CEDD INNOVATION SERIES



Special Lifting Frame Erection Method

Foreword

The successful implementation of the innovative Special Lifting Frame Erection Method along the existing railway and spanning over the 24/7 cross-boundary San Sham Road marks a notable advancement in the industralisation of bridge construction within congested urban environments. This achievement exemplifies the core values of engineering excellence, innovation, quality and safety, and sustainability.

I would like to commend the project team for tremendous efforts in pioneering novel engineering technologies to effectively address Hong Kong's challenging site constraints encountered during the construction of the major new bridge, including the close proximity to the existing railway, the 24-hour cross-boundary traffic operations on San Sham Road, and the adjacent ecological sensitive areas. The team's technical expertise and innovative approaches were pivotal in enhancing construction efficiency, mitigating site safety, and minimising disruption to the public.

I would also like to express my sincere appreciation of the exemplary spirit of collaboration among the project teams and industrial practitioners, which was fundamental to the successful implementation of this innovative methodology. The integration of advanced construction techniques with digital technologies has yielded substantial and quantifiable benefits—notably in improved construction safety, optimised programme scheduling, and enhanced efficiency. These combined outcomes have resulted in significant benefits, while establishing a new benchmark for bridge construction in constrained urban settings.

As always, CEDD is committed to promoting innovation and collaboration in the delivery of resilient, safe, and sustainable infrastructure for Hong Kong. This CEDD Innovation Series publication consolidates our experience with the Special Lifting Frame Erection Method and is intended to serve as a reference of proven best practices for the local construction industry.



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CEDD

Abstract

The Development of the Loop project successfully pioneered the innovative Special Lifting Frame Erection Method in the construction of Direct Road Link (DRL) viaduct connecting the Loop to Lok Ma Chau Station. The DRL viaduct runs parallel to the MTR East Rail and spans over the 24/7 cross-boundary San Sham Road. To overcome the limited working span confined by both a live railway and 24-hour cross-border traffic road. The project team adopted a compact 360°turntable-mounted steel frame which could erect deck segments transversely at ground level, rotate 90°, and move longitudinally to the erection front. Its manoeuvrability enabled both night-time and daytime erections, resulting in higher productivity and mitigating proximity risk.

AI-driven solutions were also applied to advance construction management, digitalisation, safety and sustainability. As the pilot for automated 3D progress monitoring, the team utilized AI-controlled drones, laser scanning and BIM integration, enabling automated progress monitoring and geometric analysis to support safely and efficiently sequence of deck erection works and improve productivity.

The DRL viaduct was successfully and safely completed in October 2025 with “zero” construction incidents. With the adoption of this innovation, it greatly reduced construction time, enhanced site safety (through reducing the use of large plant lifting operation), minimized public disturbance (through reducing road closures) and reduced carbon emissions. The entire setup can be easily replicated for application in other bridge construction having similar constraints.

CEDD hopes that the innovations under the Development of the Loop project can enhance the efficiency and safety of future bridge construction in Hong Kong as well as the Greater Bay Area, strengthening Hong Kong’s role as a super-connector and super-value adder in the region.

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1 Project Overview

1.1. Project Background

The Development of the Loop project supports Hong Kong's development into an international innovation and technology (I&T) centre. In order to establish the Hong Kong–Shenzhen Innovation and Technology Park (HSITP) in the Loop (Figure 1), the Hong Kong Special Administrative Region (HKSAR) Government and Shenzhen Municipal People's Government agreed to develop the Loop jointly, formalised via a Memorandum of Understanding signed on 3 January 2017.

The HSITP is located in the Loop, adjacent to the Shenzhen River, leveraging its strategic location, creating one river two banks, one zone two parks, which forms part of the development plan for Shenzhen Park of Hetao Shenzhen–Hong Kong Science and Technology Innovation Co-operation Zone. The Development of the Loop project is undertaken by the Civil Engineering and Development Department (CEDD) to facilitate such development. It includes site formation and infrastructure works within the Loop, construction of Western Connection Road, viaducts to Fanling/San Tin Highway and Mass Transit Railway (MTR) Lok Ma Chau Station, and establishment of an ecological area.



Figure 1 – Artistic impression of the Hong Kong-Shenzhen and Technology Park (HSITP)

The key scope of works encompasses the construction of a new Direct Road Link (DRL) viaduct connecting the Loop to the Lok Ma Chau Station, which is situated adjacent to an operational railway and spans a 24-hour cross-border traffic corridor. The viaduct superstructure features prestressed concrete box girder decks, with most spans located within highly constrained areas containing multiple sensitive receivers. These include the MTR East Rail serving Lok Ma Chau Spur Line Control Point, San Sham Road which supports round-the-clock cross-boundary traffic, and nearby ecological conservation areas. Such constraints posed significant construction challenges, especially in maintaining productivity with minimal disruption to the public.

1.2 Need Innovations

In addition to the site constraints mentioned above, this project commenced during the Covid-19 pandemic, introducing further challenges in meeting deadlines and budgets. The project team recognised early that leveraging innovative solutions to enhance productivity would be essential.

New approach for constructing the major bridge structure was developed and implemented, marking significant advancements in bridge construction. As the benefits were validated, the team sought to promote this innovation for wider industry adoption.

1.3. Strategic Significance of the Innovations

The project's innovative approaches align with 'Construction 2.0', which highlights innovation as key to industry advancement. The innovative technologies and method employed in the construction of the DRL viaduct is not limited to specific site conditions but can be widely adopted as standard solutions for building other urban viaducts in congested areas and over existing roads/railways. This solution incorporates mechanised bridge erection technique with extensive pre-assembly, thereby reducing manual labour, minimising work at height, and limiting activities over live traffic. This approach effectively addresses common challenges faced by the construction industry in Hong Kong, such as the undesirable incidence of accidents and the shortage of the skilled workforce.

2. Background of Special Lifting Frame Erection Method

2.1. Challenging Site Constraints and Limitations

The DRL viaduct is located near the Hong Kong–Shenzhen boundary within the Frontier Closed Area and adjacent to ecologically sensitive zones, imposing significant constraints on site access and logistics. The viaduct runs parallel to the MTR East Rail viaducts serving the Lok Ma Chau Spur Line Control Point, which certain sections unavoidably positioned in proximity. The DRL viaduct comprise 13 spans, with typical lengths ranging from 40m to 60m. The most critical span between Pier P9 and Pier P10 crosses San Sham Road, a cross-boundary roadway serving the 24-hour Huanggang Control Point. Construction was required to proceed without disrupting this essential traffic corridor. The general layout of the DRL viaduct is presented in Figure 2.

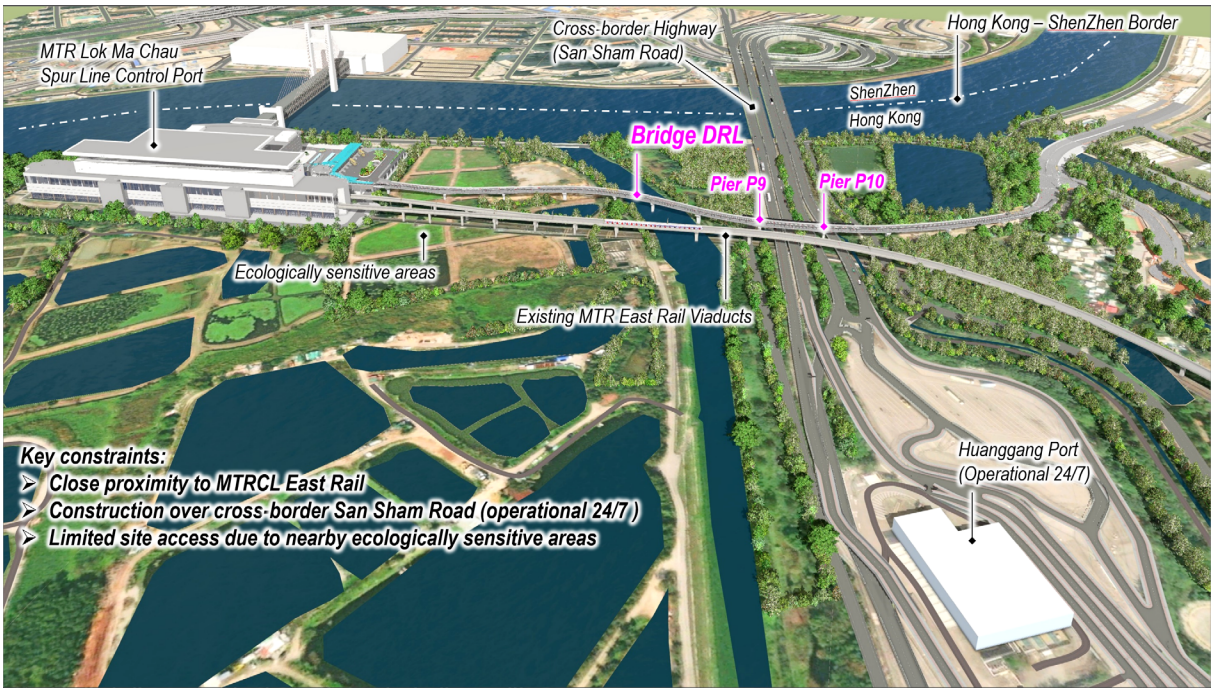


Figure 2 – General Layout of DRL viaduct and the surrounding site constraints

San Sham Road at this location is elevated and supported by existing bridges, with the DRL's viaduct Piers P9 and P10 positioned within narrow gaps between these structures, significantly constraining construction space. The span is situated where lateral clearance to the MTR East Rail viaduct is minimal (less than 6m). As the MTR East Rail is an electrified railway with overhead line infrastructure, extensive deployment of large cranes is prohibited due to the risk of accidental toppling onto railway facilities, posing severe safety and operational hazards.

2.2. Conventional Solutions and their Limitations

The conventional method for erecting bridge deck segments over extensive obstacles typically employs an overhead Launching Girder (LG). Given DRL's viaduct span length, the LG would exceed 120m. Positioned at Piers P9 and P10, it would occupy the entire airspace across all San Sham Road lanes, exposing live traffic to hazards including falling objects. Temporary traffic suspension would disrupt continuous vehicular flow to Huanggang Control Point, rendering LG utilisation impractical.

Traditional lifting frames for balanced cantilever erection were also considered. However, this approach requires segment delivery to the cantilever tip, which was unfeasible as certain areas beneath the T-span are inaccessible to lorries. Feeding segments from the rear was examined, necessitating continuous crane operations near the pier-head and trailer transport along the deck. This would entail extensive crane use proximate to the MTR East Rail viaducts, unfavourable for railway protection. Frequent crane and trailer operations near the MTR East Rail and San Sham Road would introduce unacceptable construction risks. Accordingly, traditional lifting frames were also deemed unsuitable.

2.3. Development of the Innovative Solution

Following the evaluation of conventional solutions, the project team developed the Special Lifting Frame (SLF) in 2023 to address deck erection challenges at this location. Unlike traditional lifting frames with linear motion only, the SLF features a base-mounted turntable enabling all-directional rotation. Segments transported to ground level adjacent to the pier are lifted transversely by the SLF, avoiding T-span obstructions. Once elevated above deck level, the SLF rotates 90° and transports segments longitudinally to the erection front. The SLF facilitates segment pick-up, feeding, and erection without cranes or trailers, thereby mitigating risks to San Sham Road and the MTR East Rail viaducts.

The SLF is more flexible and agile than the LG. It only needs to be stationed at the erection front above San Sham Road during limited nighttime shifts. During daytime, when the road experiences heavy traffic, the SLF is moved back to the pier-head location, away from the airspace above the road, improving safety. While stationed on the pier-head, the SLF is anchored to the permanent structure underneath by prestressed bars, ensuring stability and posing no risks to the adjacent railway.

The use of the SLF is innovative because no previous lifting frame could combine all these functions, making bridge deck erection easier in highly constrained areas near various sensitive receivers. Its multifunctionality and agility enable a high production rate – typically two segments per night shift (see Figure 3 for features and advantages).

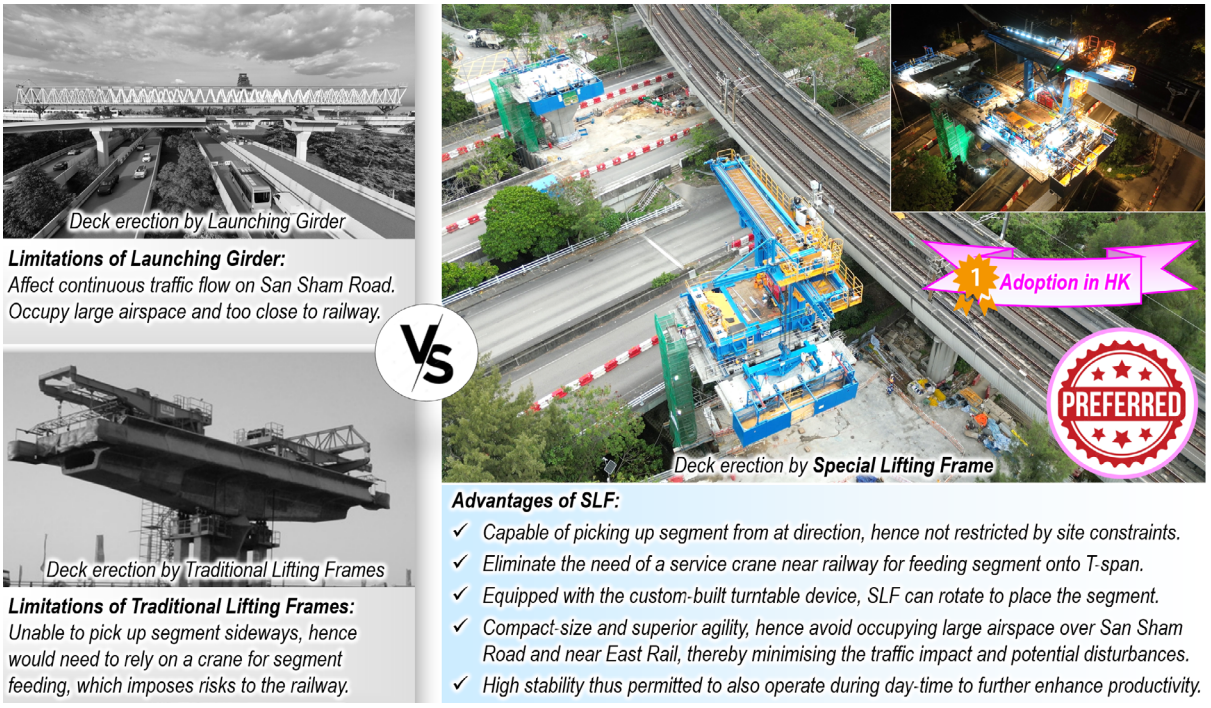


Figure 3 – Key features of Special Lifting Frame (SLF) and its advantages

2.4. Implementation of the Innovative Solution

Following the completion of the design, the SLF was fabricated at the Dongguan fabrication yard (Figure 4) in 2024. A full trial assembly of the entire SLF was subsequently carried out to verify that all components could be properly connected. After the trial assembly, the SLF was dismantled into smaller components for delivery to Hong Kong.



Figure 4 – Dongguan Fabrication Yard

The SLF was commissioned on site in 2025. It was delivered in modular components for straightforward crane-assisted installation. Factory testing and trial assembly verified component compatibility for rapid site assembly (see Figure 5).



Figure 5 – SLF turntable trial on site before assembly

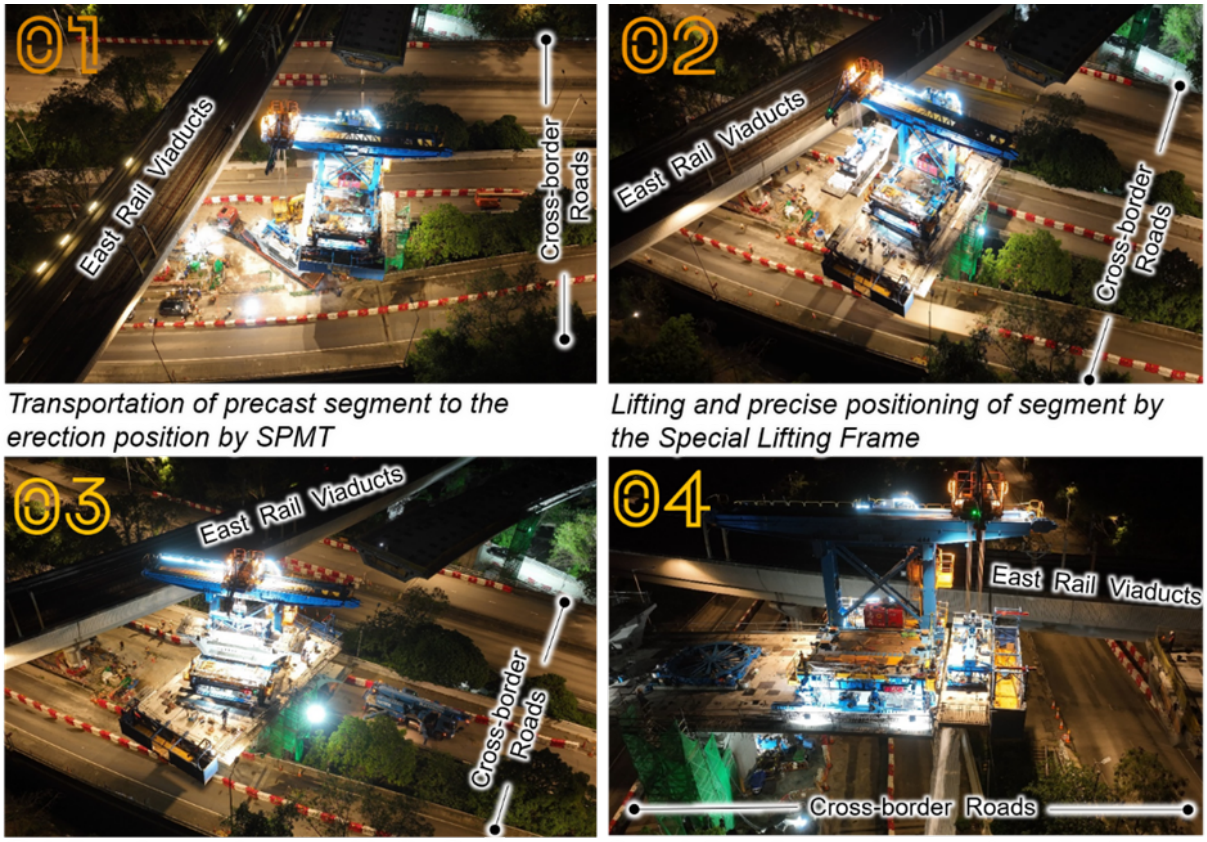
Upon installation at the pier-head, a comprehensive load test was conducted. The SLF performed key operations under superimposed load, including segment pick-up, rotation, and translation to the erection front. The entire load test process was closely monitored to identify any anomalies for subsequent rectification.

Following successful load testing, SLF operations commenced for deck segment erection using the balanced cantilever method. Each movement was executed by trained specialists under the supervision of experienced resident engineers, achieving planned efficiency (refer to Figure 6).



Figure 6 – Highly efficient operation of Special Lifting Frame (SLF)

As only a single SLF was required for both sides of the balanced cantilever T-span, its self-weight induced an out-of-balance moment during temporary erection. Instead of using temporary props, the bridge structure was strengthened using higher-grade concrete and reinforcement. The first segment erected served as a counterweight to temporarily balance the SLF, and was subsequently relocated to its final position following erection of the adjacent segment. This methodology maintained deck stability while preserving construction productivity, as illustrated in Figure 7.



Transportation of precast segment to the erection position by SPMT

Lifting and precise positioning of segment by the Special Lifting Frame

Rotation of precast segment to the final orientation by turntable

Completion of precast segment erection by Special Lifting Frame

Figure 7 – Key steps for Special Lifting Frame segment erection for DRL viaduct

2.5. Features of Special Lifting Frame and Turntable

The SLF was designed with a Safe Working Load (SWL) of 110-tonne, providing a clear capacity margin above the maximum segment weight of 85-tonne while accommodating ancillary attachments, including the stressing platform and davit arm. The frame has an overall height of approximately 14m, with longitudinal support leg spacing of 7.2m, configured to optimise the height-to-width ratio and enhance stability during deck-level operations.

In plan view, the Upper Cross Beam (UCB) is configured to travel longitudinally along the twin main beams over a span length approximately 18m, with 5m cantilevers extending beyond each support. The primary load-carrying system comprises twin longitudinal main beams; MB1, a box section designed to resist downward vertical loads, and MB2, an I-section beam configured to resist uplift forces. The UCB is supported on a bogie system driven by chain-pulling units for longitudinal travel, with uplift rollers providing lateral restraint.

A distinctive C-shaped support frame is adopted, with all vertical members positioned on one side of the segment during rotation. This configuration eliminates physical obstructions, enabling the segment to navigate the tight clearances between the pier table, T-span webs, and adjacent existing structures. The Segment Lifting Beam (SLB) is connected to prestressed anchorage beam cast into each segment and incorporates hydraulic jacks for fine adjustments to crossfall and gradient. A rotation device is integrated at the SLB connection to facilitate the required 180° segment rotation. The lifting system is equipped with a hydraulically actuated braking system to provide emergency stopping capability.

The turntable system, anchored to the pier table, consists of a base frame and an upper rotational frame sliding on a Teflon-lined interface (PTFE), actuated by four long-stroke hydraulic jacks providing controlled rotation in both directions up to 90° per operation. A launching system of short rail beams, lift-off jacks, sliding shoes, transverse adjustment jacks and CT-bar tension bracings enables safe, incremental movement of the SLF along the deck while limiting longitudinal and lateral forces transmitted into the main frame and deck structure.



Figure 8 – Feature of Special Lifting Frame and Turntable

3. Innovative Use of Digitalisation Technologies

3.1. Innovative Digital Solutions

The construction site of the DRL viaduct exhibited significant congestion due to proximity to existing roads, structures, and sensitive receivers such as constraining equipment manoeuvring space while the innovative method required larger prefabricated elements and high-precision installation.

To facilitate effective planning, the team implemented advanced digital solutions from 2023, including photogrammetry and LiDAR scanning to generate accurate digital representations of existing site conditions. Building Information Modelling (BIM) served as the central platform to integrate all project data, including on-site survey data and modelled elements of proposed permanent works and planned equipment. Augmented Reality (AR) tools were used in the field to visualize planned SLF positions, crane locations and diversion routes against the real site context, supporting stakeholder briefings and safety reviews. This enabled accurate planning and examination of construction sequences, allowing all stakeholders to visualise activities and identify potential issues at an early stage.

During the installation of the SLF on DRL viaduct, the close proximity (less than 6m) to the MTR East Rail and the stringent requirements within the railway protection zone necessitated digital verification to ensure that all the safety requirements were fulfilled. Consequently, approval from MTR was swiftly granted, thus enabling timely commencement of the works, and the safe clearance was upheld throughout the actual operation on site, as shown in Figure 9.



Figure 9 – Digital technologies safeguarding innovative erection solutions at DRL viaduct

3.2. Smart Site Management System

Beyond conventional applications, the Loop project deployed the following innovative AI-driven solutions to advance construction management, site digitalisation, safety and sustainability –

- **AI and BIM Integration:** Point cloud data is integrated with BIM to strengthen progress monitoring and optimise project workflows.

- **Autonomous Site Digitalisation:** AI-controlled drones and robotic dog systems capture as-built site conditions, while AI-based 360° image mapping synchronises field observations with BIM planning parameters.



Figure 10 – Innovative AI Adoption

4. Design for Safety

Through collaboration among the client, consultant, contractor and subcontractors, design-for-safety measures were fully implemented to enhance the safety margin for the innovative SLF Erection Method.

4.1. Adoption of Contra-flow Temporary Traffic Arrangement

As the DRL viaduct is situated near the Hong Kong–Shenzhen boundary and its deck erection by SLF needed to be executed over the cross-boundary roads at Huanggang Port, a series of temporary traffic arrangements (TTAs) was needed to facilitate construction works and minimise impact on the strategically vital 24/7 cross-boundary road.

Since the project's inception in 2021, the project team has maintained close contact with relevant authorities in Shenzhen to address interfacing issues. A special task force was established with Hong Kong and Shenzhen representatives (see Figure 11), enhancing collaboration.



Figure 11 – Innovative initiative of cross-boundary collaboration between Hong Kong and Shenzhen

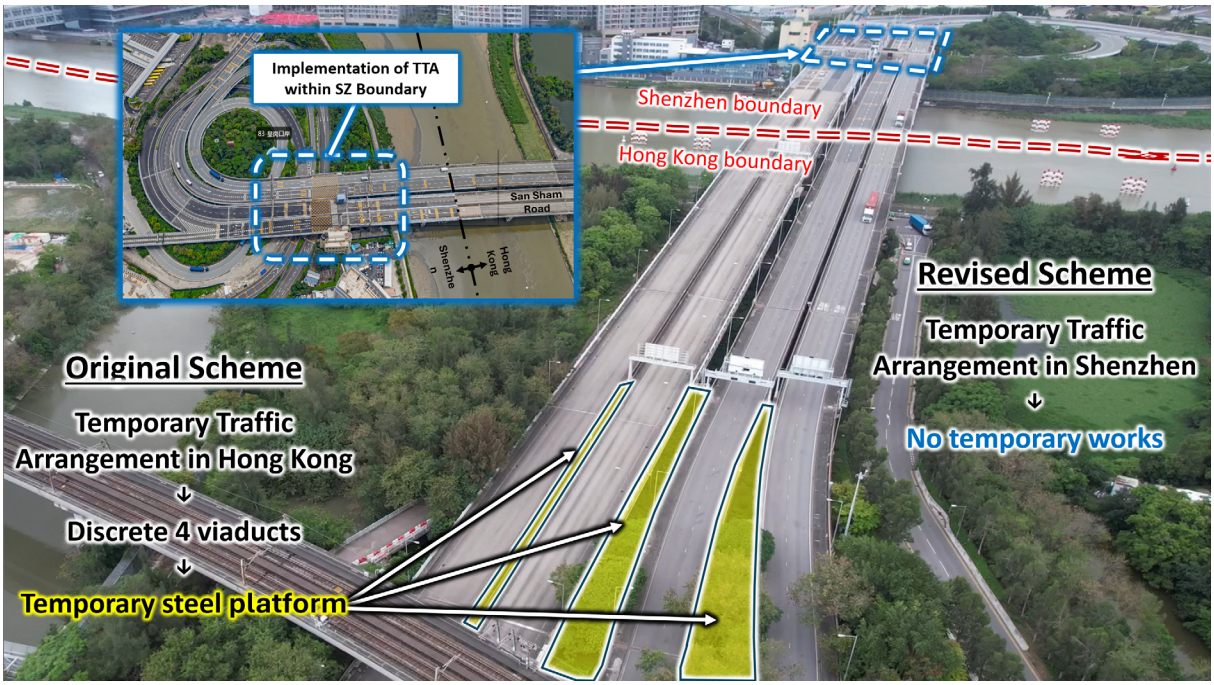


Figure 12 – Innovative temporary cross-boundary traffic diversion

This arrangement facilitated effective coordination among multiple agencies and optimised the cross-boundary TTAs at Huanggang Port. Implementing diversions in Shenzhen proved more efficient, minimising lane diversions and eliminating the need for large temporary steel platforms in Hong Kong (see Figure 12).

4.2. Temporary Propping System for the Turntable of Special Lifting Frame

A key feature of the SLF is its 360-degree rotational capability, enabled by a turntable assembly. To ensure stability during operation, the turntable must be sufficiently large; when positioned at the pier head, it extends beyond the pier-head segment and partially bears onto the first pair of box-girder segments.

Unlike the pier-head segment, which incorporates a solid diaphragm, the adjacent segments are typical voided box girders not inherently designed to resist the additional concentrated loads imposed by the turntable. To address this, a tailor-made temporary propping system (see Figure 13) was designed to support the turntable loads. The system comprises robust steel elements that bear against the top slab of the first pair of segments at locations aligned with the turntable supports above the deck.

Loads from the turntable are transferred through the propping system to the robust pier-head diaphragm, establishing a dedicated load path from the turntable to the pier-head and down to the pier. This arrangement eliminated the risk of overstressing the deck segments during SLF operations.

The temporary propping was installed prior to the commencement of balanced cantilever deck erection and remained in place until deck erection was completed. Its tailored design enabled safe and reliable turntable operation throughout segment lifting, while significantly reducing the risk of overloading or overstressing the permanent works. This approach exemplifies the application of design-for-safety principles to complex engineering operations, enhancing overall site safety.



Figure 13: Turntable with Propping System Assembly on Pier

5. Construction Challenge

5.1. Challenges for installation and dismantle of Special Lifting Frame and turntable

The installation of the SLF posed considerable logistical and safety challenges, primarily due to its substantial physical dimensions. These challenges were exacerbated by the close proximity of the MTR East Rail viaducts, which is situated just 6 m from the pier-head where the SLF was to be installed. Both the limited pier-head working area and the constrained ground-level space for positioning a crane with sufficient lifting capacity demanded meticulous planning.

Initially, the proposed installation method involved using a 750-tonne mobile crane to transfer the SLF directly from DRL-P09 to DRL-P10. However, the MTR rejected this approach over safety concerns related to the live railway. In response, the project team developed an alternative, more robust methodology that prioritised safety while safeguarding the construction schedule. Under the revised plan, the SLF was dismantled into manageable components away from the sensitive railway infrastructure, pre-assembled at ground level, and then lifted sequentially onto the pier-head for final on-site assembly. This approach not only mitigated risks associated with the constrained site conditions but also ensured full compliance with railway safety requirements. Key elements of this revised approach (Figure 14) included:

- **Sequential dismantling at P09:** The SLF was dismantled in stages. The Main Beams, Upper Cross Beam, and Davit Arm assembly were lowered at P09, while the C-Frame top part was dismantled near P08, effectively distancing the most critical lifting operations from the MTR structure.

- **Self-propelled Modular Transporters (SPMTs) transportation:** The dismantled components were transported using SPMTs to DRL-P10 for re-assembly, rather than relying on a single, high-risk crane lift.

- **Adoption of a 500-tonne mobile crane:** The alternative methodology successfully utilised a 500-tonne mobile crane with specific operational limitations (e.g., boom orientation not facing the railway, maximum lifting capacity limited to 80%), which was ultimately accepted by MTR, allowing the works to proceed.



Figure 14: Dismantle and Relocation of Special Lifting Frame from DRL-P09 to DRL-P10

6. Outcome and Benefits

The innovative construction method underpinned by digital technologies has delivered quantitative and qualitative benefits to the project.

- **Health and Safety** – The SLF Erection Method eliminated 80% of crane operations within the railway protection zone. Zero safety incident was achieved during all lifting operations.

- **Productivity** – The innovative method enabled the daytime work for the assembly and erection of precast deck segments, unlike the conventional methods, which require significant night work. This increased productivity, resulting in 4-month saving in deck installation.

- **User Experience and Sustainability** – The innovative method reduced night works and road closures by 70%. Minimizing night-time work and disruptions contributed to reduced light and noise pollution for the surrounding community. Shorter durations for road closures and heavy lifting operations also led to a 30% reduction in carbon emissions.

7. Recognition

7.1. Local and International Awards

The project team is fully committed to advancing innovative and sustainable infrastructure developments that better serve the community. This innovative SLF Erection Method, coupled with digitalisation, enables faster and safer construction, reduces carbon emissions, and minimizes public disturbance. It sets a benchmark for future bridge construction in Hong Kong.

This innovative bridge construction method has received recognition internationally and locally, earning a number of awards as listed in Figure 15 below.



1. NEC Martin Barnes Award 2024: Leading the Future through Best Practice and Collaboration (Runner-up)
2. The 9th International BIM Award (Gold)
3. CIC Construction Digitalisation Award 2024 – Project Category (Bronze)
4. HKICBIM Award 2025 (Diamond)
5. The Lighthouse Club 7th International Design for Safety Award (Merit)
6. HKIE Civil Division Civil Engineering Excellence Award 2024/2025 (Platinum)
7. CIC Construction Innovation Award 2025 (1st Prize)
8. The HKIE Grand Award 2026 (Bronze)
9. HKIE Design for Safety Excellence Award 2026 (Silver)
10. HKBIM BIM Award 2026 (Bronze)
11. CIC AI Award 2026 (Gold)

Figure 15: Awards for the implementation of "Special Lifting Frame Erection Method"

7.2. Recommendation for Future Applications

The smart and innovative approach adopted for this project has significantly enhanced construction efficiency while reducing carbon emissions from construction activities. By employing the innovative SLF Erection Method, the project aligns with the principles of Construction 2.0 and establishes a new benchmark for future bridge construction. More importantly, it represents a major advancement in the industralisation of bridge construction in congested environments.

The successful delivery of this innovative construction method has been recognised through multiple industry awards. The pioneering construction solution is expected to be applied in future projects locally and internationally, generating wider benefits for the construction industry and society. This is particularly relevant to the development in the Northern Metropolis and the Greater Bay Area, strengthening Hong Kong's role as a super-connector and super-value adder in the region.

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