The Eastern Harbour Crossing

Hong Kong

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1.011 Project Evaluation and Management
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1 Overview

Hong Kong’s Eastern Harbour Crossing (EHC) is the third cross-harbour tunnel built between Hong Kong Island and the Kowloon Island, the two most populated islands in Hong Kong, constructed in 1986 - 1989.

Prior to the completion of the EHC in 1989, the only connections between the two islands were the original Cross Harbour Tunnel (CHT) for road traffic and the Tsuen Wan metro rail tunnel, operated by the Mass Transit Railway (MTR) Corporation (Legislative Council Panel of Transport of Hong Kong, 2010). These two existing tunnels were popular commute routes that quickly reached capacity in the mid 1980s. Traffic on the approach of the Cross Harbour Tunnel gridlocked local streets on both sides, and the cross-harbour section of the Tsuen Wan metro line was severely overcrowded during rush hours despite trains running at frequent two-minute headways. Platform doors were installed along the line because the Hong-Kong-Island-bound platform of the Mong Kok station was so overcrowded during peak hours that dangerous conditions could have developed without platform doors shielding passengers from falling into the track. MTR recognized the need for additional capacity to accommodate suppressed demand for cross-harbour trips (Sorton, 2015). Since road and rail traffic bottlenecked into a single crossing, the systems lacked redundant paths to keep it resilient during a shutdown or emergency. In addition, the existing crossings connected Hong Kong and Kowloon at Causeway Bay and Tsim Tsa Tsui, the urban commercial cores of the two respective islands. Transportation between the industrial and working class residential developments on the islands’ eastern fringes required an inefficient circuitous path, as they must get to the western side of the islands to access the tunnel.

At the time, the Hong Kong Government was not able to fund a new cross-harbour tunnel project because of the stagnant economy. Neither could the MTR Corporation, already heavily in debt, afford to build a new cross-harbour metro line. Kumagai Gumi, a Japanese construction company, submitted a proposal to the Hong Kong Government to build a new cross-harbour tunnel under public-private partnership in 1984. The Hong Kong Government approved of the proposal in 1985 and embarked on the Eastern Harbour Crossing project, 5km east of the two existing tunnels. The MTR Corporation, solely owned by the Hong Kong Government back then,
was offered a rail crossing in the project as well. The new crossing would connect Quarry Bay on Hong Kong Island and Lam Tin in Kowloon with five immersed tube tunnels. Two of the tubes would carry road traffic, two would carry metro rail traffic (on the current Tseung Kwan O line), and the last tube would be used for maintenance and ventilation (Levy, 1996). The construction started on August 1986 and completed on time on September 1989.

This project was conducted under a complex 30-year public-private partnership and bore financial uncertainties. To make its proposal more solid, Kumagai Gumi added a few more members to the consortium, including the China Investment Trust and Investment Corporation (CITIC) and other construction companies in Hong Kong. The consortium along with the Hong Kong Government formed the New Hong Kong Tunnel Corporation (NHKTC) and the Eastern Harbour Crossing Corporation (EHCC), the two corporate entities that later became the concession companies in charge of operating the tunnels. In particular, NHKTC was responsible for designing and constructing all the tunnels and operating and maintaining the road portion, while EHCC would lease the rail portion to the MTR Corporation, which was in charge of its operation and maintenance. The concession to EHCC would expire in 2008, while that to NHKTC will expire in 2016. The project was financed through a mixture of debt, equity and land sales. The construction costs totaled 4.4 billion HKD (556 million USD, 1985), 61% of which were raised through debt financing from 50 banks. 25% of the costs were raised through equity of the two concession companies, most of which was held by Kumagai Gumi. The remainder was raised through property sales on the land along the new metro line (Levy, 1996). The returns would come from the toll revenues charged on the vehicles, but it was inherently uncertain whether enough ridership would be generated on this new tunnel, especially when the operators of the EHC planned to charge tolls that were twice as high as the CHT (Legislative Council Secretariat of Hong Kong, 2006). Therefore, the project posed a financial risk to its investors.

The Eastern Harbour Crossing also faced many construction challenges that would be interesting to investigate. The project utilized novel construction techniques such as new a watertight sealing system to join tube sections. The project was also constrained by limited construction space and unpredictable site conditions such as changing seabed currents that made tube section alignment difficult. With five immersed tubes, the overall scale of the project was also longer and wider than any other immersed tube project attempted in Hong Kong. All these complex technical challenges added to the cost, safety and scheduling uncertainty of the project.
In this report, we hope to present this project as an example of public-private partnership that turns out to be successful not only in monetary terms but also in its contribution to Hong Kong’s accessibility and development despite the various uncertainties involved.
2 Project Planning

The first plan for the Eastern Harbour Crossing was conceived in 1984 when the Japanese contractor Kumagai Gumi identified a lucrative business opportunity to build and operate a second road tunnel across Victoria Harbour (Levy, 1996). Kumagai Gumi offered to build the Hong Kong Government a tunnel between Quarry Bay on Hong Kong Island and Cha Kwo Ling in Kowloon in exchange for 30 years of tolling rights on the tunnel. Over the next year of planning, the project expanded to include both a road tunnel and a rail tunnel and many more investors and stakeholders before the final concession proposal was submitted in October 1985 and construction commenced in August 1986 (Ishikawa, 1985).

2.1 Project Viability Study

As a for-profit corporation, Kumagai Gumi would only offer to build the EHC if it expected to make monetary profit from the project. Therefore, Kumagai Gumi must have performed its own internal cost-benefit analysis to determine if the project is a financially viable undertaking. Although there are no publicly released records of Kumagai Gumi’s initial cost-benefit analysis, we can estimate the expected net present value of the project when Kumagai Gumi proposed the project in 1984.

Road Tunnel

First, we will estimate the net present value of the original project scope proposed by Kumagai Gumi, which only includes a road tunnel. The estimated construction cost of the project was estimated to be $2.04 billion HKD (Ishikawa, 1985). Instead of paying the $2.04 billion at the start of the project, the cost would be financed over the 30-year lifetime of the concession. Assuming the interest rate charged for the EHC project was comparable to the 12.5% interest charged for the construction of the Western Harbour Crossing (WHC) eight years later, the annual payment on construction costs would be $263 million annually for 30 years (Pretorius, Berry-Fong, McInnes, & Kramer, 2008). There was also no public data on the maintenance costs of the EHC. Looking at data from the WHC, the NPV of maintenance costs is negligible.
compared to construction costs (Levy, 1996). The projected benefits from this road tunnel could be calculated by multiplying the projected number of cars, trucks, buses, etc. traveling across the tunnel by the tolls charged on each of these vehicle types. Studies performed by Kumagai Gumi projected traffic flowing through the EHC to grow logistically from 40,000 vehicles per day at the tunnel opening to 90,000 vehicles per day 15 years later (Smith A., 1999). There was no public data available on the projected ratio of vehicle types in the EHC, so this analysis uses vehicle type proportions from the WHC to obtain the vehicle volumes of each type. The revenues from each vehicle type are summed together to get a total revenue for each year. The costs and revenues for each year are discounted by 16% annually, Kumagai Gumi’s expected return rate on its investments in road infrastructure (Ishikawa, 1985). In 1985, the present value of total costs is $1.62 billion and the present value of total benefits is $4.91 billion. Overall, the net present value of the EHC road tunnel was $3.29 billion in 1985 HKD. The corresponding benefit-cost ratio (BCR) would be 3.03.

Figure 6 – Costs and Benefits of the EHC Road Tunnel. The NPV of these costs and benefits is $3.29 billion in 1985 HKD.

**Rail Tunnel**

Second, we will estimate the net present value of the rail tunnel, which was added onto the initial proposal by Kumagai Gumi and ultimately constructed. The estimated construction cost of the rail portion of the tunnel was $1.36 billion (Ishikawa, 1985). This cost would be financed along with the road portion of the project at 12.5% interest for 30 years, leading to an annual payment of $175 million (Pretorius, Berry-Fong, McInnes, & Kramer, 2008). The projected benefits from the EHC were much more explicit. During the project planning process,
MTR agreed to lease the rail tunnels from MTR for 20 years for $418 million annually (MTR Corporation, 2004). However, it is important to note that these lease revenues begin in year 3, after construction has completed. An additional benefit from the rail tunnel construction is the sale of real estate above the stations, valued at $600 million (Levy, 1996). However, these properties could not be sold until the completion of construction at year 3. These revenues and benefits were discounted at 4%, because the typical returns on rail investments is much lower (Ishikawa, 1985). In 1985, the present value of costs was $3.0 billion and the present value of benefits was $4.7 billion. The overall net present value of the EHC rail tunnel in 1985 was $1.6 billion. The corresponding BCR was 1.54.

![Figure 7 – Costs and Benefits of the EHC Rail Tunnel. The NPV of these costs and benefits is $1.6 billion in 1985 HKD.](image)

**Comparison**

Both road and rail tunnels are profitable projects because they have positive net present values. When we compare the two parts of the project, the road tunnels show a much higher net profit and benefit-cost ratio. Therefore Kumagai Gumi initially proposed the more profitable road portion of the project to the Hong Kong Government in 1985. Although the road portion of the EHC is very profitable, it is important to note that it comes with very high risk. One of the largest uncertainties is the traffic flow and revenue projections. While it is relatively easy to survey and predict the number of vehicles that would be diverted from the CHT, it is much more difficult to estimate the number of new commuters that would be generated by the new convenient route. On the other hand, the rail portion of the tunnel was less profitable but less risky. Revenues were projected from fixed lease payments from MTR rather than uncertain train
ridership predictions. Due to the lower risk, Kumagai Gumi was willing to include the less profitable rail portion into its final EHC project.

Combining the road and rail portions of the project, the overall net present value of the project benefits is $4.89 billion and the combined BCR is 2.06.

2.2 Costs and Benefits to Additional Stakeholders

The cost-benefit analysis for Kumagai Gumi clearly showed that the EHC would yield financial benefits to Kumagai Gumi and its fellow investors. However, many other stakeholders affected by the project would also experience different costs and benefits. While some of these stakeholders had strong opinions on the project, their influence on the project was determined by their power, legitimacy, and urgency. Overall, the stakeholders with power, legitimacy, and urgency were all in support of the project – allowing the project to proceed efficiently.

Hong Kong Government

The Hong Kong Government was a major stakeholder in the EHC project. Prior to the EHC, the government’s Transport Department owned and collected tolls on the overcrowded CHT. The diversion of CHT traffic to the new EHC can be seen as both a benefit and a cost to the Transport Department. Reducing traffic at the CHT bottleneck would help further the Transport Department’s mission statement of “providing an efficient road and rail network for the movement of people and goods” without requiring the government to take on additional debt (Lau, 2013). On the other hand, reduced traffic at the CHT would cost the government toll revenue needed to repay bonds that financed the CHT’s construction. Overall, the traffic improvement benefits outweighed the costs and the Hong Kong Government was a supporter of the EHC.

The support of the Hong Kong Government was important because it was a powerful stakeholder. First, the government was in charge of issuing building permits and offering the public-private partnership agreement to the concessioners. Second, the Hong Kong Government had the authority to regulate the tolls charged on the EHC – affecting demand and feasibility of the project. If the government’s interests were not met, the government had the power to prevent the entire project from going forward.
The Hong Kong Government was also a legitimate stakeholder because the EHC would significantly alter traffic on government owned roads and tunnels. These shifting traffic patterns affect the long term transportation plan for the transport department. From the Hong Kong planning department’s perspective, the new link would also improve accessibility and promote development in the easternmost regions of the city (Sai Kung District Planning Office, 2002). It is a reasonable that the planning department is trying to align the new development with the city’s long term vision.

The government also had some urgency in developing the EHC. Demand on the original Cross Harbour Tunnel was nearing its 78,000 vehicle per day capacity and traffic was backing up onto local collector streets on the tunnel’s termini (Levy, 1996). If traffic on the critical cross-harbour link worsened, this would not only reduce the city’s economic productivity, but also reduce the government’s popularity. It is important to note that the EHC was not the only mega-project in the minds of the Hong Kong Government in the 1980’s. Other major public projects included: Chek Lap Kok airport, Sai Kung Reservoir, and Aberdeen Tunnel (Richmond, 1993).

Since the Hong Kong Government had power, legitimacy, and urgency, it could be considered a definitive stakeholder. The Hong Kong Government’s high salience and support for the EHC allowed it to play a major role in accelerating the project’s planning and construction.

**MTR Corporation**

The MTR Corporation owns and operates the majority of Hong Kong’s mass transit system. The new EHC would certainly benefit MTR by improving system redundancy and reducing crowding on its Tsuen Wan Line without requiring MTR to take on additional debt. MTR showed clear support for the EHC when it signed a long-term lease of the EHC rail tunnels (Levy, 1996).

MTR was urgent in pushing the EHC project because it needed a second harbor crossing to relieve crowding on its Tsuen Wan Line. The Mong Kok station on the line became so crowded that passengers were on the verge of falling off the platform. Despite the importance of this project, it is important to keep in mind the fact that the EHC was not the only MTR expansion project ongoing at this time (Richmond, 1993).

MTR did not have direct power over the EHC project because it was not the owner of the tunnel and could not make the decision to proceed on the project. However, it did have indirect power over whether the rail tunnel portion is included. If MTR decided not to lease the rail...
portion, the concessioner would have no other rail customers and would not be incentivized to build the rail tunnel.

MTR had legitimate claim to the EHC project. The EHC will be a pivotal part of the MTR’s Tseung Kwan O extension. The new crossing will also provide a new redundant route in the MTR system.

Since MTR had legitimacy and urgency but no power, it is considered a dependent stakeholder. It had strong opinions on the EHC project, but acted without the support of powerful stakeholders such as the concessioner or the government. Luckily, both of these powerful stakeholders were also on board with MTR’s proposed rail tunnel.

**Ferry Companies**

Prior to the construction of original Cross Harbour Tunnel, ferries maintained a monopoly on passenger and vehicular traffic across Victoria Harbour (Tresidder, 1963). The completion of the original Cross Harbour tunnel between the central Hong Kong and Kowloon displaced the slower and more expensive ferry services (Sham, 2007). However, ferry services remained in the far eastern and western regions because they were far away from the Cross Harbour Tunnel (Sham, 2007). Adding an Eastern Harbour Crossing would eliminate the last market for ferry services and leave the ferry companies bankrupt. From the ferry companies’ perspective, the EHC come at a huge cost and zero benefit.

The cross harbor ferry companies certainly had urgency to oppose the EHC because it would completely destroy the last ferry market in Hong Kong. The EHC’s short project duration also left limited time for the ferry companies to adapt or shift their business to new markets (Sham, 2007). Therefore, the ferry companies were urgent to know and affect their fate.

Despite their strong opposition, the ferry companies had little power in stopping the EHC project. These companies even had little lobbying power to the government because they were poorly organized independent operators (Sham, 2007).

The ferry companies also did not have a legitimate reason to oppose the project. Since the EHC would provide a faster, cheaper service than the ferries, there was no strong reason to keep the ferry service. Since the EHC was an unsubsidized private project, the ferries could not claim that they were being disadvantaged. Instead, the ferries no longer provided a competitive service and became obsolete.
Since the ferry companies had urgency, but no power or legitimacy, they can be considered a demanding stakeholder. They became the sole stakeholder opposing the EHC, but without power or legitimacy, they could not do anything about it.

Figure 8 – Image of the Hong Kong Yaumatei Ferry operating across Victoria Harbour. Constructing the EHC would make this service obsolete.

**Tseung Kwan O Property Developers**

Another major stakeholder of the EHC is the property developers of the Tseung Kwan O region in Eastern Kowloon. In 1985, prior to the construction of the EHC, the Tseung Kwan O region was a reclaimed landfill that was inaccessible to the rest of Hong Kong (Sai Kung District Planning Office, 2002). Property developers speculated that the MTR would route a new subway line (now the Tseung Kwan O line) across the new EHC and into the new area. The improved accessibility to Hong Kong’s job center would boost property values in Tseung Kwan O and make developing the area financially attractive (Sai Kung District Planning Office, 2002). Therefore, the property developers saw huge benefits in constructing the EHC.

The property developers certainly had urgency because a lot of their capital was tied up in empty plots in Tseung Kwan O. Their goal was to develop and sell the property as quick as possible, which required the EHC to be built quickly.

While the property developers were urgent, they did not have significant power to influence the EHC project. First, the property developers are not direct investors into the EHC
project and had no power to defund the project. Second, the developers cannot force the EHC project to go forward against the will of other stakeholders. However, it is important to note that the Hong Kong property industry has a strong influence in the Hong Kong Government, a definitive stakeholder of the EHC (Sai Kung District Planning Office, 2002). Nevertheless, the lobbying by the property developers will not be the largest influence on whether the Hong Kong Government issues a concession for the EHC project.

Although the Tseung Kwan O developers’ assets will severely lose value if the EHC is not built, the developers have no legitimacy in pushing the EHC project to happen. The developers voluntarily purchased inaccessible land in Tseung Kwan O and expected the EHC to be built. In effect, the property developers made deliberate decisions to become stakeholders affected by the project. The decisions for the EHC should be made to benefit the existing stakeholders rather than these artificial stakeholders.

Since the Tseung Kwan O property developers only have urgency and no power or legitimacy, they are considered a demanding stakeholder. The property developers strongly pushed for the EHC, but without power, their influence on the project was limited to pressuring the Hong Kong Government.

Figure 9 – The left image shows the Tseung Kwan O landfill in the 1980’s and the right image shows the same landfill converted to residential developments after the completion of the EHC. Developers purchased land in Tseung Kwan O in anticipation that the EHC would improve the accessibility and value of Tseung Kwan O.

Commuters

The commuters are the largest beneficiary of this project. As of 1996, a conservative estimate of the value in lost working hours caused by traffic jams “amounts to U.S. $2.3 billion - or 2 percent of the country’s economic output” (Levy, 1996).

Commuters had a legitimate reason to support the EHC project because hundreds of thousands of commuters’ journeys will be improved by the project. Even commuters not crossing the harbor would be affected by the EHC because it would divert CHT traffic that normally
backs up and gridlocks the central business districts of Causeway Bay and Hung Hom (the two termini of the CHT) (Levy, 1996).

Commuters also had urgency because the traffic at the CHT has already saturated its 78,000 vehicles/day capacity and is significantly delaying commutes (Levy, 1996).

While commuters had legitimacy and urgency to build the EHC and divert CHT traffic, they had no power to directly push the project. Thus, they are considered a dependent stakeholder. They can indirectly voice their concerns by pressing the government, a definitive stakeholder, to represent their concerns.

### 2.3 Financing the Eastern Harbour Crossing

Since the Eastern Harbour Crossing project’s benefits significantly outweighed the costs for most stakeholders, Kumagai Gumi could proceed on the project without opposition. However, it still needed to raise $4.4 billion in financing to cover the construction of the road and rail tunnels.

**Road Tunnel Financing**

$2.8 billion was needed to finance the road portion of the EHC (Levy, 1996). Kumagai Gumi partnered with the Chinese state owned investment bank CITIC, the Hong Kong Government, and other contractors such as Paul Y, Lilley construction, and Marubeni to raise $750 million in equity financing and form the New Hong Kong Tunnel Corporation (NHKTC) (Levy, 1996). Kumagai Gumi remained the largest shareholder of the project with a 69.37% stake. Another $250 million was obtained from land sales after construction is complete. The NHKTC raised the remaining $1.8 billion through debt (Levy, 1996).
Rail Tunnel Financing

$1.6 billion was needed to finance the rail portion of the EHC (Levy, 1996). Kumagai Gumi partnered with CITIC to form the Eastern Harbour Crossing Corporation (EHCC) and raised $350 million in equity (Levy, 1996). A separate joint venture was created for the rail tunnels because the concession period was shorter and the lower risk and return of the rail tunnels attracted different investors. Again, Kumagai Gumi remained the dominant shareholder with 90% interest. Another $350 million could be obtained at the end of rail construction by constructing and selling real estate built above MTR stations. The remaining $900 million in financing would come from debt (Levy, 1996).
2.4 Forming a Public-Private Partnership

The process of obtaining concessions and forming a public-private partnership with the Hong Kong Government was very quick and unchallenged – especially for a $3.4 billion megaproject (Levy, 1996).

With financing secured, the NHKTC and EHCC joint ventures submitted their revised concession proposals to the Hong Kong Government in October 1985 (Levy, 1996). The proposals established public-private-partnerships that enabled the NHKTC and EHCC to build-operate-transfer the road and rail tunnels respectively.

The concession for the EHC road tunnel required that the NHKTC build the road tunnel by 1989 in exchange for 30 years of tolling and maintaining the tunnel. The Hong Kong Government also agreed to fill in and provide the former Lam Tin shipyard to the NHKTC for a layout and casting basin for the EHC project (HKEPD, 2001). The proposed toll structure is listed below in 1985 dollars and indexed to inflation (Levy, 1996):
<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Toll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorcycles</td>
<td>$5</td>
</tr>
<tr>
<td>Private Cars</td>
<td>$10</td>
</tr>
<tr>
<td>Private Light Busses</td>
<td>$15</td>
</tr>
<tr>
<td>Light Goods Trucks and Vans</td>
<td>$15</td>
</tr>
<tr>
<td>Medium Goods Vehicles Less than 28 Tons</td>
<td>$20</td>
</tr>
<tr>
<td>Medium Goods Vehicles Less than 45 Tons</td>
<td>$30</td>
</tr>
<tr>
<td>Public and Private Single Decker Busses</td>
<td>$20</td>
</tr>
<tr>
<td>Public and Private Double Decker Busses</td>
<td>$30</td>
</tr>
<tr>
<td>Each axle in excess of two</td>
<td>$10</td>
</tr>
</tbody>
</table>

Figure 12 – Table of tolling structure for the new EHC in 1985 Hong Kong dollars. The tolls amounts will be indexed to inflation.

The concession for the EHC rail tunnel required that the EHCC build the rail tunnel by 1989 in exchange for maintaining and leasing the tunnel for 20 years. The concession did not specify the maximum price of the lease, but MTR and EHCC signed a contract for a $418 million annual lease prior to submitting the proposal (MTR Corporation, 2004). The Hong Kong Government did not grant any layout land to the EHCC for construction because the EHCC planned to pay the NHKTC to perform construction.

The review process for the concession applications occurred in less than a year because the project was backed by the most influential and salient stakeholders. By August 1986, a public-private partnership between the Hong Kong Government, NHKTC, and EHCC was formed and construction commenced (Ishikawa, 1985).
3 Construction

3.1 Tunnel Design and Construction Process

The Eastern Harbour Crossing consists of 5 sunken tube tunnels spanning Victoria Harbour between Quarry Bay and Cha Kwo Ling. The total length of each tunnel is 1.86km and the cross sectional dimensions are 35.45m wide by 9.75m tall (Ishikawa, 1985). Unlike the original CHT, the sunken tubes in the EHC would be fabricated from reinforced concrete rather than steel because the weight of the concrete would help sink the tunnel sections and reduce the cost of ballast and excavation (Lo, 2008).

To construct the sunken tube tunnels, a channel is first dredged across the seabed and partially filled with gravel using the jackup rig shown in Figure 8.

Instead of constructing the tunnels in the underwater channel, the concrete tunnels were cast in 180m long sections at the dry dock shown as shown in, floated out on a special barge, and sunk into the channel piece by piece (Lo, 2008). Ballast rock is placed above the tunnel sections before water inside the tunnel is pumped out to prevent buoyant forces from lifting the tunnel up. The process is summarized in Figure 10.

Figure 13 – Jackup barge used to excavate the trench where the sunken tube tunnel will rest (Lo, 2008).
3.2 Technical Challenges of Sunken Concrete Tube Construction

The decision to use concrete tunnel sections rather than steel tunnel sections reduced the material cost of constructing the EHC. However, the 35.45m wide tunnel sections were the widest concrete tunnel sections built in the world and the first subsea concrete tunnel built in Hong Kong (Lo, 2008). Adding to the technical challenges of the project, the EHC’s route crosses Victoria Harbour at a much deeper location than the original CHT (Lo, 2008). The scale and novel construction methods employed in the EHC led to major technical uncertainties that could augment the cost and schedule of the project.
**Tunnel Section Seals**

One of the largest technical challenges in the EHC project was designing the watertight seal between concrete tunnel sections. Segmented concrete tunnels have been built in Europe, Japan, and Korea prior to the EHC. These earlier tunnels were much narrower and traversed a relatively flat seabed and could employ bolted gina seals that could resist shear at the tunnel section joints (Lo, 2008). For the larger and steeper EHC tunnels, the watertight seals would have to resist both shear and axial movement at the joints (Lo, 2008). As a result, the EHC’s engineers designed a joint that employed gina seals as well as a new type of omega seal typically used in above ground tunneling (Lo, 2008). The dual seal system is shown in Figure XXX below:

![Diagram of tunnel section seals](image)

*Figure 16 – Close up of the Omega and Gina seal system used to connect tunnel sections (Lo, 2008).*

This new type of joint had not been tested in subsea tunnel construction in the past. Thus, the seals were a huge technical uncertainty that could significantly delay the project if they malfunctioned.

**Concrete Casting**

Concrete tunnel sections have been cast in prior to the EHC project. However, the size of the EHC’s tunnel sections is much larger than the size of previous sunken tubes. Figure XXX shows the scale of the casting operation. When concrete tunnel sections are poured, the setting concrete produces heat, which can dissipate naturally from the air after small gradual concrete
pours (Lo, 2008). However, the EHC tunnels were much larger and the project schedule was packed, so the tunnel sections were cast in a few large pours. This generated too much heat than air could dissipate, which would cause cracking during curing. To resolve this issue, engineers embedded tubes into the settling concrete which circulated cooling water through the center of the concrete (Lo, 2008). Although using circulating water to cool concrete had been employed in past projects, it was the first time the technology was implemented in a sunken tube tunnel (Lo, 2008).

Figure 17 – Photograph of the EHC’s tunnel sections being casted. The size of the truck indicates the scale of each tunnel section, which was unprecedented.

3.3 Construction Management and Logistics Challenges

Hong Kong is the second most densely populated city in the world. Within Hong Kong, population is concentrated along the two shores of Victoria Harbour (Smith D., 2012). Images of Quarry Bay and Cha Kwo Ling in Figures 13 and 14 show the high-density development along the edge of the harbor. Therefore, the space available for layout and constructing the EHC’s termini are limited.
Quarry Bay Terminus

On the Quarry Bay terminus, road traffic needed to connect with the Eastern Island Expressway (Route 4). However, this interchange had to be constructed without disrupting traffic on this major traffic artery. In addition, there was little room to build the interchange connecting the tunnel to Route 4. The government did grant the NHKTC land from a park in Quarry Bay, but it was barely large enough to make a cloverleaf turn into the tunnel (Lam, 2001). While the Route 4 interchange construction was occurring, a rail approach was created underneath the cloverleaf to connect the rail tunnels to new platforms created underneath the existing Quarry Bay MTR station (Lam, 2001). The layout space at Quarry Bay was limited to the center of the cloverleaf. As a result, most heavy equipment could not be stored at the Quarry Bay site and needed to be brought in daily (Lam, 2001). Figure 15 shows the tight project space at Quarry Bay.
Cha Kwo Ling Terminus

On the Cha Kwo Ling termini, there was slightly more land available. The government filled in the 5.5 hectare (13 Acre) Lam Tin shipyard and handed it over to the NHKTC as a tunnel approach and tunnel section casting site (HKEPD, 2001). However, the 5.5 acre site was still small for casting 180m long tunnel sections. The space only allowed 5 sections to be cast at a time (Lo, 2008). Therefore, a water cooling system had to be developed to cast the sections quickly. Due to the limited space, there was no storage space for tunnel sections. Sections that were not installed on time would be left in the casting basin and prevent the fabrication of the next set of tunnel sections. Since the casting basin would eventually become the tunnel approach and toll plaza, delaying the casting process would delay the entire project (Ishikawa, 1985). The activities along this critical path also face tremendous uncertainty. In particular, the assembly of the tunnel sections is unpredictable because new seal technology is being employed (Lo, 2008). Figure 16 shows the extent of the project area at the Cha Kwo Ling terminus.
Figure 21 – Overview of the Cha Kwo Ling terminus. The dotted line indicates the extent of the EHC’s project layout area. The land was initially a shipyard before becoming a casting basin, and finally a tunnel approach (AECOM, 2015).
4 Discussions

We have evaluated the performance of the project from the following three aspects: traffic improvement, revenue generation and real estate development along the new metro line. The effects are generally positive.

<table>
<thead>
<tr>
<th>Performance</th>
<th>Traffic Improvement</th>
<th>Revenue Generation</th>
<th>Development along the New Metro Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★</td>
<td>★★★★</td>
<td>★★★★</td>
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</tr>
</tbody>
</table>

Figure 17 – Evaluation of the Performance of the EHC project.

4.1 Traffic Improvement

Vehicular Traffic

A key measure of the success of the EHC is its ability to achieve its initial purposes, which include the provision of a shorter cross-harbour route to commuters who reside on the east side of Kowloon and the Hong Kong Island, the addition of capacity in the road system, and the diversion of traffic flow from the CHT. Our analysis shows that the traffic condition on the CHT was not alleviated as a result of the project despite that the EHC provides a new route for the cross-harbour commuters.

We were able to find the figure below that summarizes the annual traffic flow through each of the cross-harbour tunnels and through ferry service from the 2013 Annual Traffic Census of Hong Kong. Into the 1980s, the flow through the CHT (represented by the green line) had saturated, which might have led to the tiny yet steady increment in the use of unpopular ferry service (represented by the purple line at the bottom). The introduction of the EHC in 1989 did not lead to decongestion on the CHT as the traffic through the CHT was still growing; on the other hand, it led to a spike in the total number of cross-harbour vehicular trips (represented by the blue line) until 1994. These observations imply that the EHC did not divert the traffic through the CHT as desired but simply encouraged more cross-harbour vehicular trips by providing added cross-harbour capacity. One might be tempted to argue that the EHC curbed the
trend of increasing traffic through the CHT, as the slope of the green line had become smaller since 1989; however, the effect was negligible in comparison to that of the generation of new cross-harbour vehicular trips.

The EHC also enabled bus companies to develop new routes and grab a share in the expanding market of cross-harbour trips. As of today, 39 bus routes operate through the EHC, comparable to the number of buses that travel on CHT and WHC (45 on CHT, 45 on WHC) (Cross Harbour Bus Route). A study done in 1990 (merely one year after the completion of the EHC) on the two earliest bus routes that run on the EHC shows that “before the bus ran across the EHC, nearly no passenger got off the bus and the number of passengers on-board was reaching a maximum which is close to the design capacity of the bus” (Lam W. H., 1990). Although we do not have quantitative data comparing the number of bus passengers travelling through each of the tunnels, these new routes do not seem to perform any worse than the ones running through other tunnels.

The demand for ferry service gradually died out as a side effect of the EHC. We can see a sharp decrease in the year 1989 - 1990, a period of decay, and almost complete demise when the third cross-harbour vehicular tunnel (the Western Harbour Crossing, WHC) began to operate in the year of 1997 - 1998. While some of the ferry users might have switched to driving on the EHC, it would be more likely that they switched to MTR, an alternative with comparable prices but much faster.
Metro Traffic

According to Sorton’s emails, congestion relief on the cross-harbour section of the Tsuen Wan Line was MTR Corporation’s “primary reason for wanting the Eastern Harbour Crossing”, and the EHC successfully helped alleviate the overcrowding on the cross-harbour section of the

Figure 18: Annual Variation in Cross-Harbour Vehicular Trips by Hong Kong & Yaumati Ferry and 3 Tunnels Crossing Victoria Harbour (1961 - 2013) (Transport Department of Hong Kong, 2013).
Tsuen Wan Line. Due to the absence of MTR’s performance data on specific metro lines, this section is limited to a qualitative analysis.

Initially, the rail portion of the EHC was a part of the existing Kwun Tong Line, extending the service from the Kwun Tong station to the Quarry Bay station on the Island Line. The interchange at the Quarry Bay station was not so convenient, because “the new extension passed below and almost perpendicular to the existing Island Line at Quarry Bay Station”, leaving the passengers “having to negotiate one of three connecting passageways each with two sets of escalators”. To incentivize passenger to utilize the new and less convenient crossing, MTR installed “Fare Validator Machines” inside the Quarry Bay station that provided a fare reduction for passengers at the interchange. These machines were soon no longer in need because “the alternative [harbour-crossing on the Kwun Tong Line] became very popular and it became unnecessary to offer sweeteners to encourage passengers to use this route after only a few months”.

A result of its inconvenience, the Quarry Bay interchange became highly congested during rush hours. The Quarry Bay Congestion Relief project was carried out and finished in 2001 to address the issue. Under the project, an adjacent station North Point was expanded to be a second interchange with the Kwun Tong Line. It provided a more convenient interchange on the same level of the station. In 2002, the rail portion of the EHC, altogether with the Quarry Bay and North Point stations, became a part of the new Tseung Kwan O Line. The cross-harbour section of the Kwun Tong Line was used only in case of emergency and for transferring rolling stock between the Kwun Tong Line and the Tseung Kwan O Line.

The MTR system has also drastically evolved since the late 1990s, making it difficult to track the effect of the EHC on the cross-harbour trips made on the Tsuen Wan Line. For example, the Tung Chung Line was put in service in 1998 as another cross-harbour metro line, and two railways that run in the New Territories have extended to intersect in Kowloon, improving the accessibility within the northern Hong Kong. As Sorton mentioned in one of his emails, “the initial objective of the Kwun Tong Line extension through EHC to reduce congestion was certainly successful, but the effect was lost as the railway evolved”.
4.2 Revenue Generation

The project was a success to the investors of the concession companies; besides extracting stable annuities from the lease of the rail portion to the MTR Corporation, the investors made significant profit from toll revenues charged on the road portion. Up to 2013, NHKTC has an accumulated profit of $6.5 HKD (New Hong Kong Tunnel Corporation, 2013).

According to Figure 18 from the 2013 Traffic Census, the daily traffic flow in 1990 was 34000 per day, less than the figure estimated by Kumagai Gumi. The number soared high in the following years, however, almost reaching the design capacity of the EHC in 1996. The flow has decreased to about 75% of the design capacity since the WHC started its operation.

Below is a cashflow exhibit extracted from the 2013 Annual Report of NHKTC. We can see that the total revenue has been nearly constantly growing; NHKTC was able to pay back all the loans and interests at 2002 (year 16, only halfway into the concession); since then it has been able to maintain two-thirds of its revenue as free cash flow. This project has been a great success on the investors’ side.

![Annual Sources & Application of Fund](image)

*Figure 19 - Annual Sources and Application of Fund (New Hong Kong Tunnel Corporation, 2013).*
4.3 Development along the Metro Lines

The project has influenced not only the traffic system but also the Tseung Kwan O area, a previously inaccessible wasteland on the east New Territories. The EHC enabled the MTR to construct the Tseung Kwan O Line, which connects this area to the prosperous Hong Kong Island, and led to the development of high-density residential areas along the metro line in the area.

The history of the development in the Tseung Kwan O area can be traced back to days before the EHC project. Back in 1982, the Hong Kong Government approved the development of Tseung Kwan O into a new town. It was converted from a small fishing village and ship building industrial area in the 1960s to a populated community (Civil Engineering and Development Department). Due to data constraint we were not able to find population data in the area before 1996; according to the figure below, the population has almost tripled during the course of 19 years up to 2015.

![Figure 20 - Tseung Kwan O new town population](Hong Kong: Districts, Major Cities & Towns - Population Statistics in Maps and Charts).

It is not clear from the information above whether the development could be attributed to the Tseung Kwan O Line. We were able to find a study on the population density in Hong Kong
that demonstrates the correlation between metro line and population density in the Tseung Kwan O area, circled in blue. The area spanned by the north fork of the Tseung Kwan O line is much more populated than the rest of the peninsula. Along the metro line, the population is almost purely made up by residents as opposed to jobs.

In conclusion, the effects of the EHC have been generally positive - a profitable infrastructure project, it added capacity to the urban road network as well as the metro system, improved the accessibility on the east side of Hong Kong, and led to the further development of the Tseung Kwan O area.
5 Future Scenarios

Realizing that the concession of the road portion will expire in 2016, we are motivated to imagine the future of the EHC. We have planned two scenarios for the mode of operation of the EHC following the expiration of the concession, summarized in Figure 21.

- Scenario 1: operation by the Hong Kong Government
- Scenario 2: new concession to the same company or some other private company

We believe that Scenario 1 is more likely to happen than Scenario 2 for the following reasons:

- It brings the government a new source of revenue. The concession happened in the first place largely because the Hong Kong Government was in an unfavorable financial status and could not afford the high costs of building such a technically challenging cross-harbour tunnel. Today the economy in Hong Kong is in a much better shape, and the costs associated with operating and maintaining the tunnel are much smaller compared to the initial fixed costs of construction. Given that the tunnel has become a popular choice of cross-harbour trips and generates high toll revenues annually, the Hong Kong Government has more incentives to operate the tunnel themselves instead of handing the opportunity to someone else.

- The government is more concerned with the overall accessibility of the urban road network than a private company does. Part of the reason that EHC did not decongest the CHT was its high tolls, which might have discouraged the commuters from switching from the CHT to the EHC. To the public’s disappointment, NHKTC has attempted to increase the tolls in 2005 and 2012 respectively. Whereas the second attempt failed, the first attempt successfully passed the arbitration and transferred a significant number of cross-harbour trips to the CHT and the WHC. A perfect example of conflicting public and private interests, the situation can possibly be solved when the government takes over. The government can either lower the tolls on the EHC or increase the tolls on the CHT to redistribute the cross-harbour trips and achieve better accessibility.
<table>
<thead>
<tr>
<th>Scenario</th>
<th><strong>Operation by the Hong Kong Government</strong></th>
<th><strong>New concession</strong></th>
</tr>
</thead>
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<tr>
<td>Possibility</td>
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<tr>
<td>Tolls</td>
<td>Decrease; or CHT tolls increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Ridership</td>
<td>Increase</td>
<td>Decrease</td>
</tr>
</tbody>
</table>

Figure 22 – Two scenarios for the future of the EHC.
6 Conclusions

The Eastern Harbour Crossing is a unique project – it is the first large-scale multimodal infrastructure in Hong Kong, and it involved great uncertainties in technical and financial perspectives. Besides its profitability for the investors, it has improved the accessibility of Hong Kong and led to development in the once rural Tseung Kwan O area. The Build-Operate-Transfer model is also employed in the Western Harbour Crossing project.

The results of the EHC project coped with both private and public interests. The road portion has become a popular route for cross-harbour vehicle trips, and the investors have enjoyed the profits from toll revenues. On the other hand, the rail portion has benefited cross-harbour commuters who were once inconvenienced and brought opportunities to the Tseung Kwan O new town. In general, the project has accommodated the latent demand for cross-harbour trips and made the transit network more robust.

While the future of the Eastern Harbour Crossing is uncertain, we have envisioned that government operation would be more efficient in terms of optimizing the traffic flows on the tunnels and thus serve best the interests of the public. We look forward to the August of 2016 when the concession of the road portion expires.
# 7 Appendix

## Cost-Benefit Analysis for Kumagai Gumi on the Road Portion over the 30-Year Concession Period

<table>
<thead>
<tr>
<th>Year</th>
<th>Flow* (million vehicles / year)</th>
<th>Revenue (billion HKD)</th>
<th>NPV (billion HKD)</th>
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<td>808.18</td>
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</table>

* The flow is projected using a negative exponential growth model, 

\[ y = 365 \cdot 90000(1-0.5e^{-0.5t}) \], where 90,000 is the design capacity of daily traffic flow.
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