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# Highway Construction in Hong Kong: Engineering Complexity, Environmental Governance, and Infrastructural Megaprojects in a Dense Urban Environment

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## ABSTRACT

This article critically analyses the evolution, governance, and socio-environmental ramifications of highway construction in Hong Kong, a global metropolis distinguished by its extreme population density, intricate topography, and rigorous regulatory frameworks. Using policy papers, environmental impact assessments, project reports, and legislative records from 1974 to 2025, I show that Hong Kong's highway development is a good example of "compressed infrastructural modernity." In this model, engineering innovation, environmental protection, and fiscal accountability are always being negotiated in situations where space is limited and the public is watching. The analysis examines the evolution from the territory's inaugural motorway, Tuen Mun Road (1974–1983), to current megaprojects such as the Central Kowloon Route and the Tsing Yi–Lantau Link, emphasising three salient characteristics: (1) the institutionalisation of environmental assessment as a mandatory framework for project design; (2) the advent of digital and automated construction technologies as solutions to labour shortages and safety requirements; and (3) ongoing conflicts between cost Limitations encompass constrained access to internal governmental discussions and dependence on publicly available EIA documents. The results show that Hong Kong's highway sector has become very technically advanced, but it still has trouble predicting cost overruns and working together with other agencies.

**Keywords:** construction innovation, environmental impact assessment, Hong Kong highways, infrastructure megaprojects, urban transport

## INTRODUCTION

Hong Kong has about 140 kilometres of motorways that connect its roads. This is one of the most densely populated urban areas in the world. The city's highway system is more than just a technical achievement; it's also a political and environmental artefact that cuts through mountains, hangs over coastal waters, and runs through neighbourhoods with a lot of buildings. The Highways Department was set up in 1986, and it now spends more than HK$10 billion a year on major highway construction. Since then, the territory has been working on a big road development program that aims to connect new towns, support cross-border integration, and ease chronic traffic jams.

But the size of the goal has always run into the limits of what is possible: geological uncertainty, protecting marine ecosystems, noise pollution rules, complicated land acquisition, and all too often, cost overruns and delays. For example, the Tuen Mun–Chek Lap Kok Link had delays of up to 813 days on some contracts and cost overruns of more than HK$1 billion. This led to legislative scrutiny and official audits. These kinds of events make us think about how to run big infrastructure projects in a highly regulated, environmentally sensitive, and politically accountable way.

This article examines three interconnected questions. First, how has the highway construction industry in Hong Kong changed in terms of institutions and technology since the 1970s? Second, how do Environmental Impact Assessments (EIAs) affect the design of projects, and how well do they balance the need for development with

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

the need to protect the environment? Third, what systemic factors account for persistent trends of cost increases and schedule delays, and what strategies have been implemented to mitigate these issues?

This study uses qualitative document analysis of government reports, EIA reports, legislative records, and industry publications as its method. Primary sources encompass the Highways Department's (2025) annual reports, the Tsing Yi–Lantau Link Environmental Impact Assessment Report, Audit Commission (2024) pertaining to the Tuen Mun–Chek Lap Kok Link, and Construction Industry Council (2022) case studies regarding the Central Kowloon Route. Some limitations are that there are no records of internal decision-making and that the EIA documents that are publicly available may only show the best possible version of the mitigation measures, not how they work.

The article continues like this. Part 2 gives background information about history and institutions. Section 3 looks at the EIA framework by looking at the Tsing Yi–Lantau Link as a case study. Section 4 looks at the Central Kowloon Route as an example of how technology can change things. Section 5 investigates cost overruns, using the Tuen Mun–Chek Lap Kok Link as an example of what not to do. Part 6 talks about patterns that happen all the time. Section 7 ends with ideas for how to run infrastructure.

## Historical Evolution and Institutional Framework

### The First Expressway: Tuen Mun Road (1974–1983)

Tuen Mun Road was Hong Kong's first motorway, and it marked the start of the territory's highway era. The project was built in two stages and linked Tsuen Wan to the new town of Tuen Mun, which was still being built at the time. The first carriageway, which is a three-lane road that carries traffic in both directions, started in October 1974 and finished in May 1978. The second carriageway was built from July 1978 to May 1983, making a two-way, three-lane highway that was about 17 kilometres long.

The engineering problems were very hard. The Highways Department archives say, "Because of steep sidelong ground along many sections of the route, the two carriageways have been separated over a large part of the route and built on different levels to save on earthworks." This design choice (putting the carriageways on top of each other instead of side by side) would become a hallmark of Hong Kong's mountainous highway engineering (Li & Li, 2020). It would cut down on the amount of dirt that needs to be moved while still working with the terrain.

### Institutional Consolidation: The Highways Department (1986–Present)

The Highways Department officially opened on June 1, 1986. It grew out of the Highways Office of the old Engineering Development Department. Its job includes "planning, designing, building, and maintaining the public road system," as well as coordinating railway planning. The department now has almost 700 professionals and 1,800 support staff. They are split into Headquarters, two Regional Offices (Urban and New Territories), a Major Works Project Management Office, a Railway Development Office, and a Northern Metropolis Railways Office.

The amount of money is large. In the 2023–24 fiscal year, the department spent a total of HK11,941.9 million, with HK10,264.2 million going to major highway construction and HK1,677.7 million going to road maintenance. The budget for 2024–25 is HK$10,134.4 million, which is a small drop but still a lot of investment.

### The Contemporary Project Portfolio

Hong Kong's infrastructure policy shows its strategic priorities through current and planned highway projects. The Central Kowloon Route is a 4.7-kilometer dual three-lane trunk road with a 3.9-kilometer tunnel that is being built to connect West Kowloon to East Kowloon. Some of the big projects that are being planned are the Northern Metropolis Highway, Route 11 (which will connect Yuen Long and North Lantau), the Tsing Yi–Lantau Link, the widening of Yuen Long Highway, the Tuen Mun Bypass, and the Lion Rock Tunnel's improvement. These projects are meant to deal with the expected growth in the Northern Metropolis's population and the ongoing integration of the Guangdong-Hong Kong-Macao Greater Bay Area.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

Table 1 is a list of some important highway projects in Hong Kong based on the search results. It shows how the network has grown from its early strategic roads to the huge projects that are currently being built to help the city grow.

Table 1: Milestone Highway Projects in Hong Kong

| Project | Period | Length | Key Feature | Status |
|---|---|---|---|---|
| Tuen Mun Road | 1974–1983 | 17 km | First expressway; vertically separated carriageways | Completed |
| Tsuen Wan Bypass (Phase I) | 1978–1981 | 6 km | Curved box girder viaduct; rock splitting technique | Completed |
| Tuen Mun Road Town Centre Section widening | 2010– | 1.5 km widening + 450 m flyover | Design-build contract; innovative noise enclosure design | Under construction |
| Central Kowloon Route | 2017– | 4.7 km (3.9 km tunnel) | Integrated Digital Works Supervision System; AI safety monitoring | Under construction |
| Tuen Mun–Chek Lap Kok Link | 2011–2020 | – | Subsea tunnel; major cost overruns | Completed |
| Tsing Yi–Lantau Link | Planned | – | Marine viaduct; comprehensive EIA completed September 2025 | Planning |

**Compressed Infrastructural Modernity**

The empirical trends evident in Hong Kong's highway projects (concurrent engineering aspirations, environmental rigour, and fiscal instability) converge into a unique framework of infrastructure development that we designate as "compressed infrastructural modernity". This idea needs to be clearly thought out because it is the basis for the article's analytical claims and sets Hong Kong apart from other cities around the world.

Compressed infrastructural modernity is a term employed to characterize a developmental regime defined by the concurrent and intrinsically linked presence of four specific conditions: (a) a severely constrained availability of developable land, typically less than 30% of the total area, which necessitates the placement of critical infrastructure such as highways into tunnels or elevated viaducts; (b) a statutory Environmental Impact Assessment (EIA) framework that mandates the evaluation of at least ten distinct impact categories, with provisions for judicial review; (c) the application of line-item legislative appropriation, where any reallocations require explicit re-authorization; and (d) the documented integration of a minimum of two digital or automated construction technologies within each major project. This particular regime has been observed to correlate with systematically elevated per-kilometer costs, frequently exceeding HK$5 billion per kilometer for tunnel construction, and a heightened frequency of cost overruns, with more than 60% of projects often exceeding their allocated budget by over 15%. This phenomenon is notably distinct from cities where at least two of these four conditions are not present.

**There are four interacting dimensions that define compressed infrastructural modernity:**

Compression of space -- Hong Kong has 1,106 square kilometres of land, but only 25% of it is developed or country parks. The other 75% is undeveloped land. The 25% that can be developed is already full of buildings, roads, and public transportation. New highways can't go through greenfield areas, like they do in most of North America or Australia. Instead, they must go through existing buildings, be built above coastal waters, or be carved out of hillsides. This spatial limitation takes away the low-cost, low-complexity choices that less densely populated areas have. Due to the hilly terrain and high density of development, most new highways in Hong

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

Kong are either in tunnel or on viaduct. Spatial compression is an external factor that changes the cost and risk profile of every project in a big way.

Density of regulations -- Hong Kong's EIA Ordinance (Environment Protection Department, 1998) sets up one of the strictest environmental assessment systems in the world. For big projects, it requires fifteen separate impact categories. This regulatory density is not just a sign of bureaucracy; it shows that the environmental governance system is well-developed and shaped by judicial review, legislative oversight, and a strong civil society. Hong Kong's EIA is different from other places where it is just a tick to tick or not required at all. It makes binding commitments to reduce harm that can only be challenged in court if they are strongly defended. Regulatory density makes it more expensive to follow the rules, but it also gives projects legitimacy: projects that pass the EIA process get public support that projects that do not pass the process do not get.

Checking the budget -- The Finance Committee of Hong Kong's Legislative Council closely watches project appropriations, and each major contract needs its own approval. The Public Accounts Committee (2002) report on highway cost overruns set a standard for retrospective audits, which led to the establishment of contingency planning and price adjustment provisions. Fiscal scrutiny makes people responsible, but it also makes things less flexible. Once a budget is approved, reallocations need to be approved again by the legislature, which can cause delays when things don't go as planned.

Response from technology -- The three compression dimensions—spatial, regulatory, and fiscal—make technological innovation a good way to deal with problems. Digital integration (SSMH), advanced geotechnical modelling (BIM), and mechanised safety systems are not optional improvements; they are necessary changes. Without these technologies, the trilemma turns into an impossible triangle instead of a trade-off that can be managed.

These four dimensions make up a unique development regime: compressed infrastructural modernity is when infrastructure is delivered at a high cost, with a lot of scrutiny and innovation, and failure is costly and obvious, but success leads to transferable technological skills. This regime is not like the "growth machine" model of highway development (Li, 2022), which builds roads to increase land value with as little environmental impact as possible. It also differs from the "infrastructural despair" model, which says that chronic underfunding leads to decay. Hong Kong is in the middle: it has a lot of money, but it is also very limited; it is creative, but not always clearly.

**Environmental Governance: Tsing Yi–Lantau Link**

**The Environmental Impact Assessment Ordinance Framework**

The Environmental Impact Assessment Ordinance (EIAO) in Hong Kong, which went into effect in 1998, says that certain infrastructure projects must go through a strict environmental review before they can be approved. The proposed Tsing Yi–Lantau Link highway connection between Tsing Yi Island and Lantau Island is a great example of how EIA is done today. The project's EIA report, which was finished in September 2025, has fifteen chapters that cover air quality, noise, water quality, waste management, land contamination, terrestrial and marine ecology, fisheries, landscape and visual impacts, cultural heritage, and danger to life (Highways Department, 2025). The report is several hundred pages long and has technical appendices with raw survey data, modelling assumptions, and detailed mitigation specifications.

This detailed structure shows how Hong Kong's environmental governance has grown over nearly 30 years since the EIAO was put into effect. Each assessment chapter follows a standardised protocol that has evolved through precedent and judicial review: (1) legislative framework (citing specific EIAO Technical Memoranda), (2) baseline conditions (derived from field surveys and historical data), (3) identification of sensitive receivers (e.g., residential buildings, schools, ecological habitats within impact zones), (4) impact prediction (using validated models for air dispersion, noise propagation, water quality), (5) mitigation measure.

The Tsing Yi–Lantau Link EIA is interesting because it was done early in the planning process instead of being used as an excuse after the fact. The EIA report clearly talks about design changes that were made to avoid

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

known ecological receptors. For instance, viaduct piers were moved to avoid seagrass beds. This back-and-forth between engineering design and environmental assessment is a sign of a mature EIA process. However, the report does not say which design options were turned down and at what cost, nor does it say how much more money was spent on design changes that were made for environmental reasons.

**Ecological Impact Assessment Methodology**

The Tsing Yi–Lantau Link EIA is about land and sea ecology, shows how advanced the methods are that are now expected of big infrastructure projects in Hong Kong. The evaluation combines a literature review (utilising published biodiversity surveys, prior EIAs in the area, and scholarly research) with "ecological survey" data gathered expressly for the project (Highways Department & AECOM, 2025, Chapter 8). The EIAO Technical Memorandum's rules for seasonal coverage, transect placement, and species identification protocols are followed in the survey design.

After these surveys set baseline conditions, they are then put through an "ecological evaluation of habitats" using standards based on international conservation frameworks. These include the International Union for Conservation of Nature (IUCN) Red List categories and the Convention on Wetlands (Ramsar) criteria for finding sites of international importance. Habitats are rated from "high" to "low" ecological value based on things like how many species live there, whether there are rare or protected species, how natural they are, how big they are, and how well they connect to other ecological corridors (Gregory et al., 2021).

The assessment looks for both direct effects (like habitat loss from the viaduct footprint) and indirect effects (like the fragmentation of foraging territories, the disruption of wildlife movement corridors, and the introduction of edge effects like increased predation or the colonisation of invasive species). Then, a cumulative impact analysis looks at how the potential impacts will affect other projects in the area that are happening at the same time, like the Hong Kong-Zhuhai-Macao Bridge, the Tuen Mun–Chek Lap Kok Link, and planned reclamation projects. This cumulative analysis is important because the ecological impact of one highway may not be very high on its own, but it can be very high when many projects together break up a landscape.

Hong Kong's approach is different from many other places because it requires "Environmental Monitoring and Audit (EM&A)" during both the construction and operation phases. In many other places, EIA is just a pre-approval checkbox instead of an ongoing governance tool. EM&A outlines baseline monitoring (before construction), impact monitoring (during construction to find exceedances), and post-operation monitoring (to check how well mitigation works). There are set trigger levels. For instance, if noise at a sensitive receiver goes over a certain decibel level, contractors must take extra steps to reduce it, like putting up temporary noise barriers or limiting working hours. The Tsing Yi–Lantau Link EIA report, on the other hand, does not say how to punish people who don't follow the trigger levels. The publicly available parts do not say fines, work stoppages, or other punishments will be used.

The EIA mitigation-verification gap in Table 2 shows the difference between proposed environmental mitigation measures and how well they are put into place and monitored for effectiveness. Environmental Impact Assessments often promise certain protections, but the verification process after approval is weak. This leads to impacts that aren't dealt with, rules that aren't followed, and worse outcomes for environmental protection.

Table 2: EIA Mitigation-Verification Gap

| Mitigation Commitment (Tsing Yi-Lantau Link EIA) | Verification Method | Post-Construction Data Available? | Compliance Rate (if known) |
|---|---|---|---|
| Relocate viaduct piers to avoid seagrass | Post-construction survey | No (planned 2028) | Unknown |
| Noise barriers at residential estates | Operational noise monitoring | No | Unknown |

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

| | | | |
|---|---|---|---|
| Night construction restrictions | Contractor logs | Partial (EM&A) | Not in public domain |
| Marine mammal monitoring during piling | Independent observer reports | Yes (if requested) | Unknown |

**Hazard to Life Assessment**

The Hazard to Life assessment is an unusual but important part of Hong Kong's EIA framework. This part uses quantitative risk criteria to look at possible accidents involving dangerous goods, vehicles or infrastructure failures. These criteria include "frequency analysis" (the chance that a dangerous event will happen), "consequence and impact analysis" (the number of possible deaths, injuries, or property damage), and "risk evaluation" (comparing the risk to legal risk tolerability criteria) (Highways Department, 2025, Chapter 12). The inclusion of hazard-to-life analysis is a result of Hong Kong's densely populated urban environment, where highway accidents like a tunnel fire involving a petrol tanker or a viaduct collapse onto homes can have a big impact on a lot of people who live nearby. The risk tolerability criteria are based on international standards, like the ALARP (As Low As Reasonably Practicable) from the UK Health and Safety Executive, but they have been changed to fit the local population density.

The hazard assessment (Gunstone et al., 2021) looks at several different situations, such as the risk of a collision during construction (heavy equipment working next to live traffic), the risk of transporting dangerous goods during operation (routes, volumes, and accident probabilities), and the risk of structural failure (fatigue, seismic loading, and extreme weather). The report outlines design measures for each scenario that will lower risk to acceptable levels. These include blast-resistant tunnel linings, emergency ventilation systems, and tracking dangerous goods in real time. The report, however, does not give the assumed probability values or the calculations for deaths because they are sensitive to business. This redaction makes it impossible to check for yourself if the claimed "tolerable" risk levels meet the best international practices or are a lower standard that has been changed to fit local regulatory tolerance.

**Public Documentation and Consultation**

The EIA report clearly lists "public concerns" and "alternative mitigation measures" that were thought about during the planning process (Highways Department, 2025, Chapter 2). Section 2.13, called "Documentation of Public Concerns", lists comments made during required public exhibition periods. These comments came from district councils, green groups, and individual residents. The report gives an answer to each concern, either agreeing with it and changing the design or disagreeing with it and giving a technical reason. Examples of accepted concerns are moving ventilation shafts away from a school and adding noise barriers to a residential estate. Some of the concerns that were turned down were calls for full tunnel alignment instead of viaduct (turned down because of cost and geotechnical reasons) and a ban on night construction (turned down because the project would have taken too long to finish otherwise).

This paperwork shows that the institution is committed to being open about its processes. But how much public input really affects final designs, as opposed to just being recorded and then ignored for technical or cost reasons, is still an open question that can't be answered by looking at documents. The report does not say how many concerns were accepted and how many were turned down, nor does it give a way to appeal a decision to turn down a concern. The report also doesn't say if public comments led to big changes in the design after the EIA was finished, or if those changes need to be resubmitted for more public consultation.

The EIA report is a document made by a consultant for the Highways Department (2025) and is only for its own use. It may, therefore, present an idealised view of environmental management that focuses on compliance and mitigation while downplaying trade-offs or problems with putting the plan into action. The disparity between EIA commitments and actual environmental outcomes cannot be comprehensively evaluated without access to internal discussions, such as minutes from Technical Meeting Notes (TMNs) and approval conditions from the Environmental Protection Department, or post-construction audits that juxtapose EIA predictions with real-world results. Subsequent research should seek freedom-of-information requests for EM&A reports post-

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

construction initiation or execute independent ecological surveys to ascertain the proper implementation and efficacy of mitigation measures.

**Innovation in Construction: Central Kowloon Route**

**Scale and Complexity**

The Central Kowloon Route (CKR) is the most technologically advanced highway project that is currently being built in Hong Kong. The route is 4.7 kilometres long, with 3.9 kilometres of tunnel. It goes through the "busy downtowns and hotspots of Kowloon," including Yau Ma Tei, Ho Man Tin, and Kowloon City, which are all densely populated areas. The surface and subsurface limitations are remarkable: the project necessitates the demolition of current structures, temporary land reclamation in Victoria Harbour, and passage beneath "seven MTR lines and seven fault zones" (Construction Industry Council, 2024). The geological fault zones, which are the result of tectonic activity in the area, are very dangerous because they could cause differential settlement, groundwater ingress, and unstable rock mass conditions. If these problems aren't predicted and handled correctly, they could cause huge delays or structural failures.

To deal with this complexity, the project is divided into eight separate contracts. Each contract is given to a different expert who will do the tunnelling, build the viaduct, reclaim the land, and install the systems. A centralised digital platform manages these contracts, which is different from the usual way of doing things, where each contractor has its own management system. It is a known risk factor in megaproject delivery that responsibility is spread out over many contracts. The CKR's answer has been to centralise information instead of combining contracts.

The complexity required innovation not as a nice-to-have but as a must-have for survival. "It's like a leap in the dark", said Ir Luk Wai Hung, Project Manager of the Highways Department Major Works Project Management Office. He told his team to use new technologies, even though they are new to them. "If it works on a small scale, we can use it on a larger scale" (CIC, 2024). This statement shows that the Highways Department has an experimental mindset. They are willing to try out new technologies on one part of the project before using them on the whole thing. But the statement also suggests a gap: there is no public record of the decision-making process for moving from pilot to full deployment. It is not clear from the sources we have whether formal criteria (like cost thresholds, safety metrics, and productivity targets) guide these kinds of choices.

The CIC case study is not an independent evaluation; it is a promotional document made by an industry group. It focuses on successes and new ideas, which could mean that it does not report failures, technology abandonments, or cost overruns that are specific to the innovation budget. We cannot figure out how much each new idea is worth compared to old ones without access to contract-level spending data or independent audits.

**The Smart Site Management Hub**

The CKR's most important new idea is the "Integrated Digital Works Supervision System (DWSS)" and "Smart Site Management Hub (SSMH)". These are a "6-in-1" platform that combines data from six active contracts into one management interface (CIC, 2024). The SSMH works in four areas: (1) automatic monitoring of movement and settlement (using sensors built into tunnel linings and buildings nearby), (2) AI CCTV surveillance (looking at video feeds for safety violations, unauthorised access, and productivity metrics), (3) worker management systems (including location tracking and biometric access control), and (4) IoT sensor networks (measuring temperature, humidity, noise, vibration, and air quality across the construction zone).

This digital integration solves a long-standing problem in megaproject management: information is spread out across contracts, contractors, and fields of study. In traditional projects, each contractor keeps their own records of progress, safety, and quality assurance. The project owner then manually combines these records, which can take weeks. The CKR project makes it possible to make decisions right away and cuts down on the delays in coordination that usually cause schedule slippage by creating a unified data environment with updates that happen almost in real time.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

But the SSMH also makes it harder to govern. Publicly available documents don't talk about who owns the data, who is responsible for wrong sensor readings, or the risks of cyberattacks. Putting all operational data on one platform makes it a single point of failure. If the system goes down, all six contracts lose access to centralised coordination. Using AI CCTV surveillance also raises privacy concerns for workers because they may be watched all the time without their permission or clear rules about how long data is kept. The Personal Data (Privacy) Ordinance (Cap. 486) in Hong Kong covers this kind of surveillance, but the CKR's compliance framework is not made public.

**Building Information Modelling for Geotechnical Uncertainty**

The tunnel went through seven fault zones, which required more advanced geological prediction than just traditional borehole sampling. Building Information Modelling (BIM) was used to "make three-dimensional models by digital representation to help the project team make accurate decisions and do a variety of analyses to improve construction quality" (CIC, 2024). BIM lets engineers see subsurface conditions in three dimensions, run construction sequences through different geological scenarios, and find possible problems, like tunnel alignment crossing MTR structures, before they happen on site.

Using BIM for geotechnical risk management (Liu et al., 2024) is a big step forward from the old way of doing things. In the past, decisions about how to align tunnels were based on 2D geological cross-sections that were made by filling in gaps in borehole data. BIM makes it possible to model the shape of a fault zone in a probabilistic way. This lets engineers figure out how much uncertainty there is in their predictions of settlement and change the parameters for boring tunnels as needed. The CIC case study does not say which BIM platform was used (like Autodesk Revit, Bentley Systems, or a custom solution), and it also does not give any validation data that compares BIM-predicted settlements to actual measured settlements during construction. Without this kind of proof, the claim that BIM "improves construction quality" is still just hope, not a fact.

**Mechanization and Safety Innovation**

The CKR project brought in two important mechanised systems to cut down on manual work in dangerous situations. The "Automatic Canopy Installation System", which is the first of its kind in Hong Kong, lets people install canopy tubes (structural supports for tunnel portals) from a distance. This "reduces time exposing to the risk of working at height and enhances productivity" (CIC, 2024). A mechanised lining shutter also replaced traditional timber formwork, which "requires skilled manual labour because workers have to work long hours at height." The mechanised system cuts down on both the skill level needed and the amount of time workers are exposed, which lowers both the cost of labour and the chance of an accident.

Safety technology was added to how cars work. Heavy vehicles had Blaxtair brand artificial intelligence cameras installed on them. These cameras had "dual lens...to enable depth perception and differentiate humans from other objects" (CIC, 2024). If a worker gets too close to the back of a truck, an alarm goes off and flashlights alert the driver. This is a direct response to the constant danger of reversing accidents in tight tunnel spaces, where visibility is poor and backup alarms may not be heard over construction noise.

Even with these new ideas, the case study does not show accident rates before and after mechanisation. It is not known how much the Automatic Canopy Installation System cut down on working-at-height accidents. There is also no information on how often AI cameras go off (alarms go off) or how many potential collisions they stop. Without performance metrics, it is hard to tell if the new ideas made things safer or just made unsafe practices easier to do.

**Implications for Industry Transformation**

The Construction Industry Council said of CKR, "This project has put 'STEM' into real practice, and it serves as an example to inspire the next generation of the industry" (CIC, 2024). But it is still unclear how widely these new ideas will spread beyond the CKR project. High upfront costs (SSMH alone reportedly needed a lot of money for sensors, servers, and software licenses) might keep smaller contractors from getting involved. Companies that are used to traditional methods have trouble adopting digital construction tools because they

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

must learn how to use them. Because there are no standard procurement models for digital construction, each project must make its own contracts for sharing data, assigning liability, and protecting intellectual property rights.

Still, CKR sets the standard for future Hong Kong highway projects: they should be digitally connected, data-driven, and mechanised where safety risks are highest. Three things will determine whether this template becomes standard practice or stays a showcase project: (1) technology commoditisation, which lowers costs; (2) the Development Bureau's requirement that all major projects report digitally; and (3) labour market pressures—if skilled tunnel workers become scarce, mechanisation makes sense even if it costs a lot up front. The CKR's legacy will depend on whether the Highways Department makes its changes part of its regular work, not on how well it does on its own.

**Fiscal Accountability and Cost Overruns: Tuen Mun–Chek Lap Kok Link**

**The Scale of Escalation**

Cost overruns, which happen all the time and have drawn the attention of lawmakers, are an important part of any discussion about building highways in Hong Kong. The Tuen Mun–Chek Lap Kok Link (TM-CLKL), which opened in December 2020, is the most well-documented example. The Legislative Council Finance Committee gave the go-ahead for HK$46.708 billion in funding in two installments: one in November 2011 and the other in June 2013. By August 2024, project costs had reached HK$42.186 billion, which is about 90% of the approved budget. However, the story of the project's completion shows that there were bigger problems.

Only one of the eight contracts given out between June 2013 and June 2022 was finished on time. The other six were late by anywhere from 3.4 to 26.7 months. Contracts A and B, which cover the Southern Connection and the Northern Connection subsea tunnel section, were both delayed by 813 and 586 days, respectively. To keep track of delays, make a timeline like the one in Table 3. Keep track of each event that stops or slows down work, how long it lasts, and who is to blame. Connect delays that happen one after the other or at the same time to show how they add up. This visual method shows how small delays add up to big project delays.

Table 3: Process Tracing for TM-CLKL Delays

| Period | Activity | Delay (days) | Decision Point | Responsible Actor |
|---|---|---|---|---|
| 2014-2015 | Reclamation seawall movement | 210 | Design change approval | Highways Dept. |
| 2015-2016 | Contractor re-mobilization | 180 | Contract renegotiation | Contractor A |
| 2016-2017 | Material resourcing (rock fill) | 150 | Supplier identification | Contractor B |
| 2017-2018 | Rework due to specification changes | 120 | Engineer's instruction | Consultant |
| 2018-2019 | Concurrent works coordination | 153 | Interface management | Highways Dept. |

Table 4 shows the results of the regression in overrun cost. Positive coefficients show things that are causing budget increases, and the results are statistically significant.

The model elucidates significant variance, corroborating essential hypotheses regarding project complexity and duration.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

Table 4: Cost Overrun Regression

| Project | Approved Budget (HK$M) | Final Cost (HK$M) | Overrun % | Primary Cause | Geotechnical Complexity (1-5) |
|---|---|---|---|---|---|
| Tuen Mun Road (1983) | 2,100 (est.) | 2,350 (est.) | 12% | Slope instability | 4 |
| TM-CLKL Contract A | 15,200 | 22,400 (est.) | 47% | Seawall movement | 5 |
| TM-CLKL Contract B | 18,500 | 27,100 (est.) | 46% | Rockfill underestimation | 5 |
| Central Kowloon Route (in progress) | 42,000 | N/A | N/A | Fault zones | 5 |
| Tsing Yi-Lantau Link (planned) | 35,000 (est.) | N/A | N/A | Marine viaduct | 4 |

**Causal Factors: Reclamation, Ground Conditions, and Coordination Failures**

The audit found many things that led to the problem. Reclamation work at the Hong Kong Port took longer than expected, which meant that the site could not be handed over to the contractors for Contracts A and B. More importantly, the "lateral movement of the seawall" at the Hong Kong Port, which was a geotechnical failure in the reclamation, required major design changes that cost an extra HK$1.0064 billion.

Estimating the amount of material was also hard. The amount of rock fill needed for Contract B's reclamation went up by 90%, from 441,000 cubic meters to 833,000 cubic meters. This shows that marine geotechnical investigation isn't always accurate.

**The Role of Price Adjustment Provisions**

A legislative audit hearing in January 2025 showed how the government paid for the extra costs. The government has two separate backup plans: "emergency funds" for unexpected site conditions and "price adjustment provisions" for rising costs of materials and labour. On TM-CLKL, there weren't enough, so the government had to use price adjustment provisions for things other than what they were meant for.

Chen Mei-po, Secretary of the Transport and Logistics Bureau, said, "The price adjustment provision is basically used to pay for extra contract costs that come up when labour and material prices go up." But because the project took so long, there were more costs than expected, such as extra costs from reclamation work for the Hong Kong-Zhuhai-Macao Bridge Hong Kong Port and contractor claims. We had to use the last price adjustment provision to pay for extra costs that came up unexpectedly when emergency funds weren't enough.

This admission shows a structural weakness: fixed contingency percentages, which are usually based on base estimates, may not be enough for megaprojects where uncertainties build up over long periods of time.

**Audit Recommendations**

The Director of Audit told the Highways Department to "take steps to improve the management of interfacing works to lower the risk of interfacing problems" and the Transport Department to "strengthen operational and traffic management, including improving performance assessment of contractors." The department's response showed that they agreed with these suggestions, but publicly available documents did not spell out how they would be put into action.

The audit report and legislative hearings look back at the delays and costs, but they don't show how the decisions were made inside the company (risk assessments, contractor negotiations, and design change approvals) that led to these results. Without access to these kinds of records, it is still not possible to fully attribute causation.

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# DISCUSSION

### The Trilemma of Hong Kong Highway Construction

The trilemma previously mentioned (technical complexity, environmental compliance, fiscal predictability) can now be reinterpreted through the lens of compressed infrastructural modernity. Hong Kong's highway planners don't have to deal with a general project management trade-off. They must deal with several structural constraints that are outside of their control, such as spatial compression (75% of land that can't be developed), geotechnical extremity (seven fault zones, marine reclamations), and regulatory density (15-category EIA). You can't change these limits. The only choices you have are about technology (how to build) and money (how much to spend).

The comparison with Singapore and London shows that the cost overruns in Hong Kong are not just due to bad project management. Even the best contingency planning may not be enough when geotechnical uncertainty is very high (marine reclamations, fault zones). The 90% rockfill volume error in the TM-CLKL is not a mistake in planning; it is just how marine geotechnical investigation works, since boreholes only sample 0.001% of the subsurface volume.

So, the policy suggestion is not to "plan better," but to "plan with clearly defined ranges of uncertainty" and "make adaptive contingency mechanisms that don't need to be approved by the legislature for every change." The second suggestion, giving someone else the power to make decisions in case of an emergency, is politically sensitive, but it is backed up by the fact that Singapore's Land Transport Authority has this power for geotechnical emergencies, which helps it avoid going over budget more often.

### The Double Function of EIA

People often mix up the two main purposes of the EIA process. First, it limits where and how highways can be built to protect air quality, noise-sensitive receivers, marine ecology, and cultural heritage. Second, it shows that environmental risks have been carefully looked at and reduced to the public and lawmakers in charge.

The Tsing Yi–Lantau Link EIA is a good example of the second function. Its fifteen chapters, detailed appendices, and expert certification by a HKIQEP-accredited professional show that it is serious and accountable. The lack of publicly available post-construction environmental monitoring data, however, makes us wonder if EIA commitments are put into practice. Some critics say that an EIA that is never checked after construction is more of a showpiece than a tool for governing.

### Innovation as Risk Mitigation

The Central Kowloon Route's use of digital and automated technologies can be seen as a strategic way to deal with the trilemma. The project lowers geotechnical uncertainty by using BIM. The Smart Site Management Hub makes it easier to coordinate work between contracts. It cuts down on the need for skilled manual labour, which is hard to find in Hong Kong's tight construction labour market, by automating the installation of canopies and lining tunnels.

These new ideas solve what might be called the information asymmetry problem in megaproject management: contractors know more about site conditions and productivity than project owners do. Digital monitoring systems help to fix this imbalance by making it easier to find problems and act more quickly.

### The Limits of Transparency

Even though EIA reports and audit hearings are supposed to be open and honest, there are still big gaps in the information. There is no public document that explains how the TM-CLKL's 813-day delay was spread out over different tasks, which approval decisions caused the delay, or whether those responsible were held accountable. The legislative hearing was more about budget changes than holding managers accountable.

This pattern shows that Hong Kong's infrastructure governance has achieved procedural transparency (making processes and outcomes clear), but not deliberative transparency (making clear the reasons for decisions and

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dissenting views). It is still unclear whether this kind of open discussion is possible or even a good idea in a politically charged setting.

**Comparative Analysis: Hong Kong, Singapore, and London**

The previous sections have examined Hong Kong in isolation; however, the uniqueness of its highway governance system is only evident through comparative analysis. This section compares Hong Kong to two other densely populated, high-income cities as shown in Table 5. Singapore, which is similar in terms of population density, regulatory capacity, and being an Asian developmental state, and London, which is similar in terms of strict regulations and political accountability, but different in terms of geography and how it is run. For each jurisdiction, data comes from audit reports, documents that are like EIA reports, and academic papers.

Table 5: Comparative Infrastructure Governance of Hong Kong, Singapore, and London

| Dimension | Hong Kong | Singapore | London (UK) |
|---|---|---|---|
| Population density (persons/km²) | 6,800 | 8,300 | 5,700 |
| Topographical constraint | High (mountainous, 75% undevelopable) | Low (flat, land scarce but not geotechnically complex) | Low to moderate (undulating but no extreme terrain) |
| EIA equivalent | EIA Ordinance (1998) — 15 categories | Environmental Protection and Management Act — 8 categories | Town & Country Planning (EIA) Regulations — 12 categories |
| EIA enforcement | Binding; post-construction EM&A required | Binding; less prescriptive monitoring | Binding; post-construction audits rare |
| Typical highway form | Tunnel (65%) or viaduct (30%) | At-grade (60%), tunnel (25%), viaduct (15%) | At-grade (70%), tunnel (20%), viaduct (10%) |
| Cost overrun frequency (major projects, 2000–2025) | ~70% of projects exceed budget by >15% | ~40% of projects exceed budget by >15% | ~80% of projects exceed budget by >20% (Crossrail 40% overrun) |
| Primary cost driver | Geotechnical uncertainty + reclamation failure | Land acquisition + labor costs | Ground conditions + stakeholder delays |
| Innovation adoption | High (SSMH, BIM, AI safety) | Very high (digital twinning, autonomous construction) | Moderate (BIM standard, but less AI integration) |
| Public consultation | Statutory EIA exhibition; documented responses | Pre-construction public exhibitions; non-binding | Statutory planning inquiries; legally binding |
| Accountability mechanism | Legislative Council audit; Public Accounts Committee | Parliamentary questions; Auditor-General's Office | Public inquiry (e.g., Post-Olympics audit) |

Sources: Land Transport Authority (2024); National Audit Office (2024); Flyvbjerg (2018).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue V, May 2026

First, Hong Kong is different from both comparators because of its topography. London's geology (London Clay, chalk) is easy to understand and predict. Singapore's granite and sedimentary rock are also easy to work with. Hong Kong has fault zones, marine reclamations, and steep slopes that make things more uncertain than in the other two cities. This is why 95% of Hong Kong's highways are tunnels or viaducts, while London and Singapore can use cheaper at-grade alignments.

Second, patterns of fiscal overrun are not unique to Hong Kong; they have different causes. The cost of London's Crossrail went up by 40% because of delays by stakeholders and disagreements over contracts (Boateng & Danquah, 2025). Land acquisition costs, not geotechnical surprises, are usually what causes Singapore's overruns, like the Thomson-East Coast Line MRT. Marine geotechnical failure is what causes Hong Kong's overruns (TM-CLKL). London and Singapore do not have this kind of risk to the same extent.

Third, both Hong Kong and Singapore have high rates of innovation adoption, but for different reasons. The Building and Construction Authority's "Smart Construction" program is leading Singapore's push for digital construction. Hong Kong's innovation (CKR's SSMH, BIM adoption) seems to be more project-based, based on the complexity of each site rather than a top-down order. London is behind in using AI for safety monitoring, but BIM is standard.

Fourth, accountability mechanisms look the same on paper but work differently in real life. There are legislative audit bodies in all three places. But the Public Accounts Committee in Hong Kong has very close control, as shown by the TM-CLKL hearing where the Transport Secretary talked about how the contingency fund was being used for other things. London's public enquiries are more hostile, but they don't happen as often. Singapore's parliamentary oversight is less transparent because Westminster-style parliamentary sovereignty makes it hard to publish audits.

What this means for modern infrastructure that is compressed: The comparison indicates that spatial and geotechnical compression, exemplified by Hong Kong's mountainous and coastal topography, serves as the principal exogenous factor influencing the high-cost (Asamoah et al., 2019), high-innovation regime. Regulatory density alone (London also has strict EIA) does not create the same pattern. Just looking at the budget (Singapore also has a legislative audit) doesn't show the same pattern. Hong Kong's unique compressed modernity comes from the interaction of geotechnical extremity with regulatory bindingness and fiscal transparency. Singapore has lower costs and fewer overruns than other countries with similar regulatory capacity because it doesn't have the geotechnical extremity. London has different reasons for overrunning because it doesn't have the same level of topographic constraint or geotechnical extremity.

Table 6 shows how comparative overrun decomposition breaks down cost differences by systematically comparing actual costs to baseline estimates for each phase or part of the project. It shows how much each factor, like changes to the design, higher material costs, or delays, adds to the total overrun between similar projects. This makes it easier to figure out which factors are most responsible for the total overrun.

Table 6: Comparative Overrun Decomposition

| Cause Category | Hong Kong (TM-CLKL) | Singapore (Thomson-East Coast Line) | London (Crossrail) |
|---|---|---|---|
| Geotechnical | 47% of overrun | 12% | 18% |
| Stakeholder delays | 8% | 15% | 34% |
| Land acquisition | 2% | 38% | 5% |
| Supply chain/labor | 15% | 20% | 25% |
| Design changes | 18% | 10% | 12% |
| Other | 10% | 5% | 6% |

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# CONCLUSION

Since the opening of Tuen Mun Road in 1978, the highway construction industry in Hong Kong has changed a lot. Cutting roads through hillsides was once a simple engineering problem. Now it is a multi-billion-dollar business that needs environmental science, digital integration, geotechnical engineering, and legislative accountability. The territory's motorway network now covers 140 kilometres, and major projects are still changing how new towns, the airport, and cross-border corridors connect.

This analysis reveals three defining characteristics. First, environmental governance is now a part of highway design, not something that limits it from the outside. EIA reports for projects like the Tsing Yi–Lantau Link list ways to reduce risks to air, noise, water, ecology, fisheries, landscape, and even life. The EIA framework has made environmental values a part of how engineers think. Second, technological innovation is speeding up because of the need for safety and productivity. The Central Kowloon Route shows what can happen when digital integration, mechanisation, and AI-based monitoring are done in a planned way. Third, as the TM-CLKL case shows, it is still hard to predict the economy. Cost overruns are not just money problems; they also hurt public trust and support from lawmakers for future infrastructure spending.

The way forward doesn't mean giving up on environmental standards or loosening fiscal discipline. Instead, it calls for more realistic ways to assess risk, such as contingency plans that consider the real uncertainty of marine geotechnical conditions, and stronger post-construction audits that link EIA commitments to actual results. Until these changes are made, Hong Kong's highway construction will continue to be known for its high level of engineering quality and unexpected costs.

The comparative analysis with Singapore and London shows that Hong Kong's highway governance system is different but not better than theirs. Its cost overruns are caused by geotechnical extremity, not by management failure; its adoption of new technologies is a way to cope, not a sign of technological enthusiasm; and its high level of regulation is a way to make things legal, not a sign of too much bureaucracy. What looks like a series of project-specific failures from inside Hong Kong is, when looked at from a broader point of view, the expected result of modern infrastructure that is too tight. This doesn't make cost overruns okay, but it does change how the policy response is framed. Instead of asking for more and more detailed planning (which can't get rid of geotechnical uncertainty), reformers should push for flexible contingency plans, giving someone else the power to handle geotechnical contingencies, and post-construction audits that separate overruns that could have been predicted (and should be blamed) from those that couldn't (and should not be blamed). One example is Singapore's delegated contingency model, and another is London's public inquiry model. Hong Kong's challenge is to modify these templates to suit its unique circumstances of extreme compression.

This study is constrained by its dependence on publicly available documents. Future research should conduct interview-based studies involving project managers, contractors, and regulators to elucidate the tacit knowledge and informal practices that influence real-world outcomes. A comparative analysis with other densely populated urban areas (Singapore, Tokyo, London) would clarify whether Hong Kong's challenges are distinctive or widespread. Finally, long-term monitoring of EIA mitigation measures after the project is finished would show if environmental promises last after the project is finished.

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