Ministry of Transport's Minister's Value-For-Money Achievement Award.

More importantly, it gave other organisations in Southeast Asia the confidence to use such reinforced concrete. One example is the Klang Valley MRT project in Kuala Lumpur, Malaysia.

"We usually divert traffic sideways temporarily to build MRT stations and tunnels under the road, but at the Telok Ayer site, because of the tall buildings on either side of the street, we had to be more creative."

Mr Markus Ruddock, who was LTA's Senior Project Engineer, DTL 1



LIKE TOOTHPRSTE: The consistency of the soil found at the sites of the DTL Rochor and **Bugis stations**

SOFT MARINE CLAY \bigcirc ROCHOR \bigotimes BUGIS STATIONS

Additional measures were taken to stabilise the soil for construction.

R DOUBLE-DECKER BUS: The size of a boulder found at the site of the Little India station



Specialised hydraulic machinery was used to break it into smaller pieces.



> THREADING TUNNELS

How do you thread a tunnel through a narrow space and avoid damaging the foundations of nearby buildings and other structures? The answer: very carefully.

The heavy land use in parts of Singapore left the LTA and its contractors in tight spots, literally, when they were constructing some of the tunnels for the DTL.

In fact, one of the tunnels for the Telok Ayer station had to be built a mere 70 cm above another, existing tunnel for the East-West Line. The engineers had to take special care not to hit the existing tunnel when they were inserting the steel pipes that would form the foundation for the new one. "We also took measures to prevent the East-West Line tunnel from heaving up when we removed soil from the ground above it," said Mr Tan Kok Jin, who was LTA's Deputy Director, DTL 1, and is now Director, Thomson-East Coast Line, Civil Team 2. These precautions included pumping cement into the soft soil above the East-West Line tunnel to harden and stabilise the soil, as well as putting down a layer of interlocked pipes, large steel reaction frames and hydraulic jacks to push down on the tunnel.

With these safeguards, the East-West Line tunnel moved only 2 mm in total despite the construction of the DTL tunnel so close to it.



The LTA and its contractors had to take special measures not to damage the existing East-West Line tunnel pictured here when constructing the unnels for the Telok Ayer station. Picture: LTA



The LTA and its contractors achieved similar success with other DTL tunnels built in constrained spaces too. The twin tunnels connecting the Mattar station and Geylang Bahru station, for instance, passed 2.6 m above a sewer for the Deep Tunnel Sewerage System and 17.8 m under the Pan-Island Expressway and Kallang-Paya Lebar Expressway.

The tunnels also had to be constructed through very weak and water-bearing soil. Sophisticated control valves were used to make sure that the soil did not seep into the tunnels.

> WORKING THE LAND

In some cases, the land itself was the problem. In Bukit Timah, the LTA and its contractors encountered a rock structure, which they termed as 'Bukit Timah granite' and was extremely hard. "To tunnel through this granite, we had to use a special type of tunnel boring machine that is more expensive but more effective," said Mr Simon Hoblynn, LTA's 1 Deputy Director (Tunnel), 1 Tunnelling.

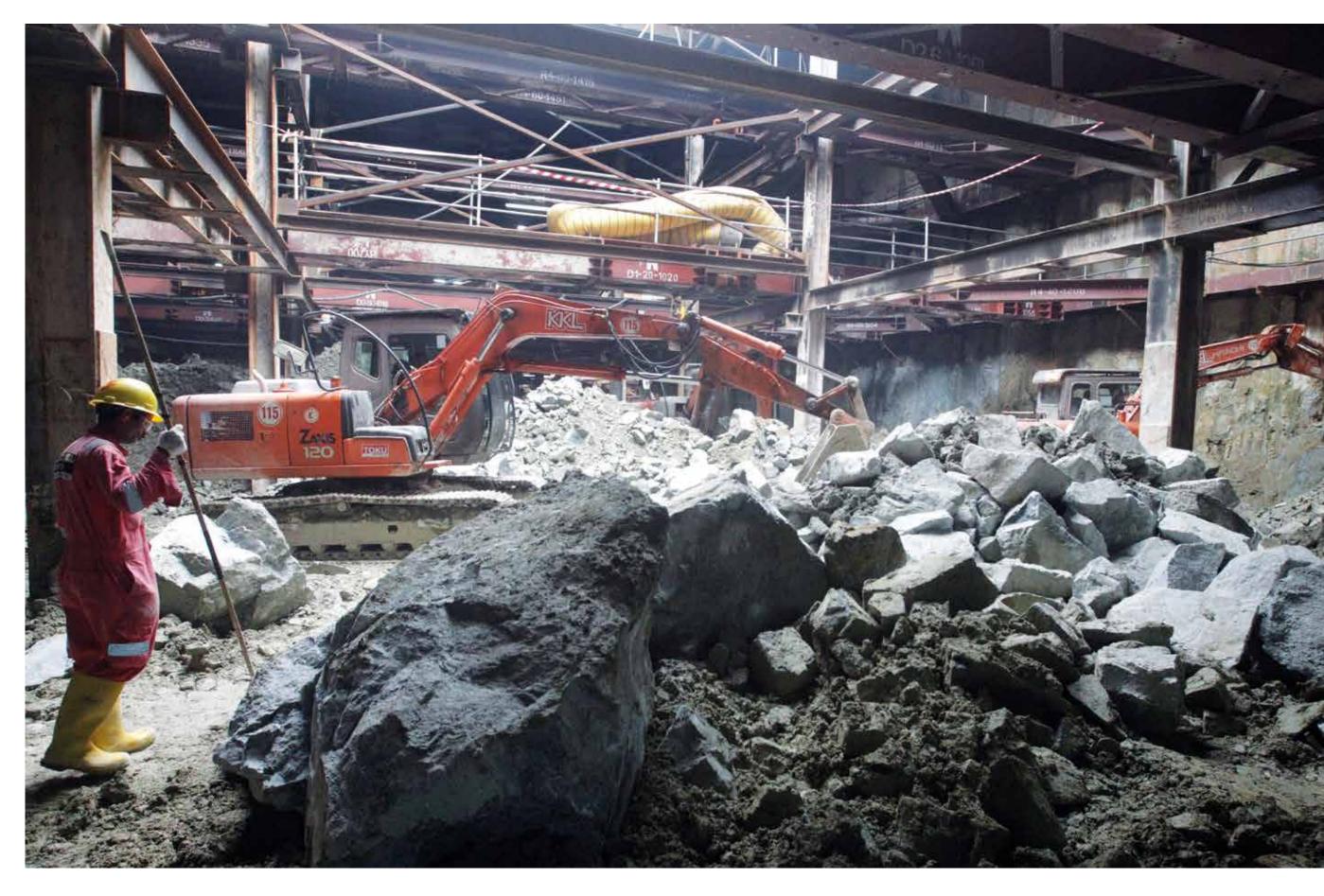
Sometimes, even these machines were not enough. About 50,000 kg of explosives were used to blast through the rock to create space for the Beauty World station and its tunnels.

"The planning behind each blast was extensive even though the blast itself lasted for only a few seconds. The roads near the blast were closed for a few seconds each time until the blast was done, for example, in case there were any flying pieces of rock," said Mr Cheong Yew Seng, who was LTA's 1 Deputy Director, DTL 2, Civil Construction Team 1, and is now Deputy Director, Thomson-East Coast Line, Civil Team 5.



Left: The LTA put up temporary traffic lights to inform motorists of nearby blast operations. Picture: LTA

Right: About 50,000 kg of explosives had to be used to blast through the extremely hard granite at the DTL site for the Beauty World station. Picture: Singapore Press Holdings





> WEAK GROUND, STRONG MEASURES

At the other end of the geological challenges was soil so soft that construction could not be carried out without affecting nearby buildings and other structures.

"At the site of the Rochor station, we found a layer of soft marine clay that was 30 m-thick. The soil was like toothpaste and we had to be very careful to make sure that the nearby buildings, especially the heritage shophouses, were not affected by the station's construction," said Mr Lim Kim Kwang, who was LTA's 2 Deputy Director, DTL 2, Civil Construction Team 2, and is now 2 Deputy Director, Thomson-East Coast Line, Civil Team 6. The project team pumped cement into the soil, built strong temporary earth-retaining structures and installed instruments to monitor the ground for movement.

The same type of soil was also found at the site for the DTL Bugis station. There, the engineers used cement and glass fibre reinforced polymer soil nails to stabilise the ground. Steel pipes were also driven under the existing East-West Line Bugis station so that supporting frames could be set up under it. These frames were necessary so that the LTA's contractor could excavate beneath the station to construct the DTL Bugis station under it.

> KEEPING YOU MOVING

With the DTL stretching across the length of Singapore, its construction crossed the sites of many roads and required many traffic diversions. Nowhere was this more apparent than in the building of the Rochor station. Located in the heavily built-up Rochor estate, the station was slated to lie under the 20 m-wide Rochor Canal as well as 10 lanes of arterial roads. With the LTA's commitment to keeping the number of traffic lanes unchanged during construction works, numerous traffic and canal diversions had to be carried out to maintain the vehicular and canal flow at all times.

"We didn't have space to divert the road sideways, so we built steel decks over the open canal to let traffic go on top of it," said Mr Tang Man, who was LTA's Senior Project Manager, DTL 2, Civil



"It is noteworthy that the project team was able to achieve zero accidents and timely delivery for the construction of such a technically complex structure."

The Ministry of Manpower

Construction Team 2, and is now Principal Project Manager, Thomson-East Coast Line, Civil Team 6. The engineers also dug a temporary canal to shift the original canal out of construction's way. To avoid disrupting traffic during the day, the Rochor construction team toiled for five to six hours each night to finish the diversions. Time was a precious commodity, with even downpours — during which work had to be halted — causing much anxiety.

As the construction site was close to the main arterial roads, the canal and other buildings and structures, the workers also had to manoeuvre their heavy machinery very carefully to minimise the danger and disturbance to road users.

Detailed sequencing and thorough planning, coupled with comprehensive safety plans and stringent control measures, enabled the project team to complete the station and its tunnels on time and without incident. In fact, the work spanned 1.6 million accident-free man-hours.

The Singapore Concrete Institute honoured the builders of the Rochor station with an Excellence Award. The Ministry of Manpower commended them too, saying: "It is noteworthy that the project team was able to achieve zero accidents and timely delivery for the construction of such a technically complex structure."

> WORKING HAND IN HAND

Take the DTL to the Bayfront station or Downtown station and you'll be able to go directly from the station to the Marina Bay Sands integrated resort or Marina Bay Financial Centre respectively. The LTA and its contractors had worked with the two firms constructing the developments to provide such seamless transfers.

In fact, the developments were slated to have DTL station entrances within their sites even during their design phase. Each development was also constructed in tandem with the DTL station serving it, with the LTA project team working in close coordination with the developer.

Mr Goh Kok Hwa, who was LTA's Deputy Director, DTL 1, and is now Director, Thomson-East Coast Line, Civil Team 1, said: "We all worked well together and achieved our goal of building the stations and the projects in a timely and safe manner."

> YOUR STATION, OUR CHALLENGE

From stacking train platforms to creating 'virtual links' between different train lines, the engineers of the DTL came up with some truly inventive solutions to overcome space constraints along the rail line's alignment. Here are some of the stations that posed unique challenges during their construction.





The number of traffic and canal diversions required to build the **Rochor station and its tunnels**

> **DLYMPIC-SIZE** SWIMMING POOLS: The volume of rocks removed from the site of the Beauty World station and tunnels to enable their construction



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Space was tight for the Stevens station, so its two platforms had to be stacked. Picture: LTA

> STACKING UP

Explore the Stevens station and you will find one of the smallest stations along the DTL. In fact, the space available for the station was so small that the LTA and its contractor had no choice but to stack the station's two platforms — one for trains headed towards Bukit Panjang, and the other for trains going towards the city.

The station had to be constructed parallel to Bukit Timah Road and near residences, shophouses, the Wayang Satu Flyover and a wide canal.

When the station opened on 27 December 2015, then-LTA's Chief Executive Chew Men Leong explained: "The flyover and canal posed exceptional challenges to building a station. To enable a station to be constructed at all within the site constraints, our engineers built what we call a 'stacked station'. Without this solution, it would be near impossible to provide a service to the residential, student and commercial population in this area."

As a result of the stacked platforms, the station has two separate sets of fare gates, one for each platform, making it the first of its kind in Singapore.

The LTA placed the fare gates at the platforms themselves so that the rest of the station can be kept open for public access.

YOUR TIME TO CELEBRATE

The New Year's Eve Countdown. The National Day Parade. The Chingay Parade. These were just a few of the events that the LTA and its contractors had to work around to realise the DTL 1 without disrupting celebrations beloved by Singaporeans.

"We were working in the heart of the downtown area, so there was a lot of coordination with various event organisers, and that was definitely a challenge," recalled Mr Goh Kok Hwa, who was LTA's Director, DTL 1, and is now Director, Thomson-East Coast Line, Civil Team 1.

Besides the yearly occasions, the agency and its contractors also had to contend with a growing downtown sporting calendar, which included the OCBC Cycle Singapore, the Standard Chartered Singapore Marathon and the Great Eastern Women's Run Singapore, as well as special events such as the first Youth Olympic Games in 2010.

The inaugural Formula 1 race in September 2008 was an especial concern. Construction on the DTL 1 had begun only just earlier that year, in February. "We had only general information about the race at the time, so it was very difficult and tedious to prepare for its impact on the DTL 1," said Mr Sha Marican, who was LTA's Deputy Director, DTL 1, and is now Director, Thomson-East Coast Line, Civil Team 4.

"But in this case, and in all the other cases, we found a way so that Singaporeans could continue to enjoy the event."

for commuters. demolish buildings.

> CREATING 'VIRTUAL LINKS'

Usually, commuters who want to transfer between different train lines in Singapore just have to walk from one platform to another within the MRT interchange.

At the Bukit Panjang, Newton and Tampines interchanges along the DTL, however, they have to tap out of the train system and then tap in again to transfer between the connected rail lines.

This is because the LTA relied on existing links — which are used for other purposes besides train travel — to connect the rail lines at the interchanges. In each case, the LTA had considered many options and decided that creating a 'virtual link' was the best option

At the Newton station, for example, the 56 m-long underpass used by the public to cross Scotts Road now also serves as the link between the North-South Line and DTL.

The underpass would have had to be closed for between five and seven years for a direct and paid link between the North-South Line and DTL to be constructed. "This would have inconvenienced those who use the underpass. And five to seven years, if you ask me, is a very long time to be inconvenienced," said Mr Tan Kian Thong, who was LTA's Director, DTL 2, Civil Construction Team 2, and is now Director, Thomson-East Coast Line, Civil Team 6.

At the Bukit Panjang interchange, the Bukit Panjang LRT line and the DTL are connected by a link-bridge.

"We configured the station such that commuters would have round-the-clock access to this connection linkway, even when the station and trains are not in operation," said Mr Tan.

Meanwhile, at the Tampines MRT interchange, the East-West Line and DTL are located at opposite sides of the Tampines bus interchange to avoid having to relocate the bus interchange or

"Building a paid link between the rail lines would have involved cutting across the bus interchange, including its main access point for pedestrians, or tearing down a one-storey building next to the interchange which houses shops and functions as a sheltered



Commuters have to tap out of the train system and tap in again to transfer between the North-South Line and the DTL at the Newton station. Picture: Singapore Press Holdings

corridor. Both of these would have caused a lot of disruption to stakeholders," said Mr Song Siak Keong, LTA's Director, DTL 3, Civil Construction Team 3.

Instead, commuters can now travel between the East-West Line and DTL via a wide sheltered corridor lined with shops, including a bakery, a store selling household items and a food-court.

While people usually have to pay a new fare when they exit the train system and enter it again, the LTA adjusted the fare system at the three interchanges so that transferring between the rail lines in them is free as long as it is completed within 15 minutes. "We worked out a system to enable commuters to still make the connection and be charged only once. That is very important to us," Mr Song said.

> LISTENING TO YOU

Some of the DTL stations were also modified in response to the public's feedback.

The Expo interchange, for example, was not originally intended to have a direct paid link between the East-West Line and DTL.





At the Bukit Panjang interchange, the Bukit Panjang LRT and DTL are connected by a link-bridge. Picture: Alphonsus Chern for the LTA "After many commuters asked for better connectivity between the rail lines, we looked at a few possibilities and decided that we could replace an existing underpass with a link. Removing this underpass was a big challenge though," said Mr Rodney Lee, LTA's 1 Deputy Director, DTL 3, Civil Construction Team 3.

To prevent the underpass's removal from affecting the stability of the surrounding ground, structures and buildings, the LTA and its contractor filled part of it with liquefied stabilised soil, cut through this soil and set up retaining walls before building the link.

Erecting the DTL Expo station beneath the elevated train tracks of the East-West Line station also posed several difficulties. The workers had to use low-headroom machines as conventional ones would have been too tall to fit under the tracks.

The foundation piles of two columns holding up the train tracks also obstructed the station's construction. The two columns were modified to rest on the DTL Expo station's roof slab instead.

> MAKING A CONNECTION

Even when the LTA was building the Circle Line's MacPherson station, it was looking ahead to the construction of a DTL station at the same site. To pave the way for a connection for the two rail lines, the LTA created a structure box beneath the Circle Line platform for the future DTL.



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Murugamoort boasts five ent The tunnel run between F Kallang-Paya

"We took many measures to make sure that the tunnelling work was safe and smooth. For example, we used radar surveys to locate existing piles so that our tunnel boring machines would not run into them. We also used many instruments to monitor the impact of the tunnelling," said Mr Ramesh Nair, LTA's 3 Deputy Director, Tunnelling.



When the contractor for the DTL MacPherson station came on board, it dismantled part of the box's slabs and walls to build new escalators and staircases. The space now provides a seamless connection between the Circle Line and DTL.

The modification of the structure box was not without challenges. Due to the limited access, conventional construction methods using cranes and other heavy machinery were not feasible. It was also difficult to transport materials into the box, erect formwork — temporary or permanent moulds into which concrete or similar materials are poured — and carry out rebar and concreting tasks in the box because of its confined space.

"Building the MacPherson station was indeed challenging. We had to mine directly under the live Circle Line station without interrupting train operations," said Mr Chelliah Murugamoorthy, LTA's Director, DTL ₃, Civil Construction Team 1. "Now, MacPherson station boasts five entrances and a seamless link between the Circle Line and DTL."

The tunnels between the DTL's MacPherson station and Mattar station were also slated to run between HDB residential blocks and hawker centres, as well as cross under a canal and a Kallang-Paya Lebar Expressway tunnel.

The DTL runs below the Circle Line. Picture: LTA



> PROTECTING OUR HERITAGE

The protection of the Jalan Besar area's heritage and history was a key consideration in the design and construction of the Jalan Besar station and its tunnels.

As the construction would take place beneath many pre-war houses in the area, the LTA and its contractor held many sessions with their tenants and owners to seek their understanding and support, and to address their concerns.

The LTA also installed steel poles to prop up the walkways of several iconic and colourful shophouses in Jalan Besar, as they had shallow foundations and could be damaged by the vibrations from the nearby tunnelling work.

When an escape shaft had to be built outside a coffee shop, the LTA mandated the use of silent pliers for the installation and extraction of sheet piles, as well as other construction methods, to minimise disturbance to the stakeholders.

The LTA and its contractor also monitored the building of the shaft and organised engagement sessions to listen to people's feedback and suggest solutions to their problems.

Although a building in the area had to be demolished because its foundation piles posed a major risk to the tunnelling work, the LTA eventually reconstructed the building.

> DIGGING DEEP

To build the Bencoolen station on the DTL 3, the LTA and its contractor had to dig deep literally.

The station is the deepest in Singapore, at 43 m below ground. Its depth is the equivalent of that of a 14-storey building underground or eight basements of the Ion Orchard shopping mall.

The engineers and workers had to overcome numerous challenges, including the site's geology, which was composed of soft soil overlaying a thick boulder bed, and limited working hours, due to the need to minimise inconvenience to residents of nearby high-rise buildings.

"Still, they soldiered on and completed the station," said Mr Rama Venkta, who was LTA's Director, Contracts 2, DTL 3, and is now Deputy Group Director, Special Projects, and Project Director, High Speed Rail.

"As with all of the other DTL stations and their tunnels, the hard work and resilience of the LTA and its contractors got the job done."

structures and all stakeholders.

as planned.

INCLINOMETER

- This device measures lateral earth movements, which might occur due to excavation or other construction work.

WATER STANDPIPE

VIBRATION MONITOR

structures.



The Bencoolen station is integrated with the extension of the Nanyang Academy of Fine Arts. Picture: Alphonsus Chern for the LTA

SAFETY FIRST

- When it came to safety concerns, the LTA and its contractors spared no expense. They used a variety of instruments to ensure that the construction of the DTL did not pose any danger to its builders, nearby
- The instruments were used to verify design data and assumptions, monitor the impact of the construction on the ground and surrounding properties, and check that the built DTL structures were performing
- The devices would have also provided early warning of impending failures so that preventive or remedial actions could be taken, and workers evacuated from the construction site if that became necessary. The instruments' data could have also served as a record of the construction's impact for damage assessment cases.
- These are some of the instruments used by the LTA and its contractors.

• It can also measure deflections in retaining walls built to stabilise the ground during excavation work.

• This measures the groundwater level, which might be changed due to construction activity.

buildings and structures.

MICRO-ELECTRO-MECHANICAL SYSTEMS (MEMS) TILTMETER

• An adjustable bracket is used to attach this instrument to the vertical or horizontal surface of a structure. The instrument then measures any subsequent tilting of the structure.

LOAD CELL

- This device monitors the load in a strut or anchor bar used in a temporary earth retaining system.



STRAIN GAUGE

• This monitors the strain and load in a strut or pile used in a temporary earth retaining system. These systems prevent the ground from shifting during excavation work.

VIBRATING WIRE PIEZOMETER

• This instrument measures pore water pressure, which is the pressure exerted by groundwater in soil or rock.

TILTMETER

• This measures the tilt of existing

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 As its name suggests, this instrument measures vibrations caused by construction. Such data is needed to prevent damage to surrounding











TURNING THINGS FROUND

he news came like a bolt from the blue. On 19 June 2013, Austrian construction firm Alpine Bau filed for insolvency even as it was in the midst of building three stations and their tunnels for the DTL 2. It had won the contracts for the King Albert Park, Sixth Avenue and Tan Kah Kee stations and tunnels in Bukit Timah.

"We were all shocked. It was unbelievable because the company's progress had been good, and there was no tell-tale sign at all that it was going to go bankrupt!" said Mr Ng Kee Nam, who was the LTA's Deputy Group Director of Rail (Civil) for the DTL and is now Group Director of the Thomson-East Coast and Cross Island Lines (Civil).

At that point in time, Alpine had completed only about half of its contracted work, and the three stations it was in charge of were in the middle of the DTL 2, throwing the planned opening of the entire rail segment into chaos. Even the LTA believed that a delay of six months was inevitable.

It was an unprecedented situation, said veterans in the LTA, including Mr Ng and Mr Tan Kian Thong, LTA's Director, Thomson-East Coast Line, Civil Team 6, and former Director, DTL 2, Civil Construction Team 2.



Mr Ng Kee Nam (left), LTA's former Deputy Group Director of Rail (Civil) for the DTL, and Mr Tan Kian Thong, former Director, DTL 2, Civil Construction Team 2, pictured at the Tan Kah Kee station on 10 December 2015. Picture: **Singapore Press Holdings**

construction history.

> SWINGING INTO ACTION

contractors.

the meantime.

Alpine had left four tunnel boring machines under Bukit Timah Road, which could stall after an extended period of inactivity and pose safety risks, Mr Ng said. More than 400 workers had been stranded by Alpine's sudden collapse. The LTA worked with the Ministry of Manpower to help them too, by finding new jobs for them or making arrangements to send

them home.

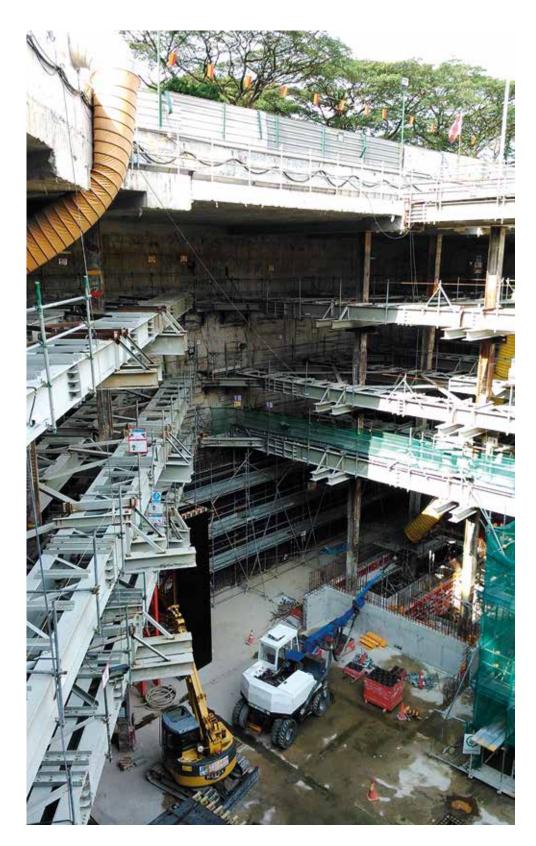
The setback, however, proved to be the making of the entire LTA team. This is the story of one of the most incredible comebacks in Singapore's

After Alpine filed for insolvency, the LTA immediately started to salvage the situation.

It hired a security firm to protect the sites and partially completed structures, reached out to the three stations' subcontractors to reassure them and engaged specialists to maintain the tunnel boring machines and recharge wells while it looked for new

It also appointed Australian construction firm McConnell Dowell South East Asia, which had won the contract to build the DTL 2 Beauty World station and its tunnels just north of the three affected stations, as a caretaker contractor to continue tunnelling works in

> The construction works at Sixth Avenue station of the DTL 2, pictured here in August 2013, ground to a halt after Austrian construction firm Alpine Bau filed for insolvency in June 2013. Picture: Singapore Press Holdings









Left: Work was also stalled at the Tan Kah Kee station, pictured here five days after its contractor, Austrian construction firm Alpine Bau, filed for insolvency in June 2013. Picture: Singapore Press Holdings

> FINDING THE REPLACEMENTS

"Meanwhile, our LTA engineers started documenting the works that had been completed on the three stations and their tunnels. This information was essential for the new tender that had to be called for a contractor to replace Alpine," said Mr Lee Chiew Kam, who was LTA's Deputy Director, Contracts, DTL 2, Civil Construction Team 2, and is now Deputy Director, Contracts, Thomson-East Coast Line, Civil Team 6. "LTA issued the new tender just six weeks after the disruption, and appointed two replacement contractors a mere two weeks after that... Everyone just rallied together to make things work!"

Ms Sandee Heng, who was LTA's Deputy Director, Contracts, DTL 2, Civil Construction Team 1, and is now Director (Covering), Contract Advisory and Insurance

A new contractor had to be appointed as soon as possible to minimise the delay in completing the DTL 2, said Mr Ng, who suffered sleepless nights and worked almost every weekend then. "We were very stressed," he recalled.

"LTA issued the new tender just six weeks after the disruption, and appointed two replacement contractors a mere two weeks after that. Usually, a tender requires at least half a year for processing and evaluation," said Ms Sandee Heng, who was LTA's Deputy Director, Contracts, DTL 2, Civil Construction Team 1, and is now Director (Covering), Contract Advisory and Insurance. "Everyone just rallied together to make things work!"

Both of the new contractors, McConnell Dowell South East Asia and South Korea's SK E&C (Singapore), had the relevant expertise and resources to swiftly pick up where Alpine had left off. Aside from its work on the Beauty World station and tunnels, McConnell Dowell South East Asia had been operating in Singapore since the 1970s, executing a range of infrastructural projects.

SK E&C (Singapore), for its part, had also worked on parts of the DTL 2, in addition to carrying out other projects in Singapore. McConnell Dowell was chosen to complete the construction of the Sixth Avenue and King Albert Park stations and tunnels, while SK E&C was put in charge of the Tan Kah Kee station and tunnels.



> RACING AGAINST THE CLOCK

With the new contractors on board, the race was on to make up for lost time. Residents such as retiree Madam Wang Yi Poh, who planned to use the DTL 2 to visit her three grandsons in Bukit Panjang, had been anticipating the opening of the rail line for years. The LTA did not want their wait to be extended.

Manpower for the three stations was boosted by 25 per cent. An additional graveyard shift was added so that work could continue around the clock, compared to the average 14-hour days for other MRT projects.

To minimise the disturbance to residents at night, wire saws were used instead of conventional breakers to cut concrete struts as they produce less noise.

"We did everything we could to save time. We looked for opportunities to do work concurrently throughout the sites, and changed the sequence of some of the work to speed things up," said Mr Ng. He added that safety was always a priority.

Other innovative solutions were put in place. A control centre was set up at the Little India station so that basic testing could be done for some of the other DTL 2 stations while work continued on the three affected stations.

Weekly meetings were held and daily site checks conducted to solve any problems on-site quickly.

"Everyone from the contractors to the designers, coordinators and planners put their work under a microscope to see what could be done to make the progress faster and better. You know, it was a new and unexpected experience for all of us, but I think we really pulled together and made it work," said Mr Tan.

> ACHIEVING THE IMPOSSIBLE

By June 2015, six months before the DTL 2 was originally scheduled to open, the LTA had pulled off a miraculous feat: it had completed 95 per cent of the work on the three stations and their tunnels.

The DTL 2 would open on time.

The achievement stunned even officials at the Ministry of Transport, who asked LTA's Mr Ng and Mr Tan if completion dates on other infrastructural projects could be brought forward in the same way.

Mr Tan said: "We did it for the DTL 2 but it was not ideal in many aspects! Our staff had to work through many weekends and suffered countless sleepless nights!"

That same month, then-Minister for Transport Lui Tuck Yew broke the good news to

"Everyone from the contractors to the designers, coordinators and planners put their work under a microscope to see what could be done to make the progress faster and better... we really pulled together and made it work."

Mr Tan Kian Thong, LTA's former Director, DTL 2, Civil Construction Team 2

14 news

Hard-won battleground of Cashew Hillview **Downtown Line 2** Beauty World King Albert Park Sixth Avenu Tan Kal Botanic Gardens 3 🕒

they were successful.

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news 15

The public gets a preview of the new Downtown Line 2 today, ahead of its opening on Dec 27. FOO JIE YING (fjieying@sph.com.sg) looks at five things you may not know about the con-







Pride and sweet relief for engineers





residents during a visit to the Zhenghua ward in Bukit Panjang. He also thanked them for their understanding in putting up with the longer construction hours.

Looking back on their marathon labour over two years to get the DTL 2 back on track after Alpine filed for insolvency in June 2013, LTA engineers were equally proud and relieved that

"Instinctively, everyone banded together and every single person on the team was cooperative. That's how we managed to complete the project on time," said Mr Sim Wee Meng, LTA's Senior Group Director, Rail.

During his speech at the official opening of the DTL 2 on 26 December 2015, Prime Minister Lee Hsien Loong paid tribute to the hard work that had been poured into the rail segment: "We feared that the project would be considerably delayed... [but] the recovery process was so successful that we managed to fully recover the initial delay of six months."

He emphasised: "Today, we are celebrating many years of hard work and planning put in by all — the policy makers, engineers, transport staff and construction workers."

The New Paper reported on 5 December 2015 that the DTL 2 would be completed on time despite the initial delay. Picture: Singapore Press Holdings

> WINNING HEARTS AND MINDS

If the Alpine achievement was a showcase of LTA's tenacity and grit, the Maplewoods saga highlighted its commitment to community engagement.

In April 2010, more than a year before construction on the King Albert Park station and its tunnels was to commence, the LTA started reaching out to the management committee and condominium manager of the nearby Maplewoods condominium, to keep them informed about the upcoming works.

In May 2011, construction work on the station and its tunnels had just begun when residents started voicing their concerns against it, even going as far as to petition Prime Minister Lee Hsien Loong to relocate the site of the tunnel launch shaft. They said that the shaft, which is a large square hole that facilitates the digging of underground tunnels, would inconvenience them if it was built as planned near the condominium's main entrance and exit point, and suggested that this should be relocated to the adjacent station at Sixth Avenue.

The residents also raised several safety concerns. Pupils making their way to the Methodist Girls' School (MGS) adjacent to the condominium might get into accidents due to the increased traffic going in and out of the construction site, they argued.

When the LTA learned of the residents' unhappiness in May 2011, it immediately stepped



Then-Minister for the Environment and Water Resources, Dr Vivian Balakrishnan (holding microphone), and his fellow Member of Parliament for Holland-Bukit Timah, Mr Christopher de Souza (in blue shirt, without tie), meeting residents of the Maplewoods condominium in Bukit Timah on 7 June 2011 to discuss the issues caused by the building of the Downtown Line. Picture: Singapore Press Holdings

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up its efforts to engage with them and resolve their complaints. "Having the community's support was very important. You see, if we had just carried on, there would have been even more concerns down the line. That would have been very disruptive to everyone. So we had to see how we could work with them for everyone's benefit," said Mr Ho Kok Khun, LTA's Deputy Director of Community Partnership.

> LISTENING AND HELPING

Over the next three months, from May to July 2011, the LTA met with the residents on numerous occasions to listen to their concerns and suggest solutions.

It explained why the launch shaft could not be relocated to the Sixth Avenue station. To assure the residents that their concerns were being taken seriously, it also suspended work at the site while it tried to find a mutually acceptable way forward.

By June 2011, the LTA had developed a suite of mitigating measures to address their concerns. It revised its plans so that trucks carting tunnelling debris from the site would not cut across the road leading into the condominium. Although doing so would affect construction operations to some degree, this would help to ensure the safety of people going in and out of the property.

Once the station's diaphragm walls were fully completed, the LTA would reinstate the footpath along the condominium leading to MGS. It would also retain the other public footpath on the perimeter of the construction site.

The construction of the new King Albert Park station on the DTL 2, pictured here in September 2011, raised safety concerns among residents of the Maplewoods condominium (building in the background) along Upper Bukit Timah Road. Picture: Singapore Press Holdings





The launch shaft site for the construction of the DTL 2's King Albert Park station blocked an existing footpath in front of the Maplewoods condominium, pictured here in June 2011. Pedestrians would have to use a new footpath requiring them to cross the entrance and exit of the site, which residents said was dangerous as many heavy vehicles travelled to and fro. Picture: Singapore Press Holdings

> FINDING SOLUTIONS TOGETHER

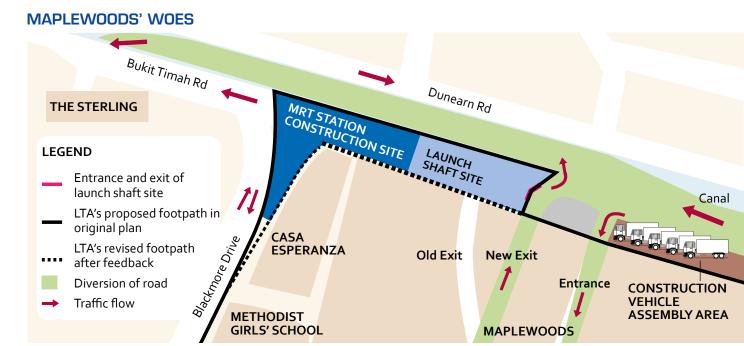
Just coming up with answers, however, would not have been enough. The residents had their own ideas about how the situation should be resolved. Mr Chew Hock Yong, then-LTA's Chief Executive, took it upon himself to listen to their suggestions.

For example, the residents wanted the launch shaft to be moved to the construction site of the Sixth Avenue station instead. Mr Chew explained that this was not feasible as it would have required demolishing 10 shophouses in the area, delaying the completion of the DTL 2 by 38 months and adding \$500 million to its cost.

The Maplewoods management committee also suggested that the tunnels for the King Albert Park station be drilled through from the Tan Kah Kee station, which is two stops away. Doing so, however, would have delayed the opening of the DTL 2 by four years.

By early July 2011, work on the King Albert Park station and its tunnels had been halted for more than a month. Mr Chew himself penned a 10-page letter to the Maplewoods residents outlining actions the LTA had taken, and would continue to carry out, to ensure their safety and reduce construction works' inconvenience to them.

This included constructing new entry and exit gates for the construction site in Blackmore Drive instead, away from the condominium, and installing new traffic lights in Bukit Timah Road. "Slow" markings were also painted on the roads leading up to the Maplewoods condominium. The LTA also initiated the erection of 'noise sheds' to shield the residents' units facing the launch shaft from excessive noise, the regular hosing down of surfaces to minimise



dust in the air, especially during dry spells, and the implementation of a full-scale waste water treatment plant at the construction site. "The King Albert Park station is an integral part of the national rail network plan, which Singaporeans will benefit from," Mr Chew wrote in his letter to the residents. "Over the next four years or so, Maplewoods and LTA will have to work closely together, and we look forward to partnering you to bring about a new transport facility that will make life better in future for Maplewoods residents, our schoolgoing children and others who use it."

> A HAPPY ENDING FOR EVERYONE

Picture: Singapore Press Holdings

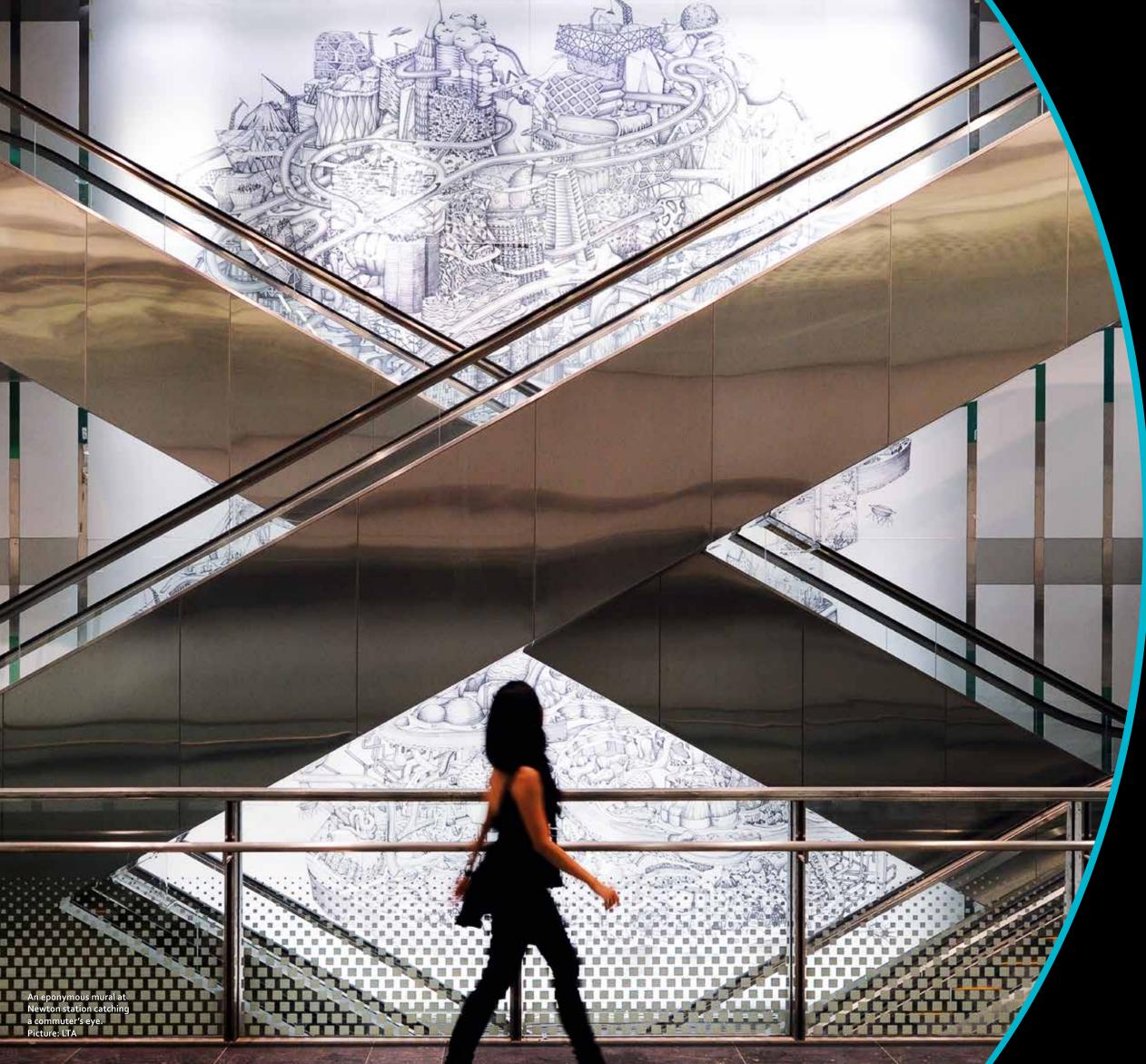
Following the months of talks with the residents, work on the King Albert Park station and its tunnels finally resumed in mid-July 2011.

Mr Ho said: "After the whole episode, some of the elderly residents even brought drinks and fruits to the site staff! They realised that the situation was not as bad as they thought, and many of them eventually became more understanding and supportive. They saw that we were sincere in working with them to resolve their issues."

In the lead-up to the DTL 2 opening, some residents even volunteered to be photographed for a banner to publicise the rail segment.

Through its hard work, persistence and patience, the LTA had changed hearts and minds, and gained the residents' support for the DTL.







FOR THE BY THE



The LTA sent newsletters to people who lived or worked near the DTL construction sites. Picture: LTA

he DTL was a massive undertaking. With its construction lasting 10 years so far and spanning the length of Singapore, some disruption and inconvenience to the public was inevitable.

But by working with the affected stakeholders, the LTA mitigated their woes and won their approval for the rail line.

In fact, a colossal infrastructural project such as the DTL could never have been constructed without the support of the community.

This is how the men and women of the LTA collaborated with residents, business owners and others to make the DTL truly a project for the people, by the people.

> WHAT'S HAPPENING AT MY STATION?

If you lived or worked near one of the DTL construction sites, for example, you would have received a series of colourful and informative newsletters filled with updates and details of how the rail line could help you to cut down on your travel time to other parts of Singapore.

These newsletters, which included information on how people could provide feedback or request for assistance, were put together by the LTA's Community Partnership, project teams and main contractors.

The LTA and its contractors also held regular briefings, meetings and site visits to help people understand what was being done behind the hoardings and under their feet, clear the air about their doubts and queries, reassure them and find solutions to any issues that might have arisen due to the construction works.

People who wanted to learn more about the DTL and its construction could also visit any of the Project Information Centres set up by the LTA. These centres featured artist's impressions of the particular rail segment's stations, models of the stations' footprints and miniature versions of the tunnel boring machines that were used to excavate the rail line's tunnels.

> TAKING CARE OF YOU

Backing up its words with actions, the LTA also helped businesses and communities whenever they experienced problems caused by the DTL's construction.

In 2008, the agency realised that four shops along Telok Ayer Street would face problems once work began on the DTL 1 Telok Ayer station and its tunnels in January 2009.

The hoardings and excavation on three sides of the street would diminish the businesses' visibility, inconvenience their customers and restrict access to the properties.

their move.

When the Telok Ayer station structure was completed in 2011, the LTA's officers also repaired the minor damages to the shop units, including cracked roof tiles, before handing them back to the owners.

> MINIMISING DISRUPTIONS TO YOU

of the Telok Ayer station.

To help the proprietors to maintain their livelihoods, the LTA gave them early notice to find alternative premises and facilitated

Afterwards, two of the shopkeepers wrote letters of appreciation to the LTA staff who had helped them during the relocation.

Ms Ng Shian Yin wrote about the LTA's site staff: "Mr Lim Kian Huat went out of his way to make the handover as smooth as possible. Not only was he on hand to ensure that the physical aspects of the shophouse were well taken care of, he was also most cooperative in arranging access to the premises whenever I requested it."



Four shops along Telok Ayer Street, pictured here in June 2007, were affected by the construction of the DTL. Picture: Singapore Press Holdings

The four business owners were not the only shopkeepers moved by the LTA's help. Through its feedback channels, the LTA learned that the owner of an Indian restaurant along Telok Ayer Street was dismayed by the noise and dust pollution caused by the building

After speaking with the owner, the LTA immediately lined the construction site with pots of large yellow palms, minimising the noise and dust from it and giving the area an extra touch of greenery in the process.

Mr Hoe Yong Keng, who was LTA's Senior Project Engineer, DTL 1, and is now Senior Project Engineer, Thomson-East Coast Line, Civil Team 2, paid for the plants and maintained them during the station's construction.

He recounted: "We promised the stakeholders that the plants would be in within the next few days. When I realised that the contractor might take a few weeks to buy the plants, I went ahead and bought them on my own. I'm happy to have made a difference."



In Chinatown, on the other hand, contractors for the DTL had to navigate a dense network of existing buildings. This lack of space meant that construction occasionally took place just 1.5 m from the area's pre-war shophouses.

One of these housed a porcelain store, where the shelves rattled during those times, recalled MrTan Kok Jin, who was LTA's Deputy Director, DTL 1, and is now Director, Thomson-East Coast Line, Civil Team 2. The LTA staff helped to move the wares to the ground as a precautionary measure.

> BUSINESS AS USUAL

The LTA's efforts also made a world of difference to the merchants operating at shophouses at Block 802, Tampines Avenue 1.



Mr Teo Beng Sai oversaw the Beauty World station project. Picture: LTA

A PERSONAL TOUCH It was "Mr LTA" to the rescue,

every time. During the building of the DTL 2 Beauty World station and its tunnels in Bukit Timah, Mr Teo Beng Sai became a familiar sight in the neighbourhood surrounding the construction site. Formerly LTA's Principal

Engineering Officer of the DTL 2 who was in charge of the Beauty World station project, and now Executive Project Engineer with the Thomson-East Coast Line's Civil Team 5, he was always seen in his white LTA polo shirt, thus earning him the nickname.

More importantly, he encouraged the area's residents and shopkeepers to call him if they had any problems arising from the station's construction.

When an eatery owner in the neighbourhood complained of a burst pipe after midnight, Mr Teo immediately rushed there from his home in Jurong West to try and fix the problem.

When the owners of the eateries along Cheong Chin Nam Road were upset at the hoardings and noise barriers that had been installed outside their premises to minimise the noise pollution from the construction site, MrTeo and his team went door to door to discuss the matter with them.

He eventually won them over when he promised to put up banners for each restaurant, as well as signage that would direct members of the public to their eateries — and did both of those things promptly.

As the construction of the Beauty World station and its tunnels required many road diversions, Mr Teo and his team also maintained a continuous line of communication with the restaurants, neighbourhood centres, hawker centre and residents in the area to keep them abreast of the latest developments. He and his team also distributed flyers and maps, and put up posters in public areas, about the diversions. He even personally handed out earplugs to people living in a condominium close to the construction site in case they were affected by the noise from it.

During most mornings, he would walk every inch of the project site to make sure that it was free from hazards that could hurt pedestrians and other road users. If he found anything that was potentially dangerous, he would fix it, whether that meant sticking tape over hoardings' sharp edges, clearing away puddles of water, removing hazardous pebbles, redrawing road markings or having lighting installed at a dim spot.

Mr Teo's industriousness and care gradually convinced the neighbourhood's residents and shopkeepers that he was on their side.

When work on the Beauty World station first started, he received hostile glares in the area from those affected by the resulting noise, dust and slower business, he recalled. But by the time the station opened a few years later in December 2015, he had become their friend.

too.

After a gasing (a game that involves spinning tops) court and a playground in Geylang Bahru were demolished for the building of the DTL 3 Geylang Bahru station, the LTA's Community Partnership team and the station's project team worked with the estate's residents to reinstate the lost amenities at another location in the neighbourhood.

"In fact, the new multipurpose court could be used for many other activities, such as table tennis. It has since become a popular gathering spot for the residents, with many using it for their morning exercises and other activities," said Mr Gregory Teo, LTA's Community Partnership Manager.

The shopkeepers had shared that their businesses were being affected by the 8 m-high noise barriers erected in front of their premises, so as to minimise the impact to their businesses from the construction of the nearby DTL 3 Tampines West station and its tunnels. As part of the LTA's usual procedures, staff from the LTA's Community Partnership team and the project team in charge of the station had placed "Business As Usual" signs at prominent locations in the neighbourhood to keep up footfall to the shops.

On top of that, they went the extra mile by working with the shopkeepers to build additional walkways leading to the stores.

The project team also replaced the noise barriers' partially opaque panels with fully transparent ones to increase the visibility of the shops, earning praise from their owners.

> CARE FOR THE COMMUNITY

Residents across Singapore benefited from the care and attention of the LTA and its contractors

Occasionally, recreational spaces had to make way for the construction of the DTL. Whenever this was necessary, the LTA sought to re-create the spaces or provide alternatives at other sites that would meet the needs of the community.



The LTA built a new multipurpose court in Geylang Bahru to replace a gasing court that was demolished to build the Geylang Bahru station. Picture: LTA





The LTA facilitated the relocation of the pick-up point for national servicemen heading to Rifle Range military camp from Rifle Range Road to the King Albert Park station's pick-up and drop-off point. Picture: LTA

> GIVING YOU A HELPING HAND

Families who lived along Rifle Range Road in Bukit Timah had requested the relocation of the pick-up point there to shuttle national servicemen to the nearby Rifle Range military camp for better traffic flow.

With the completion of the DTL 2 King Albert Park station in the vicinity, the LTA took the opportunity to help both the residents and the national servicemen training in the camp in one fell swoop.

Working with the community and the Singapore Armed Forces, the LTA facilitated the relocation of the pick-up point to the King Albert Park station's pick-up and drop-off point.

Since then, the Rifle Range Road residents have found it easier to drive along their street. The national servicemen can also now take the train instead of private cars to get to the pickup point and be ferried in shuttle buses to the military camp.

> KEEPING THE FESTIVITIES GOING

Sometimes, extra care was needed to ensure that festivals and celebrations in Singapore could continue uninterrupted too.

In 2011, for example, the route for the Thaipusam festival procession included a section of Cross Street close to the Telok Ayer station construction site.

GOING THE EXTRA MILE

Mr Low Yew Huat, who was LTA's Project Manager, DTL 2, Beauty World station, and is now Project Manager, Thomson-East Coast Line, Civil Team 5, had made an indelible impression on the residents with his attentiveness and assistance.

Committee.

> OF GREEK GODDESSES AND THE THREE KINGDOMS

More than a year after the opening of the DTL 2 Beauty World station in Bukit Timah in December 2015, residents in the nearby Hoover Park estate have not forgotten an LTA officer who went the extra mile to help them during the station's construction.

"He was the most helpful person we had ever encountered with the LTA. Whenever we needed something, he would find a way to help us," said Mr Lee Chuen Fei, the Chairman of the Hoover Park Neighbourhood

Mr Low had supported the committee's request for a yellow box to be added to the junction of the Jalan Seh Chuan and Jalan Jurong Kechil roads, to ease traffic congestion in the area. He was also instrumental in the reinstatement of a covered linkway that had been demolished due to the Beauty World station's construction.

With Mr Low's help, a proposed drop-off point for vehicles was moved from a narrow road to a main one instead, preventing a traffic bottleneck from forming at the former location. He had even lobbied the Urban Redevelopment Authority to replace a few parking spaces in the area with motorcycle parking spaces to help eateries in the vicinity.



Mr Low Yew Huat, then-LTA Project Manager, DTL 2, Beauty World station, lobbied the authorities to replace a few parking spaces in the area with motorcycle parking spaces to help eateries at Upper Bukit Timah Road. Picture: LTA

"Whenever the construction moved into a new phase, he would also ask the contractor to come in and conduct a briefing for the committee. I heard that he also did that for the merchant associations in the area," said Mr Lee, adding that these instances were just a small part of the great service that Mr Low had rendered to the residents.

Mr Lee concluded: "We will always remember his efforts."

To ensure that the procession's star attraction, a 7 m-high silver chariot, could be carried down the street, the LTA and its contractor temporarily raised the street lighting cables that would have obstructed its passage.

"It was a small thing to do, but it made a big difference to the people organising the procession. The Chettiars' Temple Society sent us a letter of thanks afterwards too," said Mr Markus Ruddock, who was LTA's Senior Project Engineer, DTL 1, and is now Senior Project Manager, Thomson-East Coast Line, Civil Team 2.

The support for the DTL went both ways.

While the LTA and its contractors provided much help to many residents and businesses, they also received aid and encouragement in return.

Whenever the LTA invited schools to propose names for the tunnel boring machines used to excavate the rail line's tunnels, for instance, it received hundreds of submissions.

"We were thinking, how could we get students involved and help them to understand the scale and complexity of construction works in Singapore? This seemed like a good way. Hopefully, by taking part in the naming process, they also felt a sense of pride and ownership in our public transport system," said Mr Victor Quek, LTA's Community Partnership Manager.



Bottom from left to right:

community. Pictures: LTA

The LTA decorated hoardings with

attractive artwork to engage the

were encouraged to come up with names for the DTL 2 Stevens station's two tunnel boring machines. After a flurry of suggestions and a vote, the machines were named Guan Yu and Zhuge

The idea was certainly a hit with students from the four Anglo-Chinese Schools, who

Liang, after two legendary statesmen in China's Three Kingdoms period.

Not to be outdone, more than 380 pupils at Pei Hwa Presbyterian Primary School participated in the naming of the DTL 2 Beauty World station's two tunnel boring machines.

The winning suggestions were Artemis and Athena, after the Ancient Greek goddesses of wisdom and of the hunt respectively.

In the east of Singapore, Gongshang Primary School's Clara Goh, a Primary 5 pupil, had the perfect name for the DTL 3 Tampines East station's tunnel boring machine: Resilience.

She explained: "I chose this name because I think that both the machine and the people driving it will be able to withstand difficult conditions to build the tunnel successfully, serving their country and nation."

> PAINTING A PRETTY PICTURE

In a first, students from the Lasalle College of the Arts, Nanyang Academy of Fine Arts,

sites.

friends and family. new line."



School of the Arts Singapore and Raffles Design Institute also created artwork for the hoardings of the DTL 3 construction

The attractive panels incorporated alignment maps of the rail segment and information about how residents could use it to travel around Singapore more quickly, so that they could spend more time with

Ms Gerlynn Chan, a Bishan resident, was a fan. She told the LTA after they were put up: "The new visuals are emotive with simple statements that communicate how the new line will reduce my travelling time. The alignment chart is also useful because it tells me which stations are along the



Students created artwork for the hoardings of DTL3 construction sites, through an art competition organised by the LTA. The top three prizes were won respectively by: Ms Chin Wing Yan (centre) from the Nanyang Academy of Fine Arts, Mr Ryan Benjamin Lee (right) from the School of the Arts Singapore, and Ms Yvonne Soh (left) from the Nanyang Academy of Fine Arts. Picture: LTA



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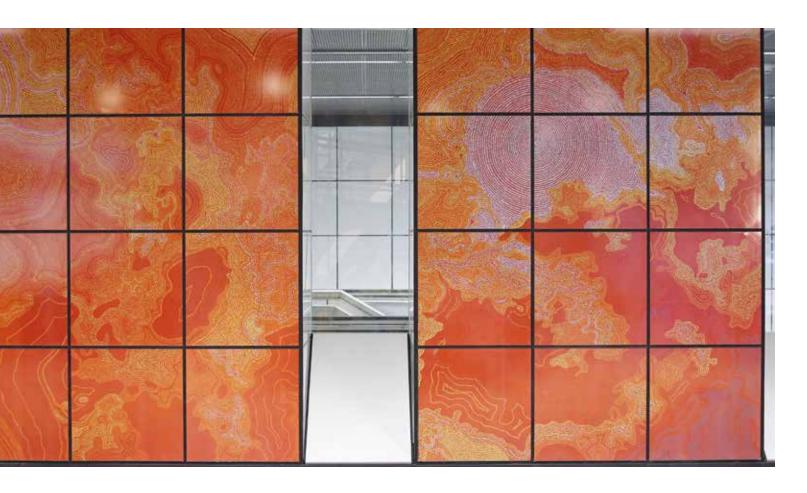


> YOUR STATION, YOUR ARTWORK

Walk around the DTL 2 Tan Kah Kee and King Albert Park stations in Bukit Timah and you'll also find the handiwork of students, artists and even botany experts in Singapore.

In the Tan Kah Kee station, streams of colourful handwritten text form an artwork called *Resilience & Gratitude.* It was created by students from Hwa Chong Institution (HCI).

The writings that make up *Resilience* are inspirational reflections on determination, as well as tributes to enduring human endeavours. "When viewed from a distance, the words dissolve into bands of white and yellow, forming a blazing sun that shares its





light through thick and thin, without fail," explained the students.

"Gratitude, on the other hand, honours those who have walked before us and those who walk by our side in the present. From a distance, the words look like trickles of blue and green, symbolising the running river that connects us all to our rich history and cultural heritage," they added.

Mr Tan Siang Yu, HCI's Principal Consultant for Aesthetics, told *The Straits Times* in 2015 shortly before the artwork was unveiled: "It's exciting to see the collective consciousness of the school reflecting on the values of resilience and gratitude, and to know that thousands of commuters can reflect on these thoughts as they pass through the station."

Far left top and bottom, top and bottom: In the Tan Kah Kee station, streams of colourful handwritten text form an artwork called *Resilience* & *Gratitude*. It was created by students from Hwa Chong Institution. Pictures: LTA



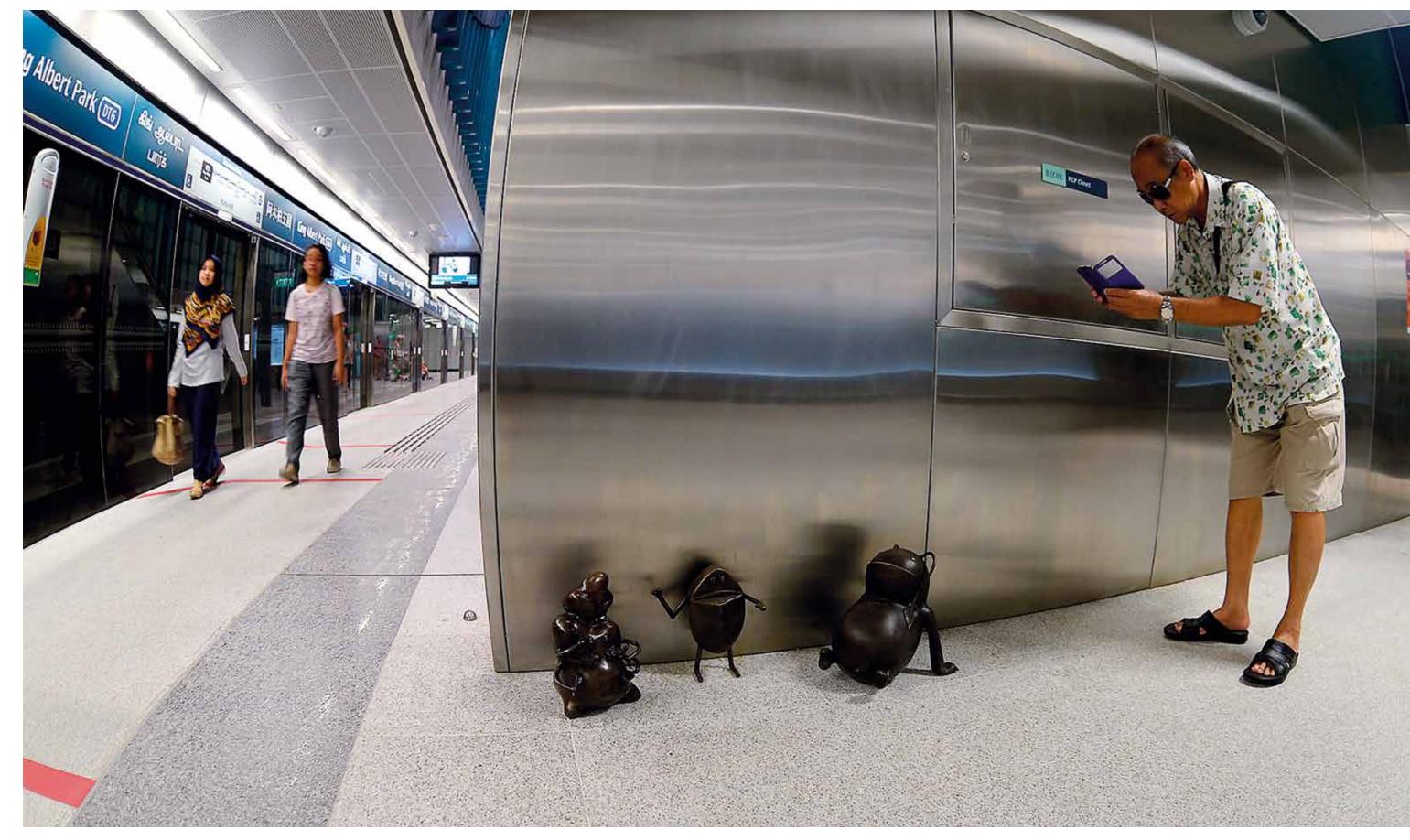
"Our artwork is a whimsical narrative that illustrates the juxtaposition between the natural and built habitats in our environment. The collaboration reveals the secret lives of mythical creatures from the Bukit Timah Nature Reserve."

Artists Caravan

Explore the King Albert Park station and you'll come across fantastical bronze creatures that have made their home in its nooks and crannies.

The art installation, called *The Natural History of Singapore's Mythical Botanic Creatures*, was designed and brought to life by the artist collective, Artists Caravan, students from the Methodist Girls' School (MGS) and two botany experts, Ms Tan Beng Chiak and Ms Kok OiYee.

"Our artwork is a whimsical narrative that illustrates the juxtaposition between the natural and built habitats in our environment. The collaboration reveals the secret lives of mythical creatures from the Bukit Timah Nature Reserve," the artists said.



A passenger taking pictures of the bronze art pieces, representing the mythical creatures from the Bukit Timah Nature Reserve, at King Albert Park station when it opened on 27 December 2015. Picture: Singapore Press Holdings





The LTA shifted the Chinese High School's iconic gateways, one of which is pictured here in November 2008, to a temporary location while the Tan Kah Kee station was being built. Picture: Singapore Press Holdings

UPHOLDING HISTORY

Farther west in Singapore, another conservation challenge arose in Bukit Timah in 2010 when the LTA turned its attention to the DTL 2 Tan Kah Kee station and its tunnels.

In 1979, the Chinese High School, now part of Hwa Chong Institution (HCI), had built a pair of iconic gateways at the school's entrances to mark its 60th anniversary. The 10 m-tall structures were modelled after those at the now-defunct Nanyang University, and they were each topped by an arch decorated with emerald-green tiles imported from China. "These gates stand where the original school gates, built in the 1920s, stood, so there's great historical value and emotional attachment to them. There are also feng shui (geomancy) reasons for not wanting to change their location," Mr Robson Lee, the Secretary of the Chinese High School's Board of Directors in 2010, told The Straits Times at the time.

With the alignment of the Tan Kah Kee station and its tunnels slated to pass under the gateways, however, the LTA had two options: either underpin the gateways to ensure their stability during the construction works, or move them temporarily. "Underpinning the gateways turned out to be unfeasible due to the extensive excavation that had to be carried out below them," said Mr Ong Lui Lin, then LTA's Project Manager, DTL 2, Civil Construction Team 2, and now Senior Project Manager, Thomson-East Coast Line, Civil Team 6.

After extensive discussions, HCI agreed to the LTA's proposal to shift the gateways temporarily to a new location about 40 m away. "There were no as-built drawings of the gateways available, so our first step was to investigate whether the structures were made of reinforced concrete or other materials, such as stone and brick, and whether they were built on piles or footings. We needed such information to determine their weight," said Mr Bai Qian, who was LTA's Project Engineer, DTL 2, Civil Construction Team 2, and is now Senior Project Engineer, Thomson-East Coast Line, Civil Team 6.

A careful, non-destructive examination confirmed that the gateways consisted of reinforced concrete and were built on piles made of bakau (a type of tropical mangrove tree). "This meant that



"These gates stand where the original school gates, built in the 1920s, stood, so there's great historical value and emotional

attachment to them.

Mr Robson Lee, the Secretary of the Chinese High School's Board of Directors in 2010

they could be moved, so our next challenge was to figure out how to protect them during the move," Mr Bai added.

A temporary supporting frame was specially designed and created using steel to support and hold the upper half of the gateways in place during the relocation. A diamond saw cutter was then used to cut their columns, while a new foundation with micro piles and columns was constructed at the new location.

Meanwhile, multiple meetings had been held to go through the transportation procedure to ensure that all of the risks were identified and mitigation measures put in place. For example, the LTA and its contractor would have to lift the gateways near the heavily used Bukit Timah Road. The lifting itself would be obstructed by trees near the gateways. The trailer and crane transporting the gateways would have to use a sloping road to get to the new location.

To prepare for these difficulties, the LTA and its contractor crafted a detailed lifting plan that took into account the crane's position, capacity and lifting load, as well as the radius of its boom. The trailer and crane would also move slowly and be monitored by a safety and lifting team throughout the transportation process.



The LTA conducted briefings and presentations for the HCI's board members to reassure them of the safety and precautionary measures. A toolbox meeting was also held for the moving crew shortly before the actual operation, to remind them of the safe work procedures.

"We were able to relocate the two gateways to their temporary location, and then back again, safely and successfully without any hitches or damage to them," recalled Mr Cheah Chee Khoon, who was LTA's Deputy Director, DTL 2, Civil Construction Team 2, and is now Deputy Director, Thomson-East Coast Line, Civil Team 6.

"In fact, throughout the entire process, the LTA project team and its contractor met all of HCI's requirements, even down to the selection of an auspicious date for the relocation."

The building of the Tan Kah Kee station and its tunnels had also encroached on the school's field. The LTA provided alternative sports venues during the construction works and, after the station was completed, it reinstated the school field to HCI's full satisfaction.

To thank the LTA and its contractor for protecting the gateways during their temporary relocation, HCI organised a dinner and performances by its students on 16 October 2015.

Just a month earlier, in September, the school had also put together an appreciation day for the migrant workers who had built the Tan Kah Kee station and its tunnels.

Ms Lim Siew Hui, HCI's Principal Consultant for Student Development, said: "Since most of the workers were non-Singaporean, the students played traditional games such as pickup sticks and five stones with them, and put up lion dance and *wushu* (martial arts) performances, to show them different facets of Singapore and HCI's rich Chinese culture.

"The students also found out and prepared the workers' favourite foods, crafted thank-you cards and made arrangements so that the workers could take Polaroid photos with their workmates and bring the photos home.

"We also brought in our alumni from the medical community to conduct free health checks for the workers. It was a very meaningful way to thank the workers for their hard work."

Hwa Chong Institution organised an appreciation day in September 2015 for the migrant workers (bottom) who had built the Tan Kah Kee station and its tunnels. They were treated to free health screening (right) and student performances, such as a lion dance (left). Pictures: Courtesy of Hwa Chong Institution







> AN ALL-INCLUSIVE RIDE

Before and after the first two stages of the DTL were officially opened, the LTA also partnered with the SPD and Disabled People's Association, two charities in Singapore that help people with disabilities, to conduct station walkthroughs for the people.

Each station on the DTL is barrier-free and includes lifts, wheelchair-accessible toilets as well as tactile flooring — paths that are made up of raised bars and bumps on the floor, to guide the visually impaired to key locations in the station, including the wider fare gate and exits.

The walkthroughs helped the people with disabilities to become more familiar with the stations' layouts and barrier-free accessibility features. They also learned how to use the stations' locality maps and signage to identify places and find the appropriate exits.

The LTA itself benefited from these tours. During one of them, a participant noted that there was not enough time for commuters with disabilities to enter the station's lift before its doors began to shut. The agency alerted the station's project team, which promptly rectified the problem.

Mr Ho Poh Kee, a stroke survivor, was among those who visited the stations on the DTL 2 during a walkthrough held on 29 December 2015. He said afterwards: "The information about the stations was useful for me as I take the train on weekends."

Ms Teng Mei Ling, an SPD occupational therapist who was also on that tour, added: "Such walkthroughs are definitely beneficial to people with disabilities, as they give them the confidence to explore new places, improving their independence. We are grateful to the LTA for organising this familiarisation session."





Bottom: Tactile flooring (left) and directional signage (right) at the DTL Bencoolen station. Pictures: Alphonsus Chern for the LTA

A WALK IN THE STATION WITH YOU

Are the signs and maps in the MRT stations accurate, and can people use them easily to find the right exits and landmarks in the area? These were some of the questions that 100 volunteers set out to answer during a signage walkthrough for some DTL 3 stations in August 2017.

During the one-day exercise organised by the LTA, the volunteers were split into four groups and tasked to find exits, landmarks and other station facilities, and to take the train to other stations, by relying on the stations' signs and maps.

Such walkthroughs, which help the LTA to identify gaps in information and errors in the signage, had been carried out for the first two stages of the DTL, the Circle Line and the Tuas West Extension too.

Madam Chong Sook Fong, a retiree, suggested using symbols in the maps to indicate places of interest, such as religious or government buildings. "It'll be easier for people to find the landmarks and which station exits to take," she told *The Straits Times* after the walkthrough.

The volunteers, who consisted of residents living near the stations and grassroots leaders, added that they were able to get around the stations without fuss, and the exercise was a fun way for them to contribute to the rail line.



"It's great that the LTA got feedback from the public transport enthusiasts in Singapore, and engaged and interacted with us. There's a sense of achievement and satisfaction that the little help you gave can benefit everyone who uses the DTL in the future."

Mr Ong You Yuan, a student and train enthusiast

> YOUR WAY TO SCHOOL

Schools along the Bukit Timah corridor have also been encouraging their students to use the DTL instead of private transport for their daily commutes.

Before the opening of the DTL 2, the LTA's Community Partnership team collaborated with Methodist Girls' School (MGS) on a series of outreach programmes to increase awareness of the rail line.

Now, during the first week of every school year, older students walk with younger and new students from the nearby King Albert Park station to the school, to familiarise them with the path. MGS's staff also send email to the students' parents to inform them about the MRT station, and suggest that they let their children travel to school using the rail line.

Meanwhile, Nanyang Girls' High School uses its annual events, such as open houses and fun fairs, to promote the use of the DTL to its visitors, students and parents. These events typically draw up to 4,000 people. For its May 2016 open house, the school included want to support sustainable commuting."

> A NATION UNITES

decade of support.

GROWING UP WITH THE DTL

For young train enthusiasts such as Joash Chee, a 13-year-old student, the building of the DTL has been the great infrastructural project of their lives. They have grown up with the rail line, gone on outings to its construction sites and even given feedback on its trains to the LTA.

Joash was just nine years old when the first stage of the DTL began operations on 22 December 2013. He persuaded his parents to let him ride on the first service train of the rail line, even though it was slated to leave the Bugis station at 6.28 am.

"I was so excited that I couldn't sleep the previous night! It was very nice when we got there, to see all the LTA staff and how they carried out the first day of service. I was also intrigued by the fact that the DTL has brighter headlights than the other train lines in Singapore, so you can see the tunnels if you sit at the front of the train," he said.

In fact, in the months before the opening, he would sometimes go to the Circle Line's Bayfront station just to see the DTL's trains whizzing by the connected DTL platform for tests. "I prefer to take the DTL whenever I can, because it just feels fresher and more futuristic," he said.

Other train enthusiasts such as Mr Ong You Yuan, a 25-year-old student, also helped to shape the DTL and its trains. Mr Ong and several others were invited to view the prototype of the rail line's trains and give their feedback on it, for example.

"One of the things we pointed out was that the prototype's hand grips might injure people because there was a piece of metal in the straps. If you accidentally hit someone's head with the straps you might hurt them," Mr Ong recalled. "That was changed."

He also visited the DTL 1 Telok Ayer station while it was under construction, and attended the openings of the first two stages of the rail line. He said: "I think the DTL is very different from the other train lines in Singapore. It has many new features, such as the perch seats, and the interior of the trains are very colourful and vibrant.

"It's great that the LTA got feedback from the public transport enthusiasts in Singapore, and engaged and interacted with us. There's a sense of achievement and satisfaction that the little help you gave can benefit everyone who uses the DTL in the future."



information on the nearby Tan Kah Kee station in all of its publicity materials, and asked prospective students and their parents to take the DTL to the event. It also created an Instagram contest to encourage visitors to snap photos of themselves using public transport. It worked with the LTA to share safe cycling tips through games and a Safe Cycling Clinic at the open house. Ms Agnes Ng, the school's Dean of Relations And Communications, explained: "We want every Nanyang girl to be equipped with basic cycling skills because we

Furthermore, the school has organised outings for its teachers that involve riding the DTL, to acquaint them with the rail line and inspire them to use it instead of their cars when travelling to and from school.

The building of the DTL was a national affair, with communities across Singapore rallying around its construction from 2008 to 2017 and thousands of people thronging the open houses that were held for each segment of the rail line. Here's a look back at the country's



Far left: Mr Ong You Yuan (in red) and several others during a visit to the Gali Batu MRT Depot in August 2017. , Picture: LTA

Left: Joash Chee with Rolling Stock engineers from LTA on the first DTL 2 revenue service train on 27 December 2015. ture ITA



















FILL SUSSEEMS TREEK



A TRAIN FOR THE FUTURE

he story of the DTL goes beyond its stations and tunnels.

To keep commuters moving in comfort, the LTA invested in state-of-the-art trains and tested each segment of the rail line hundreds of times before opening it to the public.

Even now, a purpose-built operations centre in the northern part of Singapore is keeping an eye on the DTL and its trains to ensure that its passengers' journeys are as smooth and problem-free as possible.

From the international collaboration to produce the trains to the building of a depot at the northwest end of the DTL, here's how the other half of the rail line project unfolded.

> DESIGNING A BETTER TRAIN AND LINE FOR YOU

The next time that you board a DTL train, take a good look around.

Each carriage has new and innovative features that were introduced specifically for the rail line's trains.

"In 2008, while construction on the DTL tunnels and stations was ongoing, the LTA knew that it wanted next-generation trains for the rail line that would stand out from the rest of Singapore's train stock and provide more comfort and convenience for commuters," said Mr Xun Haitao, LTA's Deputy Project Manager, Rolling Stock & Depot Equipment.

In November that year, it appointed a consortium formed by Canadian transport company Bombardier Transportation, Bombardier (Singapore) and Changchun Bombardier Railway Vehicles Company to design and build the trains.

By late 2009, the consortium had created a mock-up of a fully automated and electric train, and delivered it to the LTA for its evaluation.

Besides placing emphasis on the design of the train, the LTA also spared no effort in leveraging technology to enhance the commuting experience on the DTL while being as environmentally friendly as it could.

"With each new line and new station, we try to make sure that we further upgrade their design, taking advantage of new technology and innovations," said Coordinating Minister for Infrastructure and Minister for Transport Khaw Boon Wan.

The DTL boasts several innovative features that differentiate it from the other MRT lines in Singapore.

Among other things, it has trains with highly recyclable bodies, uses energy-efficient LED lights and tempered glass swing-flap fare gates at its stations, and is the first MRT line to adopt the Green Mark Scheme, which encourages sustainable construction.

- Ergonomic seats
- 'Perch' seats
- •
- High recyclability

Step onto a DTL train and you'll find state-of-theart features meant to improve your comfort and convenience. These are some of them.

The curves on the seats make them more comfortable.

With these seats, which replace the two-seaters on Singapore's other trains, commuters have more space to stand and can board and exit the train more easily.

Dynamic route map displays

Look at these maps and you'll see flashing lights that indicate the current or upcoming station, and the side of the train that the doors will open on. LCD and LED panels on the train also display useful travel-related information.

• Clearly marked reserved seats

If you have difficulty standing, just look for these clearly differentiated reserved seats.

Up to 90 per cent of the train's car body can be recycled when it reaches the end of its life cycle, as it is made of highcapacity aluminium.

• Environmentally friendly components

The train also has regenerative brakes that recover energy, and lightweight converters that make it lighter than other trains in Singapore. This means that it uses less electricity. Fleet-wide, this results in about 2,000 megawatt hours of electricity savings each year, which is enough to power about 430 four-room Housing Board flats for a year.







Top: 'Perch' seats free up more space for standing passengers. Picture: Alphonsus Chern for the LTA

Middle: Route map displays have flashing lights that indicate the current station. Picture: LTA

Bottom: Reserved seat stickers featuring "Stand-Up Stacey" remind commuters to give their seats to those who need it more. Picture ITA



SOME ASSEMBLY REQUIRED

1. PRODUCING THE CAR BODY (TWO MONTHS)

• Aluminium panels were welded together to form the train car's floor, roof and walls respectively.



• High-tech cutters were then used to remove excess material, and to cut spaces for doors and windows in the walls.



- After the walls were welded to the floor, a crane was used to drop the train's roof into position.
- After the car body was put together, workers took optical measurements of it to ensure that its dimensions were accurate.
- The completed car body was painted and then sent to another facility for assembly.

2. ASSEMBLING THE TRAIN (TWO MONTHS) This process consisted of seven stages.

By 2012, the production of the trains was in full swing. While the

trains had been designed in Bombardier Transportation's head

office in Hennigsdorf, Germany, their construction was a truly

Under the supervision of a Bombardier team which was based

in Singapore, components were sourced from several countries, including Britain and Sweden, and the trains were assembled

overseas too. This is how the assembly was done.

STAGE 0 (PRE-ASSEMBLY)

international affair.



STAGE 1



Workers put together various components for the train, including highvoltage cables, battery boxes, wiring ducts and bogies, which are the frames that carry the trains' wheels.

These components were installed on the train later.

Insulation that prevents warm air in tunnels from heating up the train was installed.

- Windows were set in the window frames, while a machine was used to seal gaps in the floor.
- Air ducts and cable ducts were installed.

STAGE 2



- use to evacuate the train.

STAGE 3

of the train.

STAGE 4



• Passenger doors were fixed in place, as well as a detrainment door that passengers could

• Pneumatic systems that aid in the braking of the train were installed.

• The train's interior walls were installed. An air-conditioning unit was installed on top

• The train's ceiling and lighting were installed. The couplers to link the train's carriages and the gangways between the carriages were also fixed.





STAGE 5

Passenger seats, glass partitions and grab poles were installed.

STAGE 6

- The bogies were installed beneath the carriage.
- Various labels such as those for reserved seating were also put up.

3. TESTING THE TRAIN (TWO MONTHS)

- Each completed train car underwent static tests for its lighting, airconditioning and other functions. Later on, each three-car train was also tested on a 3 km test track.
- Other contractors providing signalling, communications and platform screen door systems were brought in for integrated tests. The train has to run smoothly with these systems as well.



5

Pictures: Singapore Press Holdings

THE FIRST TRAIN ARRIVES

The first completed DTL train arrived in Singapore on 12 October 2012.

- 1 On that day, engineers from the LTA and Bombardier Transportation prepared to receive the train at Singapore's Jurong Port.
- 2 By the time the three-car train arrived, it had travelled for 13 days by land and sea from Bombardier Transportation's overseas manufacturing facility.

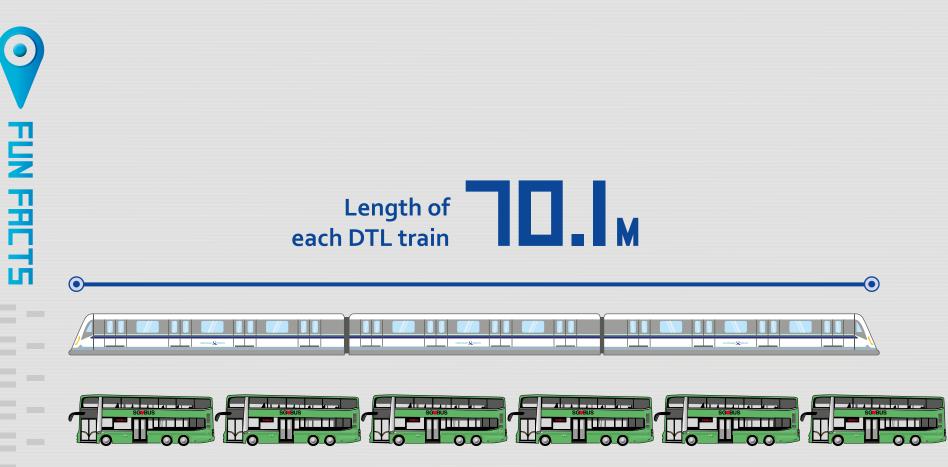






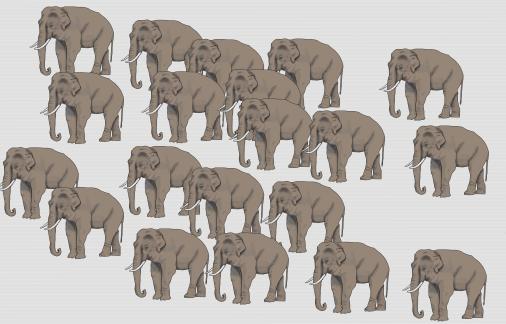


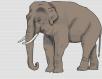




This is slightly shorter than the total length of six SBS doubledecker buses lined up end to end.

Weight of each DTL train when empty





This is approximately the weight of 21 adult, male Asian elephants.



> DELIVERING A DEPOT

In March 2009, the LTA announced that it had chosen a consortium of two companies, South Korea's GS Engineering and Construction Corp and Singapore's Hock Lian Seng Infrastructure, to build the depot.



As the construction of the Gali Batu MRT Depot would encroach on part of the Kwong Hou Sua Teochew Cemetery, pictured here in November 2008, nearly 2,000 graves had to be exhumed beforehand. Picture: Singapore Press Holdings

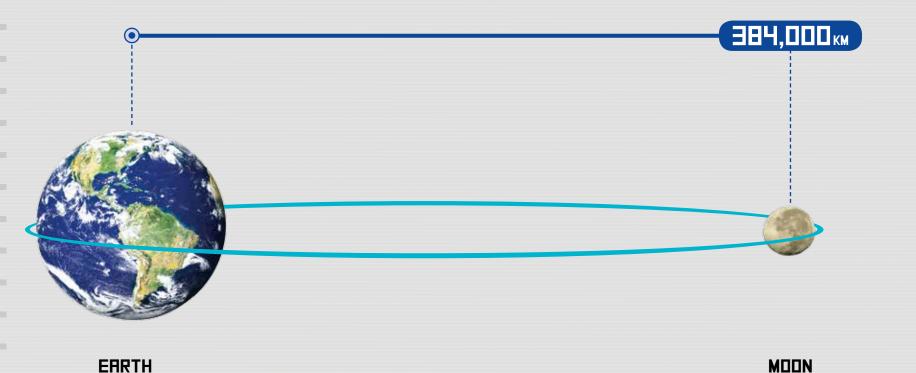
> A HOME FOR THE TRAINS

- In early 2009, with work on the trains underway, the LTA turned its attention to another critical part of the DTL: the Gali Batu MRT Depot.
- The depot was slated to be constructed at the northwest end of the DTL, beyond the rail line's terminal Bukit Panjang station.
- The completed depot would house the DTL trains.
- With the DTL trains being fully automated, the operations control centre at the depot would
- also oversee the rail line's operations and step in to fix any problems that occurred.
- Furthermore, the depot would also hold other essential facilities for the DTL, including a central warehouse for spare parts and an automatic train washing plant.



I

The designed lifespan of each DTL train, assuming a travel distance of 130,000 km per year **TERRS**



The distance covered by a DTL train in 30 years would be

10 times the distance between the earth and the moon.

alternative arrangements. late 2019.

Located off Woodlands Road in the northern part of Singapore, the Gali Batu MRT Depot contains 19 buildings in total, including a seven-storey administration cum workshop building. These are some of its most important facilities.

at all times.

GS Engineering had worked on the Seoul Subway Line and Goyang Train Depot in South Korea. Hock Lian Seng, for its part, had completed numerous road and rail infrastructure projects in Singapore, including erecting the Circle Line's Kim Chuan MRT Depot.

The two companies started building the depot later in 2009.

As the construction would encroach on part of the Kwong Hou Sua Teochew Cemetery, off Woodlands Road, nearly 2,000 graves had to be exhumed beforehand.

The LTA set up a website listing the names of the deceased which could be discerned from the tombstones, to notify their next-of-kin.

The LTA also paid for the remains to be cremated individually, and for the ashes to be placed in urns and kept in a government columbarium unless the next-of-kin had requested

The depot was originally intended to house 42 three-car trains, but the LTA later decided to increase its capacity to 81 trains instead.

The main depot was completed in 2015, while the expansion works will be finished by

By then, the depot will occupy 25 hectares, a land area equivalent to that of 38 football fields, up from 21 hectares now.

> KEEPING WATCH OVER YOU

• The Operations Control Suite

The nerve centre of the DTL, this suite consists of the operations control centre, the depot control centre and the training development centre.

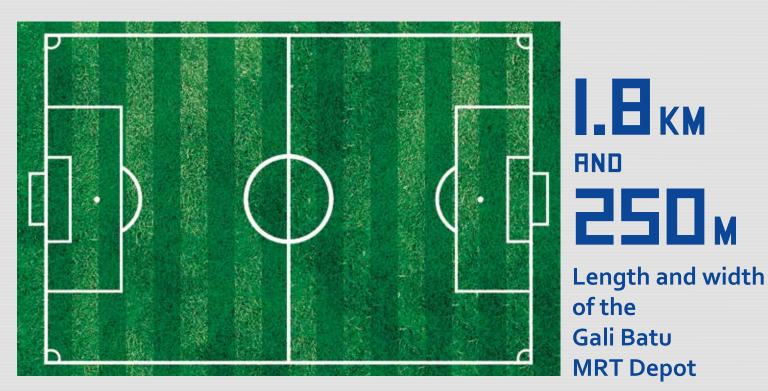
At the operations control centre, staff monitor, supervise and control the operations of the entire DTL. A large video wall displays the location of each DTL train

"When there is a fault, the staff can act to correct it, either by resetting the train system remotely or directing employees at a station to do so," said Mr Ng Tian Beng, LTA's Senior Project Manager, Integrated Control Systems.

The depot control centre manages the subsystems and equipment within the

depot, while the training development centre houses systems for the training of staff.

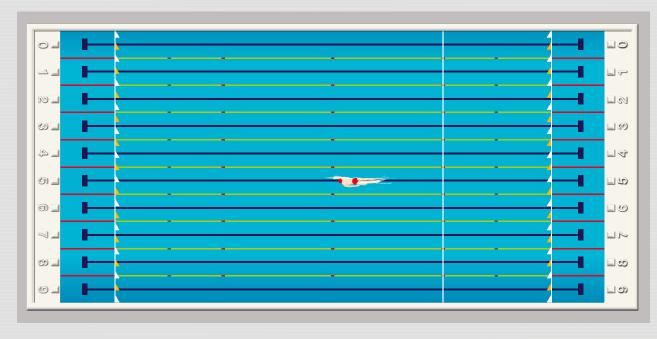




The length of Gali Batu MRT Depot is approximately the length of 15 football fields and the width is about 5.

3.9 MILLION CUBIC METRES

The volume of earth dug out to create the depot



This is enough to fill more than 1,500 Olympic-size swimming pools.

• as needed.

•

• The Train Stables



The Automatic Storage and Retrieval System

- This warehouse stores the materials, equipment and spare parts that are necessary for the maintenance of the DTL and its trains.
- It has 13 m-high racking bays and a storage capacity of 3,600 pallets.
- The depot's staff can use a computer system to command two automatically
- rail-guided stacker cranes to collect items from the warehouse.
- Another computer system also keeps track of the stocks to replenish them

The Auto Train Wash Plant

- This automated wash plant can clean up to 50 trains in its daily wash mode, or eight trains per day in its weekly wash mode.
- It also collects about 80 per cent of the water used for each wash for reuse.

By 2019, these stables will be able to hold up to 81 three-car trains, up from 42 now.

Bottom left and right: The warehouse at Gali Batu MRT Depot stores materials, equipment and spare parts in 13 m-high racking bays. Pictures: Alphonsus Chern for the LTA





> EAST COAST INTEGRATED DEPOT

By 2024, some of the DTL trains will be housed and maintained at a new depot called the East Coast Integrated Depot.

This new depot, which will be located in the east of Singapore, will be the world's first to combine three rail depots and a bus depot.

The DTL depot will be located underground, beneath a surface-level depot for the upcoming Thomson-East Coast Line and an elevated depot for the East-West Line.

The bus depot will be housed in an adjacent five-storey building.

The DTL section will be able to house 75 three-car trains.

"With this new depot in the east, we'll be able to optimise how we launch DTL trains in the morning and stable and maintain them," said Mr Chia Choon Poh, LTA's Director, Rolling Stock & Engineering.

An artist's impression of East Coast Integrated Depot. Picture: LTA





and coupling drills.

"The preparation for the tests was extensive too. Before each day's tests began, LTA officers walked along the train track to check that it was free of foreign objects and safe for use."

Mr Jerry Mak, LTA's Project Manager, Trackwork

> MAKING SURE IT WORKS FOR YOU

Mass rapid transit systems are extremely complex and consist of many subsystems. Each of them has to be checked multiple times to ensure that it is working well, and working well with the others.

The LTA, its contractors and SBS Transit, the operator of the DTL, completed hundreds of tests that spanned every part of the DTL before each of its segments was opened to the public.

Ms Term Siok Lim, LTA's Deputy Director of System Integration and Commissioning, said: "These tests were progressive. We started with single-train integrated tests and eventually moved on to multiple-train integrated tests to simulate revenue service operations.

"At each stage, we also had to look at how the system performed under normal, degraded and emergency scenarios.

"Other systems such as the fare gates and platform screen doors were similarly 'stresstested' too, to see that they worked impeccably and safely.

"At the end of the test running, a systems acceptance test was carried out to evaluate the performance of the entire system under simulated revenue service conditions for seven consecutive days.

"LTA staff and engineers from various contractors worked around the clock to conduct the test and resolve any faults found."

Ms Leow Hwee Peng, LTA's Deputy Project Manager, Communications, added: "To ensure that passenger information was correct for all scenarios, roving teams were deployed to verify this at each station during multiple-train tests."

> PREPARING FOR THE TESTS

"The preparation for the tests was extensive too. Before each day's tests began, LTA officers walked along the train track to check that it was free of foreign objects and safe for use," said Mr Jerry Mak, LTA's Project Manager, Trackwork.

A toolbox meeting was conducted before each test shift to ensure that the personnel involved were aware of the safety and test requirements. A book-in and book-out procedure was also instituted to account for every person.

"We also assigned duty officers at the operation control centre and depot to make sure that the tests were carried out properly and safely, and all testing processes and safety requirements were strictly adhered to," said Mr Ng Ken Meng, an LTA Deputy Project Manager of System Integration and Commissioning for the DTL.

Ψ

> READY FOR ALL SCENARIOS

The tests were also varied in nature, ranging from equipment tests to contingency exercises

To prepare for emergency situations such as evacuations and train breakdowns, SBS Transit customer service officers were trained to operate the usually automated DTL trains if that became necessary. They also took part in 'coupling drills' where a train is linked to a stalled train to push the latter to the next station.

Simulations of various scenarios and joint exercises with the Singapore Civil Defence Force also helped to prepare the SBS Transit staff for many eventualities.

The DTL has 15 stations that are also Civil Defence public shelters. For each of these stations, an overpressure regime and airflow test was conducted. This involved the test team staying in the station for three days after it was fully sealed and its tunnel blast doors closed, to ensure that people could survive in it.

Once the station was sealed, the team members used air handling units to pressurise

SBS Transit staff observing the train recovery exercise. Picture: Singapore Press Holdings





For each of the 15 DTL stations that are also Civil Defence public shelters, including the Tampines East station pictured here, an overpressure regime and airflow test was conducted. Picture: LTA

the station. They then checked for leakages in the station's openings and gaps. Once they confirmed that there were no leakages, they activated the intake of fresh air, checked the performance of the station's chillers and carried out other tasks.

Other LTA staff monitored the test results externally through an Environmental Control Panel computer program, and kept an eye on the test team members to ensure their safety.

> GETTING THE SIGNALS RIGHT

The DTL's unique signalling system was also tested rigorously.

This system, which was built from scratch, is the first in Singapore's rail network to have both a primary communications-based train control system as well as a fallback signalling system for additional redundancy.

Overlaying the two component systems meant that design and testing works had to be done twice, once for each system.

The extensive testing of the DTL's signalling system included validating detection and

control signals from all of the train line's equipment individually, shunting track circuits to validate shunt resistances and detection feedback, and more. The LTA also provided support to SBS Transit in the system's use.

Line trains. Ms Hnin.

MOVING HOME

Depot built for the Circle Line.

> TESTING IN ALL WEATHER

For Ms Hnin Ei Phyu, Deputy Project Manager of System Integration and Commissioning in the LTA, the most memorable tests were the ones carried out at the overseas DTL test track. As the DTL trains had been specially designed for the rail line and featured numerous innovations, the first two completed ones were put through 17 months of rigorous core system integration tests, two months longer than the testing period for the North East Line and Circle

From September 2011 to January 2013, there were five LTA staff at the DTL test track at any given time to oversee the system integration, rolling stock, signalling, communications, and integrated supervisory and control system respectively.

The staff did not stop the tests even during the winter, when the harsh weather conditions imposed restrictions on the trains' speed and the activities that could be conducted.

"The temperature sometimes dropped to as low as minus 25 degrees Celsius. We had to place heaters in the train to keep warm and shunt the train back to the workshop daily as most of the equipment on the train was not designed for operations in such cold conditions," said

For about two years, the staff from LTA and SBS Transit who were monitoring and controlling the day-to-day operations of the DTL 1 had to work from a temporary operations control centre in the Kim Chuan MRT

Although the DTL 1 was opened to the public in December 2013, the rail line's own operations control centre was ready only in October 2015 because it was housed in the Gali Batu MRT Depot built as part of the DTL 2. After the tests for the Gali Batu operations control centre and the DTL 2 were completed, a migration exercise was carried out to shift the DTL 1 operations from the Kim Chuan centre to the Gali Batu one.

Not only was this the first time that the LTA had shifted the operations control centre of a revenue service rail line, the team in charge of the migration had to complete all of the system network switches, system configuration updates and functional checks within three hours to avoid disrupting the operations of the DTL.

Before carrying out the actual migration, the team conducted migration tests on three nights every week for six months.

Mr Jason Ong, LTA's Executive Project Engineer of System Integration and Commissioning, said of the experience: "The seamless switchover was possible only because of the close cooperation among the 200 staff involved, including those from the LTA, its contractors and SBS Transit."



"To ensure that the final connection was made safely and would not affect train services plying along the DTL 1 and DTL 2, our team of staff and contractors conducted numerous table-top exercises and working sessions with various stakeholders to work out the procedures and timelines."

Mr Koh Lip Yung, LTA's Senior **Project Engineer of Trackwork**

> BRINGING THE INTAKE POWER SUBSTATION UNDERGROUND

To promote the efficient use of land resources, the first underground intake power substation for the MRT system was built at the eastern end of the DTL.

This allows the surface land area originally intended for the intake power substation to be utilised for other purposes, and thus, harmonised with the surroundings.

To further improve the reliability of the rail line's power supply system, an integrated system comprising voltage limiting devices and a fault identification system had been successfully trialled in the DTL 1. The system is being implemented for the entire line.

This system is able to perform quick detection and identification of faults, thereby minimising operational disruption.

To enhance operational reliability, all traction cables have also been rerouted to a high level, providing ease of maintenance and inspection.

> THE FINAL LAP

The tests reached a fever pitch in the months before the October 2017 opening of the DTL 3, the third and last segment of the rail line to be completed.

In preparation for trial runs to be conducted by SBS Transit teams, the LTA had to do a final connection to bridge the power rails within the fully constructed DTL 3 to the operational DTL 1 and 2, over a few nights.

"To ensure that the final connection was made safely and would not affect train services plying along the DTL 1 and DTL 2, our team of staff and contractors conducted numerous table-top exercises and working sessions with various stakeholders to work out the procedures and timelines," said Mr Koh Lip Yung, LTA's Senior Project Engineer of Trackwork.

Furthermore, the first two stages of the DTL had a combined length of 21 km and 18 stations. The DTL 3 alone is 21 km and has 16 stations.

"Adding 16 stations and doubling the number of trains in operation meant that the normal three engineering hours each night were not enough to run the trains for a full loop test from the Bukit Panjang station in the northwest to the Expo station in the east," said Mr Yee Boon Cheow, LTA's Deputy Group Director of Rail Electrical and Mechanical, Rail Systems.

One full round-trip loop from the Bukit Panjang to Expo stations takes about 2.5 hours. Beyond running the test trains, the LTA also needed more time for the preparatory works before each test, and to ready the systems after each test for passenger service.

To give engineers enough time to test the entire DTL as an integrated line, the LTA decided to start existing train services on the line later on Sundays for three and a half months in the

The depot's main workshop, locomotive workshop and central warehouse are naturally ventilated and lit with sunlight during the day to minimise the use of air-conditioning and artificial lights. Bicycle racks are also provided

lead-up to the opening of the DTL 3. of 6.28 am.

A GREEN AND GOLD DEPOT

From its extensive use of natural ventilation to its bicycle racks and solar panels, the Gali Batu MRT Depot is a model for sustainable train depots in Singapore and beyond. The depot is the first in Singapore to achieve the Gold certification under the Green Mark programme managed by the country's Building and Construction Authority. The programme aims to encourage the construction of more environmentally friendly buildings. The only two higher certification levels are Gold Plus and Platinum.

at convenient locations to encourage the depot's staff to cycle to work.

All of the depot's taps and sanitary appliances are water-saving ones. Solar panels were also installed on the main workshop's roof. These panels can generate up to 1 megawatt of power in total, with the electricity being used for the workshop's airconditioning system.

The LTA said that the greening of the Gali Batu MRT Depot was part of its efforts to make public transport in Singapore more sustainable.

"Every little bit helps, so we're using regenerative brakes to recover energy on trains, recycling water from train stations' air-conditioning systems, making depots more environmentally friendly, and more," said Mr Melvyn Thong, LTA's Director of Rail Services.



Solar panels at the Gali Batu MRT Depot generate electricity for the workshop. Picture: Alphonsus Chern for the LTA

From 14 May 2017 to 27 August 2017, the first train travelling from the Bukit Panjang station to the Chinatown station left at 7.31 am on Sundays instead of the usual 5.50 am. The first train in the opposite direction also left Chinatown station later, at 7.31 am instead

To help commuters who needed to travel before the new opening time on the rail line, the LTA introduced a temporary shuttle bus service that ran parallel to the DTL alignment and stopped at each of the 18 stations between Bukit Panjang and Chinatown. The fares for the bus also followed the rail line's fare structure.

"With the additional time, we conducted intensive performance checks on the train systems as a full line, including on train service punctuality and the automatic movement of train services. You know, more than 200 people were involved in these tests, from LTA teams to SBS Transit staff and engineers from various contractors," said Mr Yee.

"The LTA staff and test teams also stayed behind after each test in case there were any issues when the DTL opened for service," he added.







Photographer Darren Soh's series of photos, titled *What Remains*, displayed at the Hillview station documents the remnants of the old Keretapi Tanah Melayu railway line. Picture: Alphonsus Chern for the LTA





The second state





xit the Bencoolen station on the DTL and you'll find a paradise for pedestrians and cyclists.

The Bencoolen Street has been revitalised, with two of its four original car lanes converted into a wide footpath for pedestrians and a dedicated cycling path. Singaporeans can now enjoy lush greenery as they stroll along the walkway, and they can also take sheltered links from the train station to nearby developments such as the Nanyang Academy of Fine Arts (NAFA), Manulife Centre and Hotel Rendezvous.

The section of the street between Middle Road and Bras Basah Road was previously closed for the construction of the Bencoolen station.

"Building the station gave us a great opportunity. Bencoolen Street is at the heart of Singapore's cultural district, so instead of just reinstating the road, we thought, 'Why not convert part of it into a shared space, with a wide footpath, trees and benches?'

"Now, everyone can enjoy the street more," said Mr Eugene Chiam, LTA's Senior Executive, Active Mobility Unit.

The street's transformation is also part of the Singapore government's Walk Cycle Ride SG plan to make the country more 'car-lite', and give people more options to walk and cycle.



Coordinating Minister for Infrastructure and Minister for Transport Khaw Boon Wan cycling on the dedicated cycling path, during the official launch of the revitalised Bencoolen Street, in conjunction with the special edition of Car-Free Sunday SG on 28 May 2017. Picture: Singapore Press Holdings

throughout Singapore. via East Coast Park.

Of the two remaining vehicle lanes, one has been changed into a full-day bus lane to encourage people to take public transport.

About 125 bicycle parking lots have been built at key locations along the street, including at the entrances of the Bencoolen station, NAFA, V Hotel and Bayview Hotel. The dedicated cycling path will also connect to existing and future cycling routes

Singaporeans will be able to ride safely and comfortably to the city centre, Queenstown in the west, Bishan and the North South Corridor to the north, and the Central Area cycling network in the south.

This network extends from Marina Bay and connects to the eastern part of Singapore

Cyclists can go from Bencoolen Street to Rochor Canal, ride along the canal to Kallang River, and can even go farther north to Geylang.

> PUTTING A SMILE ON STUDENTS' FACES

The new Bencoolen station and street are also boons to NAFA students. The school's fourth campus is built on top of the station and integrated with it, so students can go to their classes easily in rain or shine.

The wide footpath also earned their praise. "It's much more spacious now," Ms Wahyu Rosli, an advertising student, told *The Straits Times* in 2017.

In fact, walk along Bencoolen Street and you'll find a set of seven playful and funky benches that were created by the school's students and alumni.

NAFA had organised a design competition to come up with innovative benches for the revamped street, and the winners were chosen by judges from the school, LTA, Urban Redevelopment Authority, National Heritage Board and other organisations.

Ms Belinda Gan, an alumna, developed a trio of fibreglass benches shaped like animals and painted in ombre colours reminiscent of Paddle Pop ice cream. Two of the benches are double-seater ones shaped like dogs, while the third is for one person and looks like a cat lying on its back.

"I hope my bench brings joy to someone's day! That would make the hard work and sweat worth it," she told *The Straits Times* in 2017.

The Bencoolen station is not the only DTL station that is integrated with a school. Students at the Singapore University of Technology and Design can take the rail line to its Upper Changi station and then walk to their school via an underground linkway.

"Bencoolen Street is at the heart of Singapore's flourishing cultural district, so instead of just reinstating the road, we thought, 'Why not convert part of it into a shared space, with a wide footpath, trees and benches?"

Mr Eugene Chiam, LTA's Senior **Executive, Active Mobility Unit**





Doggo & Kitty Cat (foreground) and Haus (background), designed by NAFA alumnae Belinda Gan (left) and Kwek Sin Yee respectively, are among the unique benches that line the revitalised Bencoolen Street. Picture: Singapore Press Holdings

> GOING ON HOLIDAY? TAKE THE DTL

Indulging your wanderlust has never been simpler. All you have to do is to hop onto the DTL and breeze into Changi Airport.

Tourists visiting Singapore can take the MRT line in the reverse direction to travel to the city. All it takes is a transfer at the Expo station, an interchange with the East-West Line that connects to the airport.

> ON HOME GROUND

With the DTL, more places in Singapore are now closer than you think.

Nature lovers, you can zip right to the doorstep of Bukit Timah Nature Reserve for a rejuvenating trek.

If you prefer retail therapy, the DTL can also take you downtown for as many shopping sprees as you desire. Food enthusiasts will also adore the line as they can go to even more cafes and restaurants.

Here are some of the interesting places located near the DTL's stations. Have a look!

Depth of the Bencoolen station, the deepest MRT station in Singapore





Recreational divers can dive to the maximum depth of 40 m.



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> IN THE HEART OF THE CITY

PROMENADE

• Singapore Flyer

This is one of the world's largest Ferris wheels, at 165 m-tall.

• Marina Bay Waterfront Promenade

Dine in style at this broad, landscaped promenade, which has a variety of eateries offering alfresco dining by the sea.

• F1 Pit Building

An event venue, this building housed the 2017 Army Open House and concerts during the annual Formula 1 race in Singapore.

BAYFRONT

- ArtScience Museum
- Helix Bridge
- Gardens By The Bay

This sprawling nature park includes two glass conservatories and 18 towering "supertrees" made of concrete, metal and nearly 170,000 plants.

Clockwise from top left:

A capsule of the Singapore Flyer rising against the morning sun.

A pair of joggers running along Marina Bay Waterfront Promenade with the skyline of the central business district silhouetted by the setting sun on 5 February 2015.

People soaking in the atmosphere at the opening of The Helix, Marina Bay's spiral-shaped pedestrian bridge, on 24 April 2010. About 12,000 people turned up at Marina Bay to witness the event.

The ArtScience Museum cloaked in an animated projection named the *Garden of Light*, created by local company Hexagon Solution, as part of i Light Marina Bay, Asia's sustainable light festival, in March 2012.

The Formula One Singapore Airlines Singapore Grand Prix taking place at the Marina Bay street circuit on 18 September 2016.

Pictures: Singapore Press Holdings

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1500

The approximate number of LED lights used in DTL 2 stations

These lights are about 30 per cent more energy-efficient than the conventional ones used in Singapore's previous rail lines, and have a longer lifespan of about 50,000 hours. They are also used in DTL 3 stations.



The DTL 2 was the first MRT line in Singapore to adopt the Building and Construction Authority's Green Mark scheme, which aims to promote more environmentally friendly construction and buildings.

> Gardens By The Bay, pictured on 26 September 2014, includes two glass conservatories and 18 towering "supertrees" made of concrete, metal and nearly 170,000 plants. Picture: Singapore Press Holdings

FUN FACTS



> JOURNEY TO THE NORTHWEST

BUKIT PANJANG

Rail Corridor

Take a walk along this 24 km-long green corridor for some respite from urban living.

HILLVIEW

• Dairy Farm Nature Park

Go hiking or cycling in this park, and visit the Singapore Quarry — which has been converted into a wetland habitat — at its southwestern end.

BEAUTY WORLD

• Bukit Timah Nature Reserve

This reserve contains one of the world's richest and most diverse ecological systems. It is also home to the Bukit Timah Hill, which is Singapore's highest hill at 163 m.

BOTANIC GARDENS

• Singapore Botanic Gardens

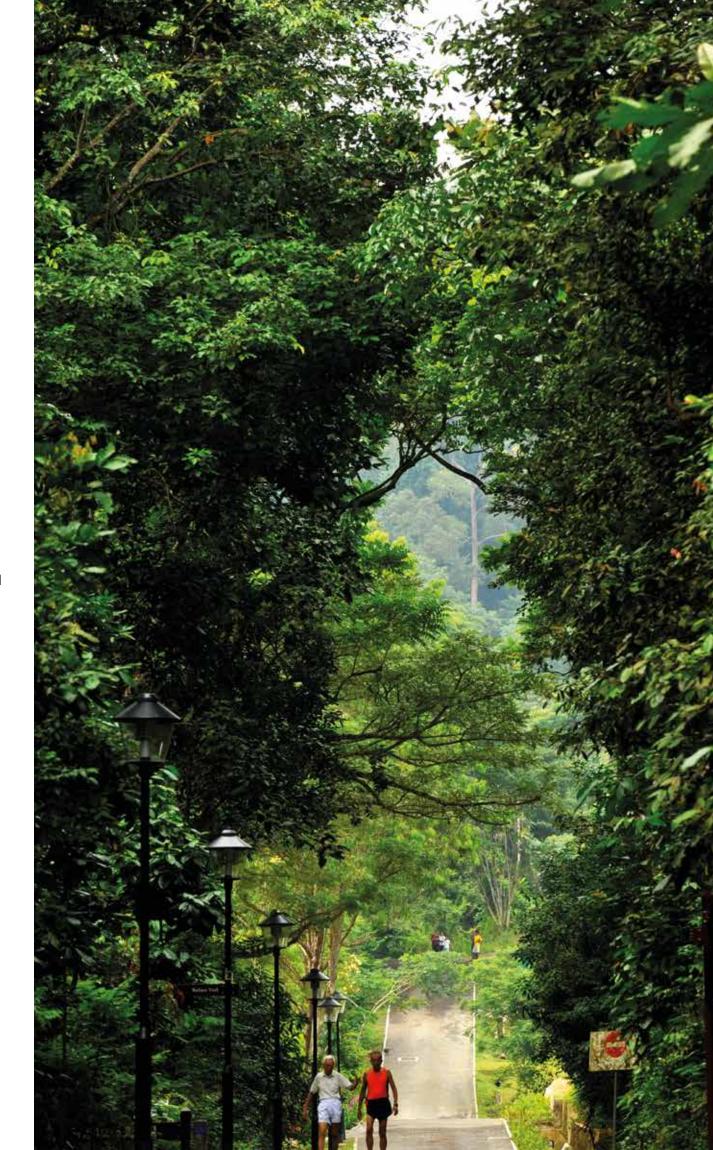
Singapore's only United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage site, this beautiful botanic gardens was created in 1859 and showcases the best and most spectacular of tropical flora.

> **Clockwise from left:** The Dairy Farm Nature Park was officially opened in September 2009.

The green corridor stretches from the former Tanjong Pagar Railway Station to the old Bukit Timah Railway Station, near the railway bridge pictured here on 3 July 2015.

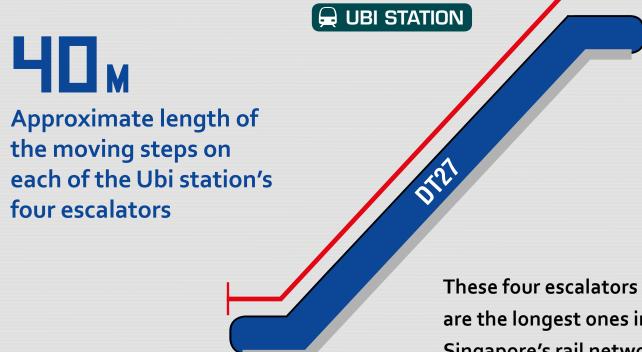
Bukit Timah Nature Reserve was reopened in October 2016 with handrails and boardwalks after two years of upgrading works.

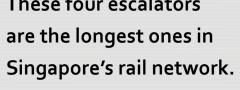
Pictures: Singapore Press Holdings

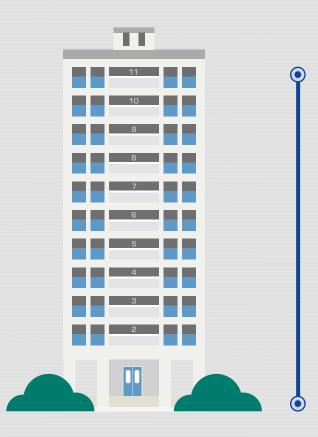




An aerial view of the Singapore Botanic Gardens with the city skyline in the background as taken by a drone on 29 May 2015. Picture: Singapore Press Holdings







34.22^M

Depth that the lifts in the **Stevens station descend** to from the street level, to the lower platform

This depth is equivalent to an 11-storey HDB block, if it were underground.



The Ubi station has the four longest escalators in Singapore's MRT network. Picture: LTA -

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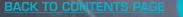
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> EXPLORING THE EAST

FORT CANNING

• Fort Canning Park

Steeped in history and lush with greenery, this hilltop park contains ancient artefacts and hosts concerts, theatre productions and festivals.

BEDOK RESERVOIR

• Bedok Reservoir Park

Spend a weekend at this park and try the Forest Adventure, Singapore's only treetop obstacle course. There are also water sports and other amenities here.



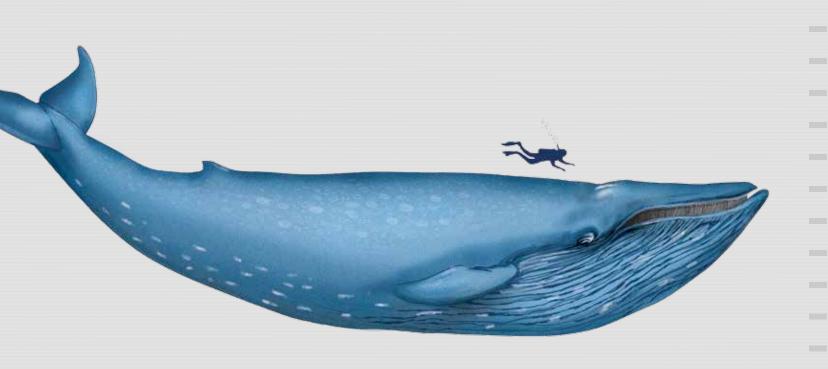


Top: The Tamalan tree at the Fort Canning Park.

Bottom: A 200 m-long zip line is one of the features available at the Forest Adventure aerial obstacle course at Bedok Reservoir Park.

Pictures: Singapore Press Holdings

Length of the Fort Canning and Upper Changi stations, the two longest DTL stations





The length of each station is approximately the total length of 8 adult blue whales.



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TAMPINES WEST

• SAFRA Tampines

Get a good workout at this sports facility's swimming pool, soccer pitches or multipurpose hall. There are also food and beverage outlets.

TAMPINES

• Our Tampines Hub

This integrated community and lifestyle hub has food and beverage outlets, an 800seat hawker centre, a library, a playground, multipurpose and event atriums, a rooftop garden, sports facilities and more.

TAMPINES EAST

Cycling routes

This station is connected via a cycling path to the Sun Plaza Park and Tampines Eco Green park.

UPPER CHANGI

• Singapore University of Technology and Design

Visit this university's campus to see four antique Chinese buildings — a pavilion, an opera stage and two houses — donated by movie star Jackie Chan.

EXPO

• Singapore Expo Convention and **Exhibition Centre**

This centre has exhibitions, festivals and shopping fairs every weekend. Go to its website to check out its event calendar.

Top: Our Tampines Hub was officially opened on 6 August 2017 by Prime Minister Lee Hsien Loong.

Bottom: Four antique Chinese buildings donated by movie star Jackie Chan are now part of the Singapore University of Technology and Design's campus in Changi.

Pictures: Singapore Press Holdings



> BRINGING BEAUTY TO YOUR RIDE

Singapore's MRT stations are not just stops on a rail line. Each one has been lovingly designed to reflect the character and history of the neighbourhood around it. Explore the stations and you'll also see unique artwork incorporated into their architecture — an artistic endeavour that goes back to the first few stations in Singapore's train system.

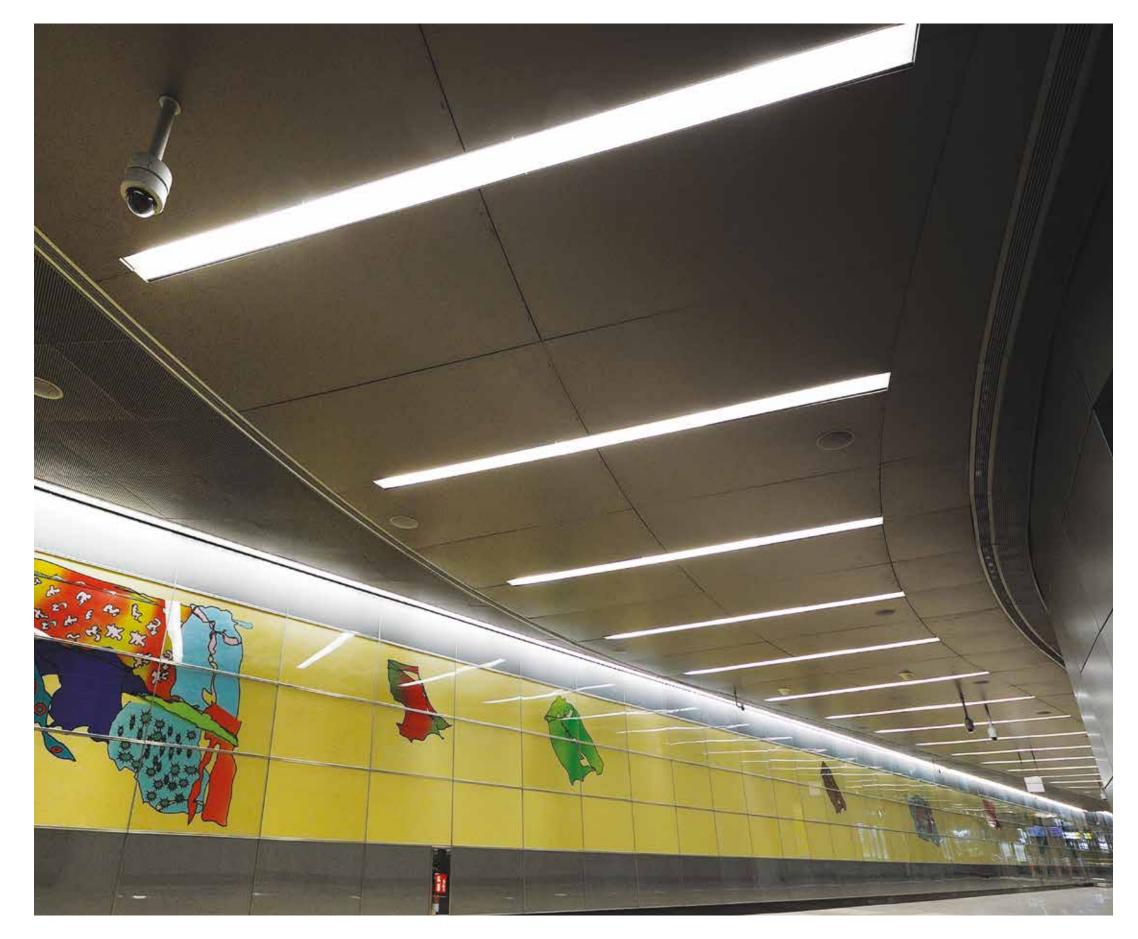
In 1997, the LTA established the Art In Transit programme with the North East Line to formalise the use of Singapore's train stations as a canvas for artists, especially local ones.

From colourful murals and arresting sculptures to vibrant stained glass and intricate mosaics, the art pieces in the stations have become a collection of works that speak eloquently about Singapore's history and culture, and add a touch of beauty to commuters' travel experience on public transport.

Think of them as an art gallery accompanying you on your daily commute!

"While all the stations are designed with safety, comfort and convenience in mind, we also want them to showcase the heritage and culture of the surroundings, where possible," said Mr Paul Fok, LTA's Group Director of Infrastructure and Design Engineering. "For example, Fort Canning station has art that reflects the history of the area, and the architecture also pays tribute to the old National Theatre, which is a nice touch."

For the DTL, the LTA commissioned renowned Singaporean artists and photographers, students and others to put their mark on the stations. Here are some of the creations.





Left and above: The artwork by artist Cheo Chai-Hiang gives the illusion of clothes flying in the wind. Pictures: LTA

CHINATOWN

Flying Colours, by Cheo Chai-Hiang

Singaporeans have been hanging their clothes out to dry on bamboo poles from their flats since the 1960s. Taking inspiration from this familiar sight in Singapore's public housing landscape, this artwork gives the illusion of clothes flying in the wind.



BUKIT PANJANG

Punctum of the Long Hills, by John Clang

'Bukit Panjang' means 'long hills' in Malay. The rows of tall public housing blocks in his images are a nod to the neighbourhood's long hilly landscape, while the giant *kampung* boys peeking around the flats represent Singaporeans' curiosity.

Right: The artwork at the Bukit Panjang station by visual artist John Clang comprises the front and back views of the two boys peeking around the flats. Pictures: LTA

Bottom: The third part of the artwork depicts the two boys from the side. Picture: Alphonsus Chern for the LTA



NEWTON

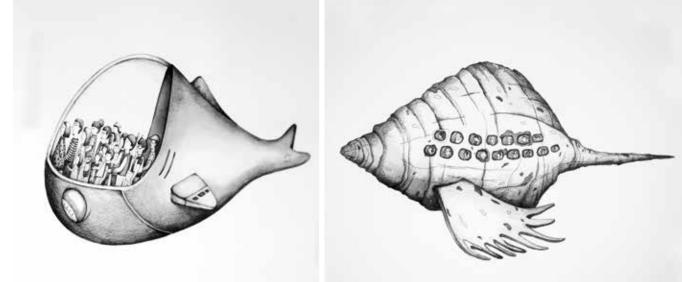
Newton, by Tan Zi Xi, also known as MessyMsxi

An imagination of Singapore's landscape in 2200 and Newton's architecture now are the two inspirations behind this artwork. It is divided into two tiers, with the top part representing Singapore's dry landscape above ground, and the bottom part 'revealing' the country's underwater landscape.





The artwork by illustrator Tan Zi Xi in the DTL Newton station depicts Singapore's dry landscape (below) and its underwater landscape (right). Pictures: LTA





FORT CANNING

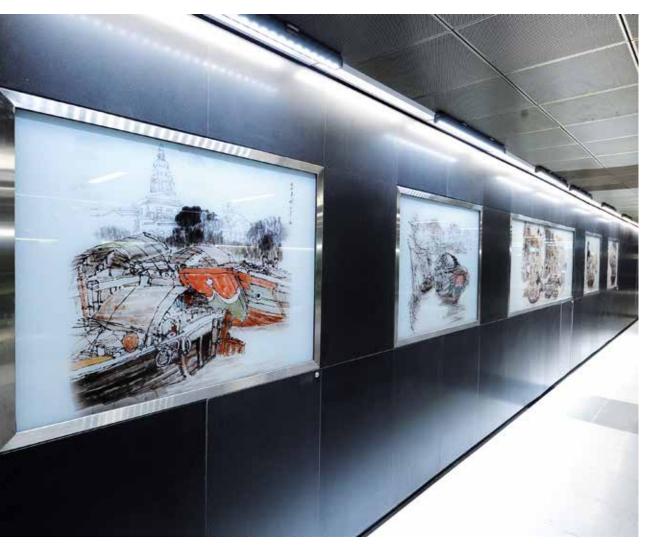
Through His Eyes, by Lim Tze Peng

This artwork features the bustling port that Sir Stamford Raffles, who established Singapore as a trading port in 1819, might have seen from his house on Fort Canning Hill.

The design of the station itself has numerous nods to the nearby hill, which is now part of Fort Canning Park, and to the former National Theatre which stood on the park's slope. The theatre was officially opened in 1963 to commemorate Singapore's self-government in 1959, and

was the country's first national theatre. It hosted international performances and National Day rallies before it was demolished in 1986.

The station's curved ceiling, and the green accents around its walls and vent shafts, are inspired by the park. At the station's concourse, the black granite walls have motifs of the theatre etched into them, the glass panels' balustrade supports are shaped like the theatre's profile, and the station lift has decals inspired by that profile too.







Clockwise from top: The design of the DTL Fort Canning station has nods to the nearby Fort Canning Park and the now-defunct National Theatre. Picture: Alphonsus Chern for the LTA

The station's black granite walls have motifs of the now-defunct National Theatre etched into them. Picture: LTA

The National Theatre, pictured on 1 April 1965, was demolished in 1986. Picture: Singapore Press Holdings

Artworks by artist Lim Tze Peng depict the scenes of the port that might have been seen from Fort Canning Hill in the 19th century. Picture: LTA

BENCOOLEN

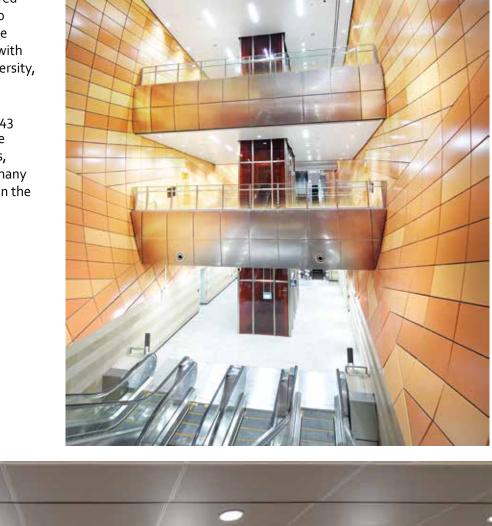
Tracing Memories, by NAFA students

This artwork was created entirely by NAFA students. Inspired by the community around the station, they used about 800 photographs of buildings, objects and people to build these human figures. Look closer and you'll see that the figures with laptops point the way to the Singapore Management University, while those with drawing tools line the way to NAFA.

The Bencoolen station is the deepest one in Singapore, at 43 m-deep, and its design reflects that too. The walls from the concourse to the platform are curvilinear, like canyon walls, while the earth-tone colours in the station symbolise the many layers of Earth's depths, and the scarlet-tinted glass walls in the lift evoke a journey to the Earth's core.

Right: The walls (left) from the concourse to the platform in the Bencoolen station (right) are curvilinear, like canyon walls, while the earth-tone colours symbolise the many layers of Earth's depths. Picture: Alphonsus Chern for the LTA

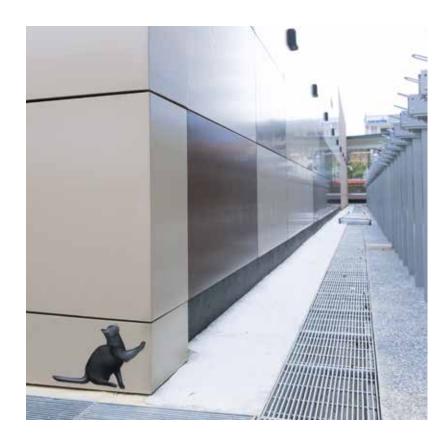
Bottom: The artwork by NAFA students was created using about 800 photographs of buildings, objects and people. Picture: Alphonsus Chern for the LTA











GEYLANG BAHRU

Constructed Memories, by Marienne Yang

A bag of *kopi-o* (black coffee), construction workers drilling into the ground, and a person on a ladder painting a wall — these scenes of a Singaporean community going about its daily business are captured in Ms Marienne Yang's artwork. A Senior Lecturer and Vice-Dean at the Nanyang Academy of Fine Arts, she also included whimsical pictograms of a kitten, a safety boot and other items in the station.

The station's leaf-shaped ceiling and floor also represent Singapore's tropical climate, while the rest of the station's rectilinear design is an allusion to the surrounding residential and industrial estate.

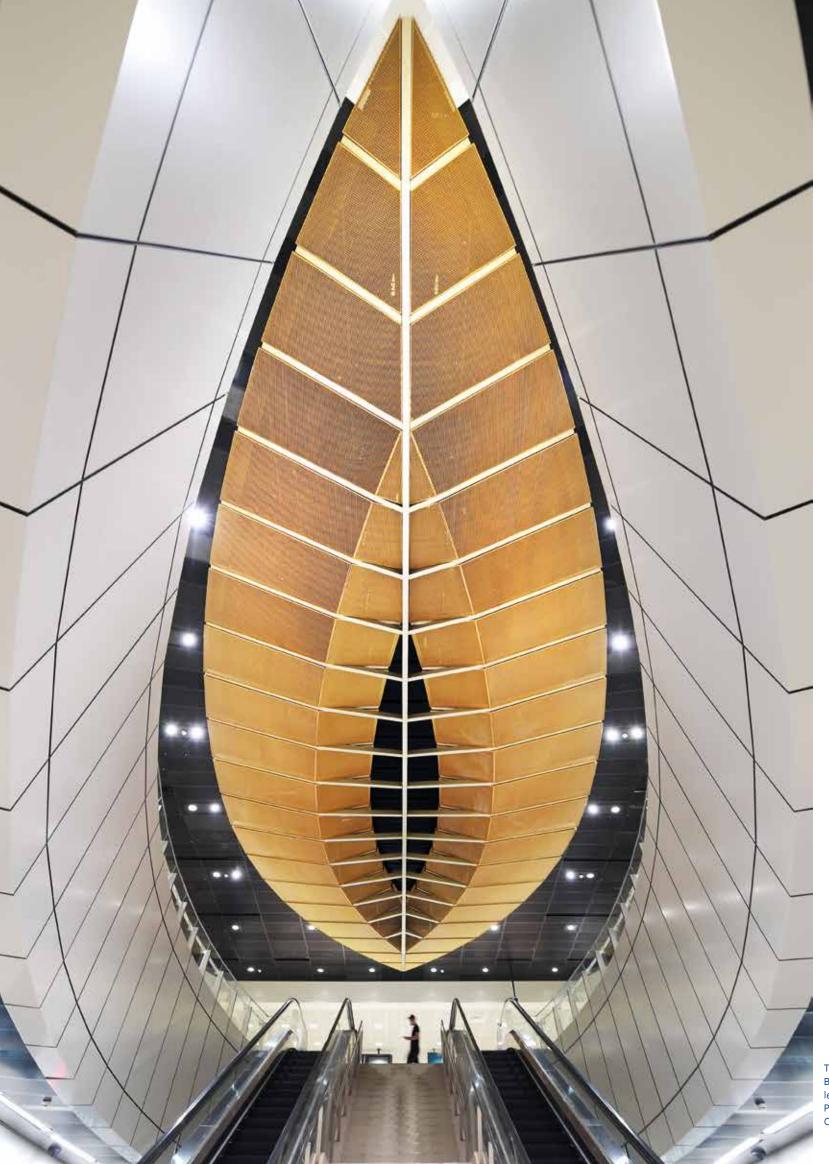
Left: A whimsical pictogram of a kitten. Picture: LTA Bottom left: A bag of *kopi-o* (black coffee) Bottom right: Construction workers drilling into the ground Right: A person on a ladder painting the wall Pictures: Alphonsus Chern for the LTA











MACPHERSON

Trails of Thoughts, by Aminah Mohd Sa'at

Walk around the station and you'll see what some of the residents in MacPherson have said about their community. Ms Aminah, a locally trained artist, interviewed 27 residents, including senior citizens, parents and youths from all races, on National Day in 2013 and reproduced their thoughts on the station's concourse wall. The artwork is rendered in Singapore's four official languages — English, Chinese, Malay and Tamil — too.



The DTL Geylang Bahru station has a leaf-shaped ceiling. Picture: Alphonsus Chern for the LTA

Right: The artwork reflects what the residents think about their neighbourhood. Picture: LTA

Bottom: Visitors getting a group photograph with the artwork at the DTL MacPherson station. Picture: Alphonsus Chern for the LTA









THE RIDE FHEFD

Those living near King Albert Park station can now take the train instead of driving. Picture: Alphonsus Chern for the LTA

n 4 January 2016, the first workday of that year, Mr Calvin Chua left his car at home and took the train to his workplace for the first time. After he rode the DTL from the King Albert Park station near his home, he made a transfer and arrived at the Circle Line's Bartley station close to his office.

"It was a bit of an adventure because it was my first time taking the MRT all the way to work, but it was a good experience!" he told *The Straits Times* that day.

"When you drive on the road all the time, there are traffic jams, a lot of disruption, and there might also be accidents along the way, so there is a lot of delay. The MRT is the most efficient way for me right now, and I'm going to use it regularly."

More people have begun to think like Mr Chua. After its second segment opened in December 2015, the DTL's average ridership during weekdays has more than tripled from 83,000 in October 2015 to 300,000 in July 2017.

Even more people are expected to use the DTL after the opening of its third and final segment in October 2017. Its ridership is projected to increase to about 500,000 on average each day.

> MORE CHOICES FOR YOUR JOURNEY

The DTL is more than just Singapore's fifth MRT line. Its completion is also a great leap forward in the completion of the country's plans for public transport up to the year 2030.

As outlined in the latest Land Transport Master Plan, by 2030, Singapore's rail network will span 360 km across the country, and eight in 10 homes will be located within a 10-minute walk from a train station.

More than 200 km of sheltered walkways, including 29 km of them from stations on the DTL, will enable residents to travel in comfort even during the first and last legs of their journey.

The LTA has already introduced new bus services and extended existing ones to connect more commuters to the DTL. The rail line also connects to every other one in Singapore.







Prime Minister Lee Hsien Loong taking a wefie with students from Methodist Girls' School during the DTL 2's opening ceremony at Botanic Gardens Station on 26 December 2015. Picture: ingapore Press Holdings

The DTL's connectivity and length across Singapore make it essential to realising the nation's goal for at least 75 per cent of trips during peak hours to be made by public transport by 2030. Achieving this target will vastly improve the country's liveability and sustainability.

The rail line is also a crucial component of Singapore's Walk Cycle Ride SG plan. This vision calls for Singapore to be an inclusive city with a transport system that enables everyone.

To attain this, the LTA is building a comprehensive network of buses and trains, as well as walking and cycling paths, to turn the country into one that is less reliant on cars, or 'car-lite', in other words.

"How we travel every day plays a significant role in shaping our experiences and our perceptions of Singapore, and influences how liveable our city is and how pleasant our lives are," said Prime Minister Lee Hsien Loong at the official opening of the DTL 2 on 26 December 2015.

He continued: "It is therefore important that we have a transport system that everyone will not only use, but also enjoy using."

> A JOB WELL DONE

From its conception to the completion, the creation of the DTL has spanned 16 years.

This success has been possible only because of the LTA teams and contractors who laboured day and night to accomplish it.

While this book has captured the highs and lows of the journey to build the DTL, including the construction complexities that were overcome, the race to make up for lost time after Austrian construction company Alpine Bau's insolvency, the efforts to engage people and the system tests, these stories reflect only a fraction of the day-to-day work.

"Everyone involved in the DTL, from designer to engineer to worker, gave their full attention and effort to the job. I especially want to thank LTA's staff, partners and contractors. The fact that we're celebrating the opening of the DTL is a testament to their hard work and resilience over the years," said LTA's Chief Executive, Mr Ngien Hoon Ping.





Picture: Singapore Press Holdings



> YOUR DOWNTOWN LINE, IN YOUR WORDS

As each stage of the DTL opened, more and more Singaporeans literally came on board the rail line.

Over the past few years, many residents have shared stories with the media about how the DTL has shortened their commutes, helped them with their businesses and given them more time to spend with their friends and family. These are some of their testimonials.



A light morning peak-hour crowd at the Bukit Panjang station on the DTL 2 on 28 December 2015, a day after its opening. Picture: Singapore Press Holdings

The DTL has brought a lot of convenience to me because the Bukit Panjang station is right at my doorstep. Going to town is a breeze now, and of course the traffic conditions will also ease because definitely more people will switch from driving cars to taking trains."

Ms Serene Tong, a Bukit Panjang resident, speaking to Channel NewsAsia in December 2015



I take the DTL when I do part-time work in Marina Bay Sands. I take the North-South Line from Novena to Newton station, and then use the DTL to go straight to the Bayfront station. It's really convenient. I also use the DTL when I'm going to hang out with my friends in Bugis."

Mr Woo Yao Jie, a student, speaking to *The Straits Times* in January 2016

Commuters walking past a wall of the DTL Bugis station on 5 January 2014. The station is about 26 m below ground level and is linked to the East-West Line Bugis station. Picture: Singapore Press Holdings









I am looking forward to the opening of the Upper Changi station as this means I can zip over to Singapore Expo for retail therapy at rock-bottom prices!"

Ms Daphne Khong, who lives near the Upper Changi station



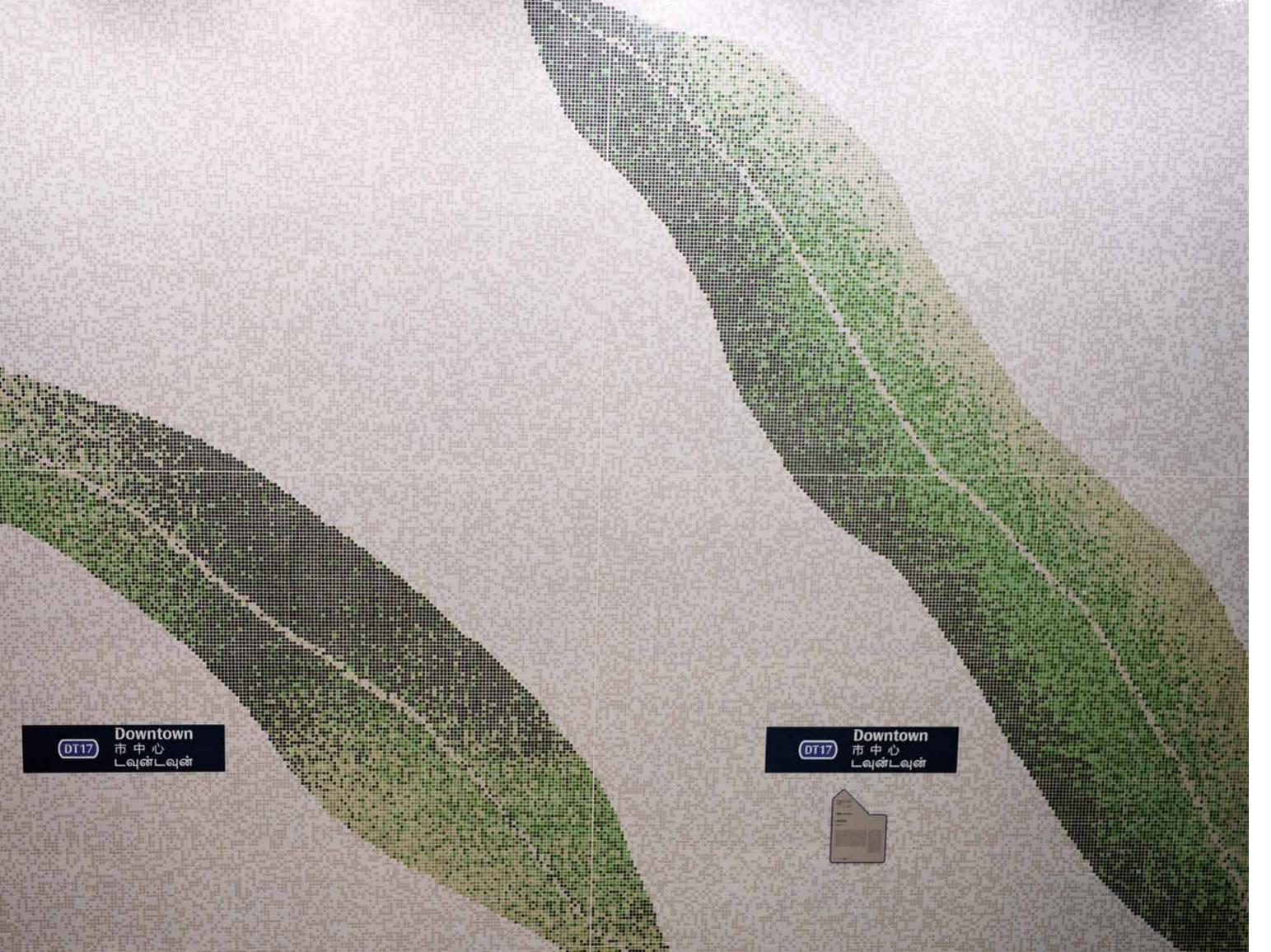
Kayaking, my favourite activity, is just a stone's throw away at Bedok Reservoir with the DTL! The DTL is truly awesome!"

Ms Christina Ong, who lives near the Tampines East station

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Bedok Reservoir is a playground for activities such as kayaking, dragonboating and sport fishing. Picture: Singapore Press Holdings





> LOOKING TO THE FUTURE

By 2024, the DTL will become even more convenient for commuters.

The rail line will be extended by 2.2 km from its Expo station, to connect with the upcoming Thomson-East Coast Line (TEL). Two more stations, Xilin and Sungei Bedok, will be built along that extension.

People who work at the Xilin Districentre, Tangs Logistics Centre and Changi Depot will be able to walk from the Xilin station to the buildings. The new stop will also benefit those who live in the area.

The Sungei Bedok station, for its part, will be located next to the Bedok Food Centre and only a few minutes' walk from the Bedok Camp for military servicemen. It will also serve the many condominiums and homes in the neighbourhood.

The Sungei Bedok station is also slated to be an interchange with the TEL. Singaporeans will be able to use the linked DTL and TEL as an alternative to the East-West Line when they want to travel to the eastern parts of Singapore. With three MRT lines serving the region, there will also be more space for people on the trains.

The next time you're headed out or home, see if the DTL can take you to where you need to go. If you're near one of its stations, make it a part of your commute. The DTL is ready for you. The DTL is yours.

Artist Jason Lim's mosiac of supple bamboo leaves, titled *Leaves*, displayed at the Downtown station, is a visual metaphor for the complex network of businesses and financial services in the Central Boulevard area where the station is located. Picture: Singapore Press Holdings





A commuter crossing the bridge linking the Tan Kah Kee station to Watten Estate. Picture: Alphonsus Chern for the LTA







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The Bedok North station is one of the 16 stations on the DTL 3. Picture: LTA



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