COST-BENEFIT ANALYSIS OF THE GREEN DECK DEVELOPMENT

(Final Report)

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Executive Summary

The area of Hung Hom Station and the Kowloon entrance of the Cross Harbor Tunnel currently serve as a major transportation route for rail and road vehicles, as well as pedestrians. To improve the local environment and revitalize the district, Green Deck was proposed by the Hong Kong Polytechnic University (PolyU) as an innovative social project to bring long-term benefits to the Hong Kong society.

This study aims to demonstrate the economic feasibility of the Green Deck development by adopting a cost-benefit analysis approach. Both tangible and intangible costs and benefits were considered to compute the net present value (NPV), Benefit-Cost Ratio (B/C ratio), and the Internal Rate of Return (IRR) to decide whether the Green Deck project is a viable and beneficial investment to the society. The result shows that the Green Deck project has a B/C ratio of 1.35, which falls within the interval of the B/C ratios of other urban green infrastructure development projects in Asia. The project will be paid back in 2053 with an NPV of 3.53 billion HKD and an IRR of 5.5%. Sensitivity analysis indicates that the NPV would be significantly influenced by the number of visitors. Marketing strategies, such as collaborations with the surrounding art and cultural institutions, are advised to be adopted to attract more visitors to increase the NPV. The findings of this study present quantitative costs and benefits of the Green Deck development, which can serve as a reference in the decision-making process.

Table of Content

List of Tables

List of Figures

List of Abbreviations

B/C ratio: Benefit-Cost Ratio

CHT: Cross Harbor Tunnel

CBA: Cost-benefit analysis

HKD: Hong Kong Dollar

IRR: Internal Rate of Return

NPV: net present value

O&M: Operation and maintenance

PolyU: The Hong Kong Polytechnic University

PPP: Purchasing Power Parity

TST: Tsim Sha Tsui

UHI: Urban Heat Island

WTP: Willingness to Pay

*in alphabetical order

Chapter 1. Introduction

1.1. Background

Hong Kong has been recognized as one of the densest cities in the world. Local citizens are facing the challenges of living in a crowded urban environment with limited open space, intensified urban heat island effect, and air and noise pollution. Many studies have reported the significance of urban green space to the well-being of society. Urban green space an essential element in developing a sustainable city by improving resilience to extreme weather events and climate change, reducing carbon emissions for carbon neutrality, enhancing biodiversity and ecosystem services, and improving public health and well-being, as well as increasing social cohesion (WHO, 2016). The Hong Kong Polytechnic University's (PolyU) proposed Green Deck is an ambitious project that intends to change this existing urban façade and living environment by constructing a multi-functional open space for the neighborhood. The proposed Green Deck will be located above the Hung Hom Cross Harbor Tunnel (CHT) and its Toll Plaza area, and adjacent to the Hung Hom MTR station podium (west), with an area of 30,004 m^2 (Fig. 1-1).

Fig. 1-1 Landscape Master Plan of Green Deck Development (Arup, 2022)

Despite the numerous potential benefits to the urban environment and social well-being, urban green infrastructures have previously been underrated, and regarded as having less contribution to economic growth than transportation, energy, and sanitation infrastructures. This misconception is partly due to market failure since the benefits of urban green space are mainly in the environmental and social aspects, such as air quality, public health, and carbon reduction, which are external effects that are not being considered in the market mechanism (Madureira et al. 2015, Reyes-Riveros et al. 2021). If these intangible benefits are underestimated or ignored in the decision-making process, the true value of urban green space could not be revealed, and sustainability and efficient resource allocation might not be able to achieve.

1.2. Objectives

To demonstrate the economic feasibility of the Green Deck development, the three objectives of this study are listed as follows.

(1) To identify and quantify the tangible and intangible costs and benefits of the Green Deck development, for providing a clearer understanding of the costs and benefits brought by urban green space to the decision makers;

(2) To determine if the total benefits of the Green Deck development outweigh its total costs;

(3) To conduct sensitivity analysis as a risk assessment for infrastructure investments.

1.3. Methodology

Cost-benefit analysis (CBA) is a tool to assist decision-making on investment, provided that resources are scarce (CEEU, 2012). For private investments, the main goal is profit maximization. Thus, the decision-making is according to private costs and private benefits, which are reflected in the market mechanism (CEEU, 2012). However, for the public sector like the government, investment decisions should not be solely based on private costs and benefits, but the society as a whole (CEEU, 2012). CBA could serve this purpose as it is a "process of identifying, measuring and comparing the social benefits and costs of an investment project or program" (Boardman et al., 2017). The costs and benefits evaluated in the CBA process include both tangible and intangible items. By comparing all the costs and benefits involved in the investment project, one can evaluate if the total benefit exceeds the total cost, or vice versa. Therefore, especially for green infrastructure projects, carrying out a holistic CBA is essential in the decision-making process.

The concept of opportunity cost is a central element involved in CBA calculation, as the primary purpose of CBA is to evaluate the net benefits of the investmentin comparison to an alternative or base case, referred to as the ”with” and “without” project scenarios (Steiguer, 2022). As resources are limited, resources utilized for the proposed project should be justified against its use for other purposes. As a result, this opportunity cost denotes the “cost” of project in the CBA because choosing to carry out one project needs to forgo the opportunity of carrying out an alternative project (Boardman et al., 2017). Therefore, the purpose of CBA is to compare how the society would be different “with” and “without” the investment project.

In general, four steps are involved in conducting a CBA – first, to identify the tangible and intangible costs and benefits associated with the project; second, to estimate the market values of the costs and benefits; third, apply the discounting factor and analyze the options with decision rules; and finally, to conduct sensitivity analysis to examine how the result will differ under various scenarios (CEEU, 2012). The CBA process is illustrated in Fig. 1-2.

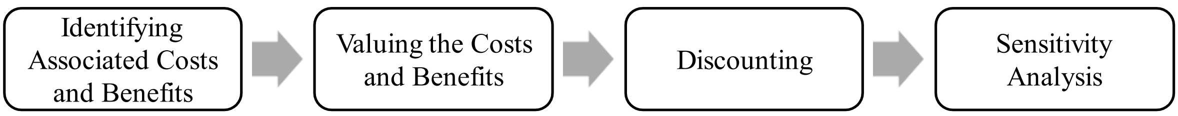


Fig. 1-2 CBA process (CEEU, 2012)

1.4. Expected Outcome

The associated economic, social, and environmental costs and benefits from the construction to operation of the Green Deck would be identified and quantified based on available data. A holistic CBA framework will be established in this study to provide decision rules such as net present value (NPV), benefit-cost (B/C) ratio, and internal rate of return (IRR) as a reference for determining whether the Green Deck development is a favorable investment in terms of the interest of the society. In addition, an Excel tool will be developed for users to reproduce or update the results of this study with new information available.

Chapter 2. A review of literature

Literature review was carried out to identify the associated costs and benefits of both the construction and operation stages of green deck development projects to construct the Green Deck CBA framework.

2.1. Construction Stage

2.1.1. Cost

2.1.1.1. Initial Investment and Design and Consultation Cost

Construction or initial investment cost is usually the largest cost involved. This cost is considered as an explicit cost since there is a direct monetary payment or a clear monetary value that can be determined (National Center for Environmental Economics Office of Policy, 2014). The design and consultation expenses are also included as part of the project cost, Which usually account for less than 5% of the total investment cost for most infrastructure projects (Lee and Jung, 2015; European Commission, 2015).

2.1.1.2. Cost of Temporary Traffic Congestion

It is indisputable that construction work on the road would lead to traffic congestion. According to a Hong Kong government report, road works are deemed one of the major reasons for traffic congestion in Hong Kong (Transport Advisory Committee, 2014). In

Nigeria, construction work could cause traffic delays for 2 minutes on average (Atomode, 2013). Simulation studies on the Guam road network indicated that road construction work would increase travel time by around 4 minutes (Zheng et al., 2014).

This traffic time delay takes a toll on society. Congestion on the road incurs a significant cost to commuters and other drivers, with cost of time loss as the primary concern (Metropolitan Planning Council, 2008). The time lost in traffic congestion of the Chicago metropolitan region could lead to an extra cost of US$5.1 billion to the commuters (Metropolitan Planning Council, 2008).

2.1.1.3. Construction Carbon Emissions

Yan et al. (2010) have identified that the major sources of carbon emissions during building construction in Hong Kong include 1) manufacturing and transporting building materials; 2) energy consumption of on-site construction equipment; 3) energy used for processing resources; and 4) fossil fuel combustion for construction waste disposal. Among these sources, the author found that the production of building materials takes up the highest percentage, about 82-87% of the total emission. Similar results were observed in a residential complex construction in Guangdong Province, China. The production of building materials was found to be the main source of carbon emission during construction, which accounted for 2/3 of the total emission (Hong et al., 2015).

2.2. Operation Stage

2.2.1. Cost

2.2.1.1. Operation and Maintenance Cost

Operation and maintenance (O&M) cost is regarded as variable cost as it changes with the volume or intensity of the output (Central Expenditure Evaluation Unit, 2012). The O&M cost of parks can vary greatly, depending on the park's use and design (The Trust for Public Land, 2008). For example, the O&M cost of urban parks in the City of Minneapolis can range from US$$229,000 to $884,000 per acre (The Trust for Public Land, 2008).

2.2.1.2. Operation Carbon Emissions

During the operation of the Green Deck, electricity use would generate carbon emissions. Kong et al. (2014) conducted a study on urban turfs in Hong Kong and Shenzhen and found that the electricity used in managing the turfs could emit 73.6 kg to 178 kg of carbon equivalents per year. In the US, Villalba et al. (2013) investigated the carbon footprint of the Yosemite National Park. Electricity use led to 7,812 tonnes of carbon emissions, which contributed to 17% of the total emissions of Yosemite National Park in year 2011.

2.2.2. Benefits

2.2.2.1. Revenue

Revenues, such as rental or entry fees to the recreation providers, should be included in the benefit valuation in CBA (Briceno and Schundler, 2015). Nadel (2005) conducted a CBA for the Golden Gate National Recreation Area, in which the fees, ticket sales, and any gross revenues have been included in the calculation.

2.2.2.2. Visitor Expenditure

Briceno and Schundler (2015) conducted an economic analysis of recreational land use in Washington State, US. The research showed that the annual trip-related expenditures of visitors on public outdoor recreation land uses was about US$10.7 billion, which as a result could generate great economic activity in the country. According to the report, the expenditures included gas and oil, food and beverage, grocery, retail, etc., and excluding the purchase of equipment. Among them, gas and oil contributed the greatest (23%), followed by food and beverage (17%) (Briceno and Schundler, 2015).

2.2.2.3. Air pollution reduction

Air pollution adversely affects human health, especially to the cardiovascular and respiratory systems (Fiordelisi et al., 2017; Schraufnagel et al., 2019). The ability of trees and shrubs to remove air pollutants has been proven by various studies. Through dry deposition, which is a process of absorbing air pollutants into the plant tissues with stomata, plants could reduce the concentration of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and particulate matters (PM) through their surface (Harnik and Welle, 2009; Jim and Chen, 2008; McPherson et al., 2002). However, the dry deposition rate depends on the plant species, roughness of the leaf surface, and atmospheric conditions (Jim and Chen, 2008). Therefore, the air pollutant removal rates of plants varies between different plant species and geographical locations.

According to Tan and Sia (2005), a green roof in Singapore can absorb 6% of atmospheric PM and 37% of SO_2 per year. A similar study has also been conducted in Hong Kong. Peng and Jim (2015) evaluated the intensive green roofs in Hong Kong and concluded that the annual reduction for SO_2, NO_2, and PM is 31kg/ha, 12.4kg/ha, and 195kg/ha respectively. On the other hand, the air pollutant reduction level in Guangzhou is found lower than that in Hong Kong. Trees on recreational land in Guangzhou could reduce SO_2 by 23.83kg/ha, NO_2 by 24.29kg/ha, and PM by 88.79kg/ha per annum (Jim and Chen, 2008).

2.2.2.4. Carbon Sequestration

Apart from the removal of air pollutants, urban parks could also act as carbon sinks. McPherson et al. (2002) suggested that urban trees in Sacramento, California can remove some 304,000 tonnes of atmospheric CO_2 a year, with a value of US$3.3 million. Using remote sensing techniques to quantitatively estimate CO_2 sequestration in Japanese forests, Iizuka et al. (2015) reported that total CO_2 sequestration in Japan based on tree age forest subclasses yielded 85.0 tonnes (coniferous), 4.76 tonnes (evergreen broadleaf) and 21.61 tonnes (deciduous broadleaf) of CO_2 emissions, with a total carbon sequestration of 111.27 tonnes. In Montreal, Canada, Grossi et al. (2022) found through experiments that the carbon sequestration rate was 0.575 $kgCO_2$ eq/m^2 of tree-covered area. Although plants can absorb CO_2, the sequestration capacity differs between species since it relies on the photosynthetic and respiration rates, as well as the weather and environmental conditions (Chen and Jim, 2008; Peng and Jim, 2015). Peng and Jim (2015) reported a different carbon sequestration rate of trees in Shenzhen compared with that in the US. The authors studied 6 typical types of urban green space in Shenzhen city and found the average annual carbon sequestration rate to be 25.7 tonnes/ha.

2.2.2.5. Noise Pollution Reduction

Noise exposure not only adversely affects human health, but also the economy as a whole. Studies concluded that when a person is constantly exposed to noise, negative health impacts including a higher risk of heart attack, hypertension, sleep disturbance, and even poorer reading performance in children can arise (Istamto et al., 2014; Swinburn et al. 2015). Economically, Brons et al. (2003) found that noise affecting school buildings, medical premises, and residential areas could have a negative effect on human capital stock, which indirectly takes a toll on the economy. With the Green Deck, Tang (2014) suggested that the traffic noise level at the PolyU campus could be reduced by 3dBA. The noise reduction would benefit the society as a study in the US proved that a reduction of 5-dB L_{DN} in noise level could reduce the number of hypertension cases by 1.4% and coronary heart disease cases by 1.8% (Swinburn et al. 2015). Moreover, the cost of traffic noise pollution to society can be measured by the Willingness to Pay (WTP) method. Studies in Europe found that the WTP for an excess dBA ranges from 15-20 euros per person (Howarth et al., 2001; Nijland et al., 2003), but this value would be affected by household income, gender, education level, etc. (Istamto et al., 2014). In Asia, Leong (2019) found that the WTP for reducing road noise per decibel per year per person in Singapore was on average S$ 20.

2.2.2.6. Surface Runoff Reduction

Another common indirect benefit of urban parks is the reduction of surface runoff. By capturing rainwater, vegetations can reduce the peak flow and runoff volume, while the soil can absorb water (Sherer, 2006; Harnik & Welle, 2009; Roehr and Kong, 2010; Vijayaraghavan et al., 2012). An experimental study found that a London plane and an *Ulmus procera* tree can reduce 20% to 26% of runoff in a 5-mm rainfall event respectively (Mariana et al., 2018), and this runoff reduction service provided by the plants is economically beneficial to the society. In Philadelphia, the total annual saving due to runoff reduction by urban parks amounted to US$5,948,613 (Harnik and Welle, 2009). The rate of runoff reduction, however, depends on the soil depth, growing medium, and plant species (Roehr and Kong, 2010). Berardi et al. (2014) concluded after reviewing a number of papers that green roofs could reduce surface runoff by 25-50%. On the other hand, a higher runoff reduction rate was reported by Speak et al.

(2012). The authors conducted a study on intensive green roofs in Manchester, UK, and a 65.7% runoff reduction rate was achieved on average.

2.2.2.7. Temperature Reduction (Energy Saved and Emission Avoided)

Vegetation can lower the temperature and alleviate the Urban Heat Island (UHI) effect, which in turn reduce energy consumption and greenhouse gas emissions. The UHI effect is caused by the high density of the built environment and the anthropogenic heat in the urban area (Chen and Wong, 2006). The high temperature would increase energy use for cooling and raise the electricity demand, as well as emitting more greenhouse gas into the environment through fossil fuel combustion during the energy production process (Chen and Wong, 2006; Zhang et al., 2014). To ease the UHI problem, urban plants could play a role as they can reduce air temperature through evapotranspiration, where the latent heat of vaporization is absorbed in the atmosphere (Zhang et al., 2014). To understand the temperature reduction potential of urban greenery in urban areas, Peng and Jim (2013) investigated the effect of intensive green roofs in Hong Kong and concluded that the green roof can lower temperature by 1.2℃ at the pedestrian level. Other studies on the cooling effect of urban parks in Asia showed a different result and revealed a range of temperature reduction from 0.1-5.1℃ (Kong et al., 2017).

Studies carried out in the US showed that with every 1℃ change in the ambient temperature, a 4% change in energy consumption from cooling could be found (Milward and Sabir, 2011; Jensen et al., 2003; McPherson et al., 1997). A similar pattern has been observed in Hong Kong. Fung et al. (2006) conducted an empirical study on the relationship between energy use in domestic, commercial, and industrial sectors and ambient temperature change. Results indicated that with a 1°C temperature change, the electricity demand will change by 4.5% on average.

2.2.2.8. Health and Well-being

More and more studies have confirmed the positive effect of the presence of parks on human health. Psychologically, it is suggested that human beings tend to get pleasure from trees through a sense of meaning and connection (McPherson et al., 2002), thus, people living near green areas rated themselves as having better mental health, and with fewer complaints on health (Sherer, 2006). Physically, studies found that people will exercise more if they could easily access to a park (Sherer, 2006; Kahn et al., 2002). According to Kaczynski and Henderson (2007), if there is a park or walking trail nearby, 55% of people would increase their exercise frequency. Evidence showed that human health would be improved with extra physical activity. Sæ lensminde (2004) reported a 1% reduction in short-term absence from work with extra physical activity, while Cavill et al. (2008) found a 50% and 40-50% reduction in the risk of getting coronary heart disease and colon cancer respectively for more physically active people. This increase in exercise due to the presence of urban parks has been found to be beneficial to the society by saving the cost of medication, as the medical cost tends to be lower for people with more physical activity than that of their counterparts.

In the US, a study showed that if 10% of adults started regular walking exercises, US$5.6 billion could be saved in a year (Wang et al., 2005). Pratt et al. (2000) compared the medical cost difference between physically active and inactive persons in the US. Physical active people in general pay US$280 less annually, which is similar to the finding of Harnik and Welle (2009) (US$250 per year). In Hong Kong, according to a survey conducted in 2001, the average monthly medical cost for a physically active person is HK$596, while for those inactive is HK$748, with a HK$152 difference (Louie and Hui, 2001).

2.2.2.9. Travel Time Reduction

Hung (2015) conducted a research study on modeling the changes in pedestrian flow at PolyU if the Green Deck was built. The study focuses on the footbridge connecting the Hung Hom Station and the PolyU campus, which has encountered congestion problems during the morning and evening peak hours. With the Green Deck, the pedestrian flow rate during the morning peak hour is reduced from 220 pedestrian/min to 59-70 pedestrian/min, while the flow rate during the evening peak house is reduced from 260 pedestrian/min to 149-176 pedestrian/min (Hung, 2015). Decreasing the flow rate can increase the walking speed of pedestrian (Lam et al., 2000), thus saving their time costs in traveling.

2.2.2.10. Property (Hedonic) Value

Various studies confirmed that with all else being equal, people are willing to pay more for a house that is close to parks, and this phenomenon is known as the "hedonic value" (Harnik and Welle, 2009; Rouwendal and van der Straaten, 2008). Bianchini and

Hewage (2012) reported that with trees or greenery nearby, property values could increase by 15-25% in general. However, a lower value was found by Luttik (2000). The author investigated a small neighborhood and concluded that with a view of open space, the house price would increase by 6-12%. Nevertheless, this increase in property value was found to decrease with distance away from the park. Studies suggested that this effect can be measured up to 2,000 feet from the green space, with the greatest value found within the first 500 feet (Harnik and Welle, 2009; The Trust for Public Land, 2010; Jim and Chen, 2010). Other research also reported similar findings. Correll et al. (1978) observed a US$4.2 decrease in property value for every foot away from the green area, and More et al. (1988) indicated that the value of an apartment 20 feet from the park could be US$2,675 higher than a same one that is 200 feet away.

Chapter 3. The CBA framework

This study analyzes the costs and benefits of the construction and operation stages of the Green Deck development. The elements of costs and benefits were defined based on the literature review in Section 2. The costs and benefits can be classified as tangible and intangible according to Boardman et al. (2017). The tangible costs and benefits are measured directly via monetary; these benefits are like quality, profitability, and performance of the derived products. The intangible costs and benefits may not be measured in terms of product metrics; these benefits include customer satisfaction and professional satisfaction.

In the Green Deck case, the government is assumed to be the investor. All the direct costs and benefits, such as construction costs, O&M costs, and revenues, would be considered as “tangible”. Other costs and benefits that are shared by the environment or individuals other than the government would be regarded as “intangible”. Based on this classification, the Green Deck CBA framework is presented in Fig. 3-1.

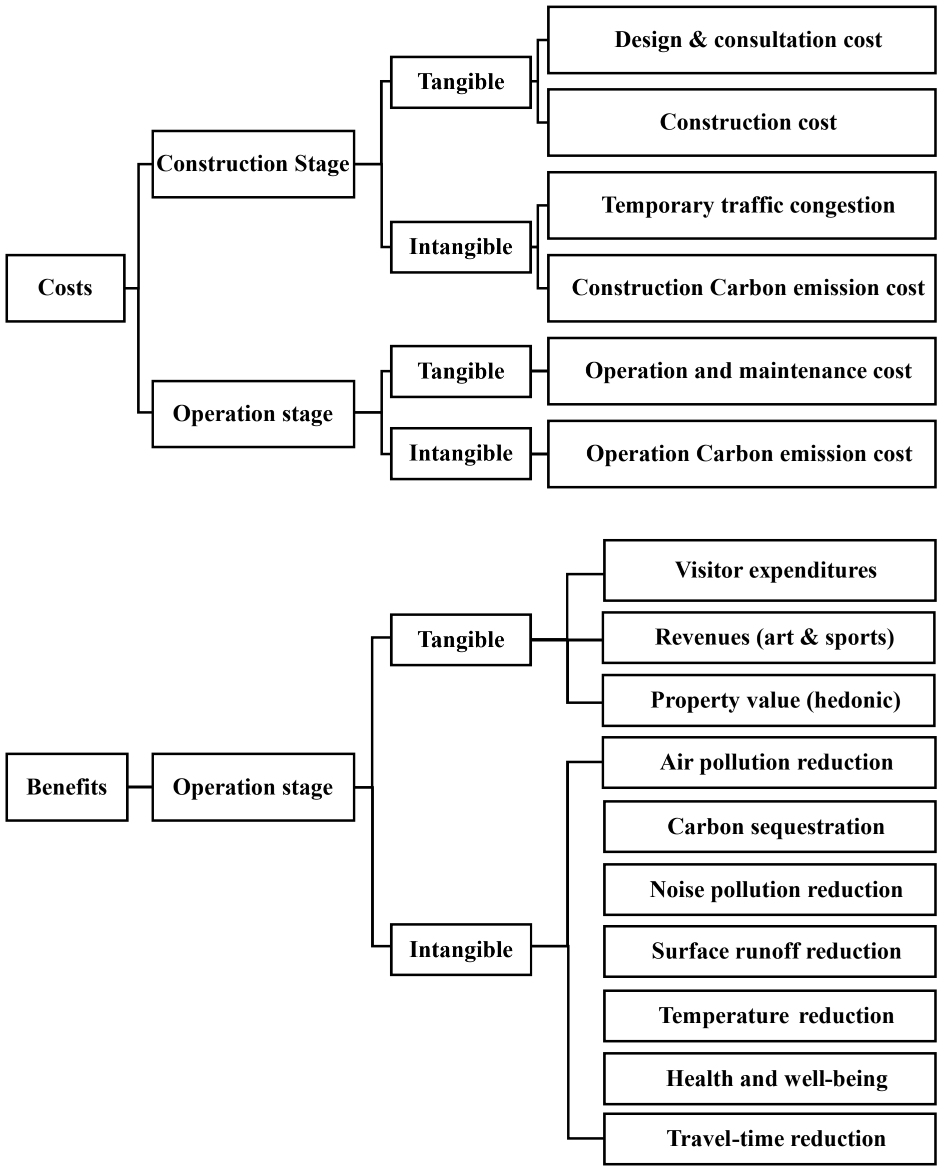


Fig. 3-1 The cost and benefit analysis framework

Chapter 4. Valuation methodology & data source

In this section, the valuation method of the costs and benefits is explained. The method of benefit transfer was used as the data limitation. Benefit transfer is "the use of estimated nonmarket values of environmental quality changes from one study in the evaluation of a different policy that is of interest to the analyst" (USEPA, 2010). In choosing the relevant data, priority was given to local research to minimize inaccuracy. Study results from other countries were used only if no locally relevant data was available. To further increase the reliability of the CBA, the dollar values adopted from the US will be adjusted to the Hong Kong dollar by using the Purchasing Power Parity (PPP) exchange rate published by the World Bank (US$1 = HK$5.89) (The World Bank, 2022) as the price level and the household income at the US are different from Hong Kong.

4.1. Tangible costs

1. Initial Investment and Design and Consultation Cost

The construction cost was assumed to be HK$6.89 billion according to the consultancy report (Arup, 2022). With 11 years of construction time, the annual cost of construction will be HK$626.36 million. The design and consultation cost was estimated to be 4% of the construction cost, which is about HK$25.05 million.

2. Operation and Maintenance Cost

The operation and maintenance (O&M) cost of the green deck was adopted from the O&M costs of Kowloon Park per hectare (ha) per year, which is HK$3.6 million (LCSD, personal communication, September 10, 2015). With 3.0004 ha, the annual O&M cost of the Green Deck will be around HK$10.8 million.

4.2. Intangible Costs

1. Cost of Temporary Traffic Congestion

The cost of traffic congestion due to the Green Deck construction was estimated by the time cost of the delay. A simple way to estimate travel time costs for each affected person is by using the average wage rate (CEEU, 2012). In Hong Kong, the median hourly wage rate is HK$75.70 (Census and Statistics Department, 2022a), so the time cost is assumed to be HK$75.70 per hour. According to McCann et al. (1999), the average traffic delay is about 10-15 minutes due to road work in the US urban areas (New Jersey and Salt Lake City). The average, which is 12.5 minutes, was taken as the traffic delay time due to the Green Deck construction. The daily average traffic flow of the CHT in the year 2021 was 107,450 according to the data from the Transport Department of the HKSAR Government (Transport Department, 2022). Referring to the Annual Traffic Census 2021 (Transport Department, 2022), the weighted average occupancy rate of motor vehicles ranged from 1.55 to 1.99. Hence, assuming that on average there are 2 persons in each cross-harbor vehicular trip, and 223 working days per year (excluding Saturdays, Sundays, and public holidays), with 5 years of the construction period, HK$755.78 million will be lost each year due to traffic congestion.

2. <u>Construction Carbon emission</u>

The carbon emission during Green Deck construction was estimated by averaging different building construction projects such as residential, commercial, and hotel in various countries including the UK, China, Singapore, and Hong Kong. The average annual construction emission found is 386.50 kg CO_2 eq/m^2 (Hong et al., 2015). To quantify the carbon value, the social cost of carbon estimated by the US government is adopted. It is "an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year", which is US$43 per tonne in 2022 dollars (Interagency Working Group on Social Cost of Carbon, 2013). As a result, with 386.50 kg CO_2 eq/m^2 emission, the Green Deck construction carbon emission will cost US$ 45,332 per annum, as shown in Table 4-1. Converted with PPP exchange rate: 5.875 HKD/USD in 2021 (World Bank, 2022), the Green Deck construction carbon emission will cost HK$266,325.

Table 4-1 Construction carbon emission and emission cost

Total Emission during construction (kg CO_2 eq/m^2)	Green deck area (m^2)	Total Emission during construction (kg CO_2 eq /year)	Cost of carbon in 2022 (US$/tonne)	Annual cost of construction emission USD
386.5	30,004	1,054,231.5 (=386.50×30004/11 years)	43	45,332 (=1,054,231.5 ×43/1000)

3. <u>Operation Carbon Emission</u>

According to the study conducted by Yang et al. (2014), the green deck is expected to consume 5,800 kWh of electricity per day. Referring to the latest emission factor of

0.55 kg CO_2 eq/kWh from CLP Power Hong Kong Limited (CLP, 2022), approximately 1,164,350 kg of CO_2 equivalent will be emitted each year due to the electricity consumption during the Green Deck's operation. The cost of carbon adopted is the same as the one used for construction carbon emission. Thus, the annual cost of operation carbon emission is found to be about HK$294,144.

4.3. Tangible Benefits

1. Revenue (art gallery & sports complex)

Referring to the Green Deck development master plan, there will be an Art Gallery and a Sports Complex on the deck for public use (DLN, 2014). We assumed that the Art Gallery on the Green Deck requires an entry fee, and the sports facilities in the Sports Complex require a rental fee. The entry fee of the Art Gallery is estimated as the standard ticket price of the Hong Kong Museum of Art (HK$10 in the year 2022). Suppose the number of visitors is the same as the Hong Kong Museum of Art, which is 579,036 per annum (Hong Kong Museum of Art, 2022), the annual entry revenue will be HK$ 5.79 million.

The sports facilities rental income of the Kowloon Park Sports Center is used as the revenue of the Sports Complex on the Green Deck. According to the Leisure and Cultural Services Department, the value is HK$3.5 million in the year 2014-15 (LCSD, personal communication, September 10, 2015). As a result, HK$9.29 million of revenue from the Art Gallery and Sports Complex will be generated annually.

2. <u>Visitor's Expenditure</u>

To estimate how many visitors are coming to the Green Deck, the average number of people visiting Tsim Sha Tsui is adopted. The information provided by the Immigration Department of Hong Kong shows that there are on average 23.34 million overnight visitors to Hong Kong from 2013 to 2019 annually. Since on average 41.7% of visitors to Hong Kong visit Tsim Sha Tsui (Vu et al., 2015), 9.73 million people is assumed to be the annual number of visitors to Green Deck. Song et al. (2017) estimated that the willingness to pay visitors are willing to pay 43.88 HKD for food and beverages at Green Deck convenience stores (a weighted-sum value of Chinese, foreigners, and Hong Kong residents' visitors). According to the Transport and Housing Bureau, the average transport fee for one trip in Hong Kong is found to be 16.67 HKD for each person. Hence, the annual visitor's expenditure for food and transport due to Green Deck is HK$ 598.47 million per year.

3. <u>Property (Hedonic) Value</u>

The presence of parks is found to have a positive effect on the rent of nearby properties. Studies showed that the influence can be as far as 2,000 feet from the park, while most of the value will be within 500 feet (Harnik and Welle, 2009; The Trust for Public Land, 2010). However, the percentage increase in rent will gradually reduce with a decrease in distance from the park (Sherer, 2006). To make a conservative estimation, the properties within 1,000 feet from the Green Deck are taken into account, where those located at the first 500 feet have a higher percentage increase of rent than the properties found at the rest of the 500 feet. The percentage increase in rent due to Green Deck is adopted from Hui (2022), which assumed that the rent is 27.03% and 7.33% higher for the properties within the first 500 feet and for the rest respectively. Fig. 4-1 illustrated the area affected by the hedonic effect.

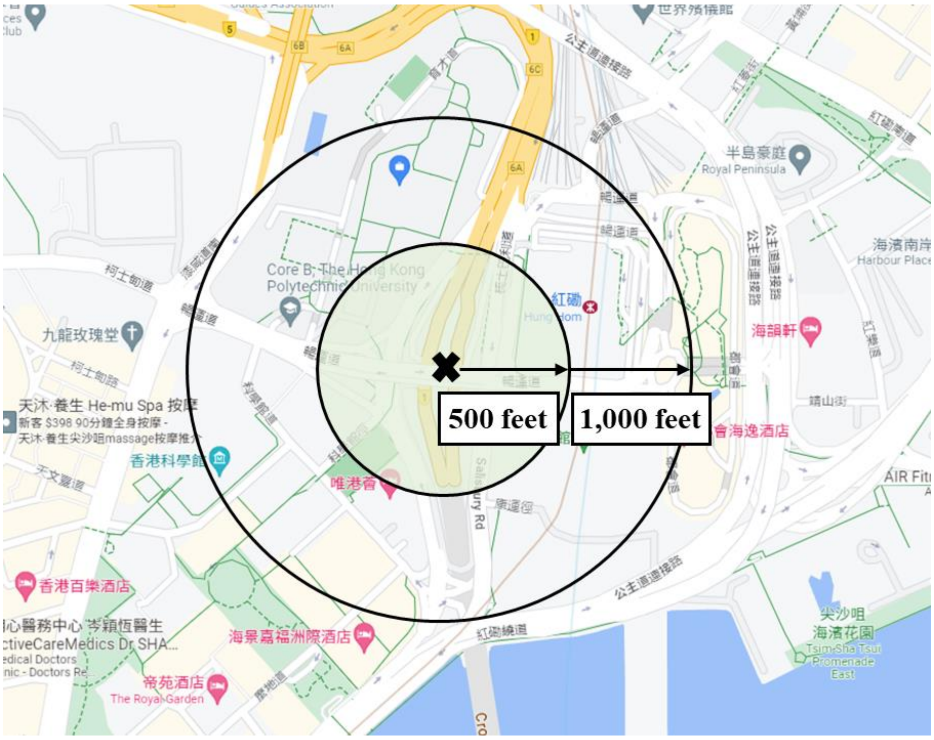


Fig. 4-1 Hedonic effect affected distance.

Including the potential retail stores in the mid-level and the restaurant on the viewing deck, the expected total rental value of these properties is about HK$1.3 billion. With the presence of the Green Deck, HK$351.39 million would be generated as the hedonic benefit. For properties within 1,000 feet, but beyond the first 500 feet of the Green Deck, the total annual rental income is HK$815 million. With a 7.33% increase in rental value, the net benefit would be HK$60 million per annum. As a result, the total annual hedonic value due to the Green Deck is HK$411.39 million.

4.4. Intangible Benefits

1. <u>Air Pollution Reduction</u>

To evaluate the air pollution reduction benefit brought by the Green Deck, the abatement cost saved and health cost saving due to the lowered concentration of NO_2, SO_2, and PM_{10} are taken into account. The amount of NO_2 and SO_2 reduced by the Green Deck is adopted from other studies on the air pollutants removal ability of urban green space. As the amount of air pollutants absorbed by plants depends on the meteorological conditions and atmospheric concentration of the air pollutants, places with similar conditions to Hong Kong are chosen as references to minimize inaccuracy.

a) <u>Abatement Cost Saving</u>

The results of Peng and Jim (2015) and Jim and Chen (2008) are used. Peng and Jim (2015) studied the ability of air pollution reduction of intensive green roofs in Hong Kong, while Jim and Chen (2008) looked at how the tree on recreational land uses in Guangzhou reduce air pollution. For NO_2, a range of 12.4kg/ha/yr - 24.29kg/ha/yr reduction was found (average 18.38 kg/ha/yr), while 23.83kg/ha/yr - 31kg/ha/yr reduction was found for SO_2 (average 27.42 kg/ha/yr). By adopting these values and assuming 80% of the Green Deck area is greenery, Green Deck could reduce 63kg and 94kg of NO_2 and SO_2 per year respectively. On the other hand, Lee (2014) conducted a survey on the amount of PM_{10} reduction by Green Deck. According to his study, with the Green Deck, there would be a 38-48% reduction in PM_{10} concentration. As the amount of ambient PM_{10} due to vehicular emission is measured at 0.058 tonnes per day (Hung, 2015), a total of 9,160 kg of PM_{10} could be reduced per year by the Green Deck.

The abatement cost of NO_2, SO_2, and PM_{10} is adopted from the cost of New York City as its urban setting is similar to that of Hong Kong. According to Milward and Sabir (2011), the cost of a tonne of NO_2 is about US$10,100, US$7,660 for each tonne of SO_2, and US$18,280 for each tonne of PM_{10}. As a result, the Green Deck is able to save US$446.13 (HK$2,620.99, adjusted by PPP exchange rate) for NO_2 reduction, US$504.76 (HK$ 2,965.47 adjusted by PPP exchange rate) for SO_2 reduction, and US$167,566 (HK$1,301,046.10, adjusted by PPP exchange rate) for PM_{10} reduction per annum. Thus, the total annual air pollution abatement cost saved would be HK$983,738.2.

(1) 3.004 ha × 0.8 (80% of green) × 18.38 (average) × US$10.1 × 5.875 (PPP exchange rate to HK$) = HK$ 2,620.99 per year for NO_2 reduction.

(2) 3.004 ha × 0.8 (80% of green) × 27.42 (average) × US$7.66 × 5.875 (PPP exchange rate to HK$) = HK$ 2,965.47 per year for SO_2 reduction.

(3) 9,160 kg × US$18.28 × 5.875 (PPP exchange rate to HK$) = HK$ 983,738.2 per year for PM_{10} reduction.

b) Health Cost Saving

The health effect of PM_{10} is commonly used as an indicator of measuring the impact of several sources of air pollutants to avoid overestimation of pollutant-by-pollutant assessment (Sommer et al., 1999). The health cost of air pollution is adopted from a study of air pollution to the health impacts in Hong Kong (EHS, 1998). Although the study was conducted over two decades ago, no similar recent study was carried out. Thus, in light of the lack of up-to-date data, the study result of EHS (1998) is used with inflation adjustment. The total cost of illness of both morbidity (cardiovascular and respiratory diseases) and mortality due to $1\mu g/m^3$ change in PM_{10} was presented as HK$28,360,000. Using this value, the per capita health cost is calculated (HK$28,360,000/6,156,100 people = HK$4.6). The per capita value of HK$4.6 is then adjusted to the 2022 value by using the annual average Consumer Price Index (CSD, 2021a). The adjusted value becomes HK$6.2.

Since Chart-asa and MacDonald Gibson (2015) suggested that the influence area of traffic air pollution is about 500 m. Referring to Fig. 4-2, the PolyU, the commercial area of TST East, and Block One of Royal Peninsula are affected by the CHT traffic emission. However, it is hard to find out the actual population in the commercial area of TST East, so the population density in Hong Kong is used to estimate the number of people in that area. Adding up the total number of full-time staff and students at PolyU (26,873 people, 2020/2021), and the residents at Royal Peninsula Block One (841 people), the total population within 500 m of Green Deck is thus estimated as 29039.

The study conducted by PolyU estimated that PM_{10} concentration will be reduced by 27.4μg/m^3 on average as a result of Green Deck (Lee, 2014). Therefore, the total annual health cost saved in an area within 500 m of the Green Deck is approximately HK$4.54 million.

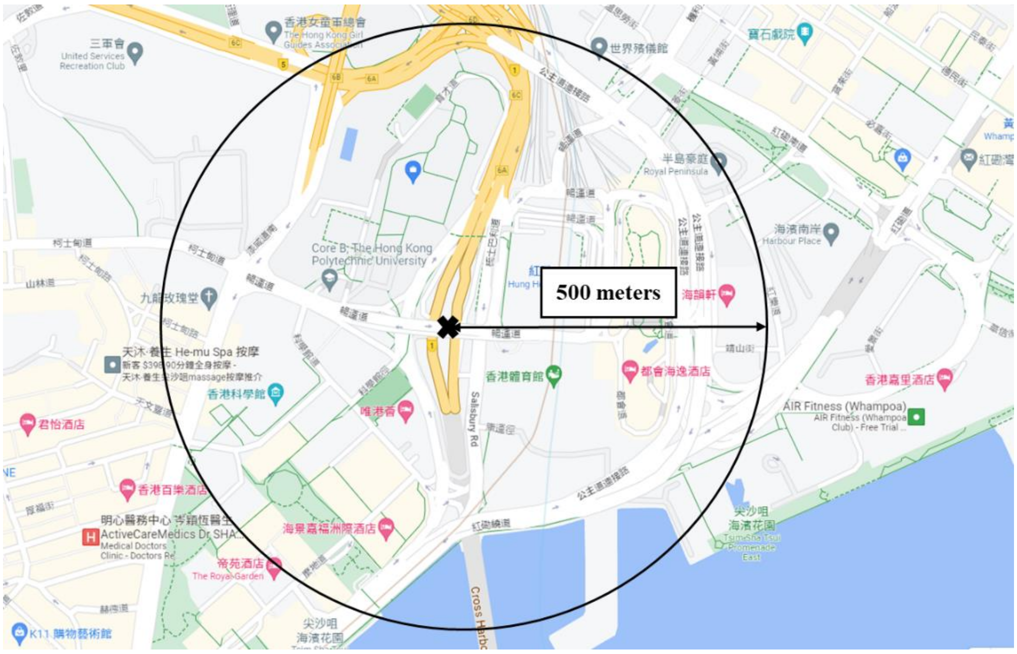


Fig. 4-2 Area affected by traffic air pollution reduction.

2. Carbon Sequestration

Research result from a place with similar tree species and weather condition as Hong Kong is chosen as the reference for Green Deck CO_2 sequestration rate. Peng and Jim (2015) studied the average CO_2 sequestration for urban green space in Shenzhen and found the sequestration rate to be 25.7 tonnes/ha/year. Assumed 80% of the Green Deck is green space (2.4 ha green space), by adopting the CO_2 sequestration rate in Shenzhen, Green Deck is able to absorb 61.7 tonnes of carbon every year. With the social cost of carbon mentioned earlier, around US$2,652.59, which is HK$15,584 (converted by the PPP exchange rate in 2022) of carbon cost can be saved by the Green Deck per year.

3. Surface Runoff Reduction

In Hong Kong, the average annual rainfall is about 2,307.1 mm ("The Year's Weather 2021", 2022), and the rainfall in the Green Deck area is found to be 69,222.2 m^3 per year. According to McPherson (1999), it is assumed that 40% of the annual rainfall will become runoff, therefore the annual amount of surface runoff at the Green Deck would be 27,688.9 m^3 (Table 4-2). To calculate the rainfall retention ability of the Green Deck, studies on green roofs are chosen as references to estimate the percentage of runoff reduced by the plants in general. According to Berardi et al. (2014) and Speak et al. (2013), the runoff reduction ability of green roofs varies from 25% to 65%, with an average of 45%. Assumed Green Deck could reduce runoff by 45%, 12,460 m^3 of rainwater will be absorbed per year.

Table 4-2 Annual rainfall in Hong Kong and annual surface runoff in the Green Deck area

Annual Rainfall in HK (mm)	Area of the GD (m^2)	Annual Rainfall in GD area (m^3)	% of rainfall becomes runoff	Annual runoff in GD area(m^3)
2,307.1	30,004	69,222.2	40%	27,688.9

The monetary value of the runoff reduction ability can be measured by the avoided cost of treating the stormwater (Millward and Sabir, 2011). According to the authors, the stormwater treatment cost is US1.93m^3$ in Canada. By adopting the PPP exchange rate in 2022, the Green Deck is able to save HK$141,281 per year by reducing surface runoff.

4. Noise Pollution Reduction

Tang (2014) conducted research on traffic noise reduction by the Green Deck and concluded that Green Deck can reduce 3dbA of noise at the PolyU campus with mitigation measures. To quantify the benefit of noise reduction, the WTP to reduce road noise per decibel per year per person is found to be on average S$20 in Singapore (Leong, 2019). The total number of full-time staff and students at PolyU is assumed to be the affected population (26,873 people in 2020/2021). By using the WTP S$20, the Green Deck could reduce approximately HK$9.32 million (adjusted by the PPP exchange rate in 2022) annually by decreasing the traffic noise level.

5. Temperature reduction

The benefit of temperature reduction by the Green Deck can be divided into energy saved and greenhouse gas emissions avoided.

a) Energy Saved

The amount of temperature decrease is adopted from Kong et al. (2017), in which they found that the trees in Hong Kong could reduce the mean radiant temperature in the surrounding urban area by 0.1-5.1◦C under different densities and species of trees (2.4◦C in average). The influence area of the temperature reduction is suggested to be one park width (square root of the park area) away from the park according to a study in Taipei (Chang and Li, 2014), so the influence area of the Green Deck will then be

207 m (square-root of 43,000 m^2). Within the 207 m from the park, the affected area/buildings include the Hotel Icon, New East Ocean Center, and about 1/3 of the PolyU campus, and their annual electricity consumption is found to be 315 kWh/m^2 (Hui and Wong, 2010), 487 kWh/m^2 (CSD, 1998; CSD, 2014; Yik et al., 1998), and 29,562 MWh (FMO, PolyU, personal communication, October 9, 2015) respectively.

To know how the temperature drop would affect electricity consumption for buildings in general, Fung et al. (2006) conducted a study in Hong Kong and found that with a 1°C-temperature change, the average electricity consumption will change by 4.5%. Assume Green Deck could reduce in average 2.4˚C in the nearby area, and the percentage of electricity consumption change is the same with 2°C and 2.4°C temperature change, 5,002,554 kWh of electricity can be saved, which costs approximately HK$10.99 million, providing that the electricity price from Hong Kong electric is HK$1.83 per kWh (CLP, 2023).

b) *Emission Avoided*

Since the reduction in electricity consumption of the surrounding buildings is about 5 million kWh per year, approximately 2.85 million kgCO_2 eq (CLP emission factor = 0.55 kgCO_2 eq/kWh) can be avoided annually. As the social cost of carbon is US$43 per tonne, the total annual emission cost saved will be HK$0.84 million (adjusted by the PPP exchange rate in the 2022 average).

6. Health and well-being

According to Kaczynski and Henderson (2007), if there is a park or walking trail nearby, people would increase their exercise frequency, thus improving their health condition. The affected population is assumed to be the people living in the 9 constituencies near the Green Deck - Whampoa East (G16)18287, Whampoa West (G17) 20847, Tsim Sha Tsui East, and King's Park (E16) 14845, Hung Hom Bay (G18) 18224, Ka Wai (G20) 19847, Oi Man (G21) 15326, Hung Hom (G19) 11515, and Oi Chun (G22) 13131, where the total population is 132,022 (CSD, 2021b). To know the number of frequent park users, a study in Hong Kong found that among the interviewees, 40% use the park frequently (more than once a week) (Wong, 2009). For the rest of the 60% (79,213 people), with the presence of the Green Deck, it is assumed that 55% would increase park use and become physically active (Kaczynski and Henderson, 2007).

Louie and Hui (2001) conducted a study in Hong Kong about the medical cost difference between physically active (taking part in any type of sports twice or more a week, with a minimum of 20 minutes each time) and inactive people. The annual medical cost difference found is HK$1,828.94 (adjusted to 2021 HKD by consumer price index – medical service). Therefore, an annual medical cost of HK$79,684,518.54 can be saved with the presence of the Green Deck.

7. <u>Travel time reduction</u>

If the Green Deck is constructed, the footbridge connecting PolyU and the Hung Hom station will be widened, and some of the pedestrians will be diverted to the upper deck as well. The total pedestrian travel time saved during the AM and PM peak hours is found to be 0.075 minutes per person (Hung, 2015; Lam et al., 2000). Assuming half of the PolyU students and full-time staff use the footbridge, the total number of people affected will be 15,953. The time cost is estimated by the median hourly wage in Hong Kong, which is HK$75.7/hour (CSD, 2022). Thus, the annual total travel time cost saved would be about HK$464,071.52.

Table 4-3 summarized the costs and benefits associated with the Green Deck. With the identified direct and indirect costs and benefits, discounting is then carried out to find out the net present value (NPV), benefit-cost (B/C) ratio, and the internal rate of return (IRR) to determine if the Green Deck investment is acceptable. Finally, sensitivity analysis is conducted to identify which parameters or variables are critical in impacting the NPV.

Table 4-3 Summary of the costs and benefits of Green Deck development

Items				Annual Values (million HKD)
Cost	Construction Stage	Tangible	Design and Consultation Cost	25.05
			Construction Cost	626.36
		Intangible	Cost of Temporary Traffic Congestion	755.78
			Construction Carbon Emission	0.27
	Operation stage	Tangible	O&M Cost	10.80
		Intangible	Operation Carbon Emission	0.29
Benefit	Operation stage	Tangible	Revenues (art gallery & sports complex)	9.29
			Visitor expenditures	598.47
			Property value (hedonic)	411.39
		Intangible	Air pollution reduction	5.53
			Carbon sequestration	0.02
			Surface runoff reduction	0.14
			Noise pollution reduction	9.32
			Temperature reduction	11.82
			Health and well-being	79.68
			Travel time reduction	0.28

 # 11 years construction period

Chapter 5. The cost-benefit analysis results

The period of CBA is set at 68 years, including 8 years of design and consultation, 11 years of construction, and 50 years of full operation (Table 5-1). The design and consultation are assumed to start at year zero, which is 2016. The project is expected to be completed in 11 years, with the major part of Stages 1-3 to be completed in year 9. 75% of the Green Deck will be in the trial operation after year 9. The analysis period will last until 2078, and benefits are expected to occur once the Green Deck starts operating in 2028. The discount rate is assumed to be 4% as it is the rate used for the CBA of infrastructure development by the Hong Kong government (Highways Department, 2009).

Table 5-1 Green Deck CBA evaluation parameters

Parameters	Value
Green Deck design and consultation (years)	Year 2016~2022
Green Deck construction period	Year 2023~2033
Green Deck trial operation	Year 2032~2033
Green Deck full operation	Year 2034~2083
Discounting period	Year 2016~2083
Discount rate	4%

5.1. Discounting

Since the costs and benefits occur at different points in time, it is not possible to do a comparison as a dollar at present is worth more than a dollar in the future. Therefore, there is a need for discounting when comparing the flow of money over time (Boardman et al., 2017). In other words, the costs and benefits are converted into present value (PV) by applying a discounting factor. The PV is calculated as follows.

$$PV = \frac{\left(B_t - C_t\right)}{(1+r)^t} \tag{1}$$

Where,

PV = present value;

B_t = cash flow of benefit at period *t*;

C_t = cash flow of cost at period *t*;

r = discount rate;

t = time.

5.2. Net Present Value

The NPV is one of the decision rules to evaluate whether the investment should be accepted. It is the sum of the discounted cash flows over the period of analysis, which is calculated as:

$$NPV = \sum_{t=1}^{T} \frac{(B_t - C_t)}{(1+r)^t} \tag{2}$$

where,

T = time horizon;

t = time;

B = discounted benefit;

C = discounted cost;

r = discount rate.

If the NPV is positive, it simply denotes that the total discounted benefits exceed the total discounted costs, which is a preferred investment option. The NPV of the Green Deck is found to be about 3.33 billion HKD (Fig. 5-1), therefore with this criterion, the Green Deck is deemed as an acceptable investment. The payback year is estimated to be year 42 (i.e., 2058) when NPV changes from negative to positive.

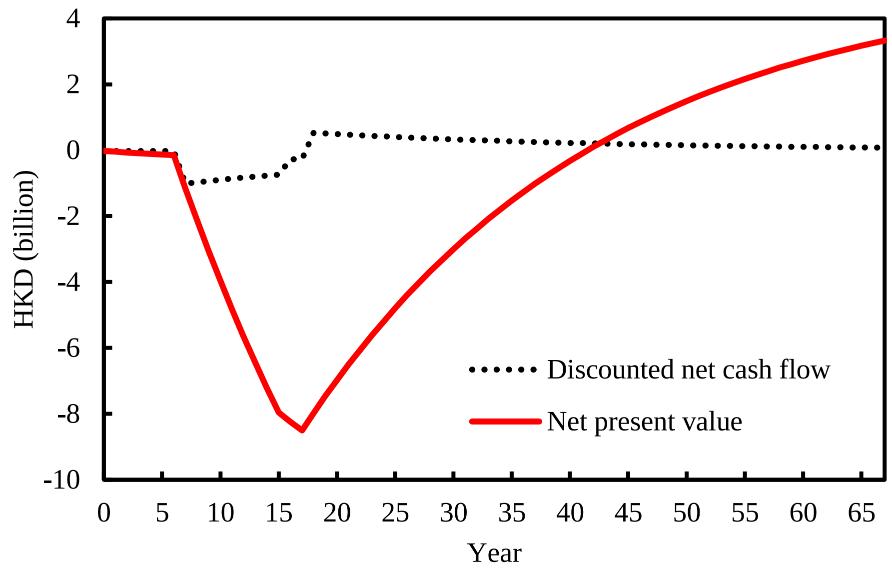


Fig. 5-1 Estimation of the discounted net cash flow and the net present value of Green Deck development

5.3. Benefit-Cost Ratio

The other decision rule that is usually used in CBA is the benefit-cost ratio, which is the ratio of total discounted benefits to total discounted costs. If the B/C ratio is larger than 1, the investment is regarded as acceptable as the total benefits outweigh the total costs. This is calculated as Eq. (3).

$$BCR = \frac{\sum_{t=1}^{T} B_t \Big/ (1+r)^t}{\sum_{t=1}^{T} C_t \Big/ (1+r)^t} \tag{3}$$

Where

T = time horizon; t = time period;

Bt = cash flow of benefit at time t;

Ct = cash flow of cost at time t;

r = discount rate.

The B/C ratio of the Green Deck is 1.35 (Table 5-2), which shows that there are more benefits than costs for the Green Deck development.

Table 5-2 Green Deck benefit-cost ratio

Item	Value (billion HKD)
Total Discounted Benefits	12.80
Total Discounted Costs	9.47
Benefit-Cost Ratio	1.35

5.4. Internal Rate of Return

The IRR is the rate of return of the investment project that makes the NPV equal to zero, which is illustrated in Eq. (4). This also means the maximum interest rate that the investment project can pay for resources used and still manage to break even (CEEU, 2012). If the IRR is larger than the discount rate, it means that the NPV is positive, which indicates that the investment project's total discounted benefits are larger than the total discounted costs.

$$\sum_{t=1}^{T} \frac{(B_t - C_t)}{(1+r_{IRR})^t} = 0 \qquad (4)$$

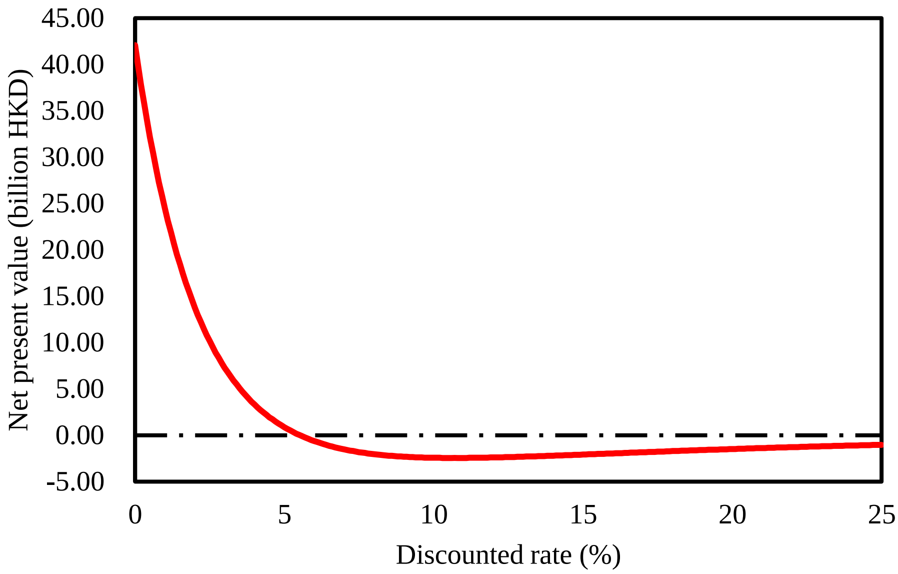


Fig. 5-2 Internal rate of return (IRR) of Green Deck

Referring to Fig. 5-2, the IRR of the Green Deck development project is 5.5%, which is larger than the discount rate (4%). As a result, under this decision rule, the Green Deck would be an acceptable project.

5.5. Sensitivity analysis

Sensitivity analysis is an essential element in the CBA process. It is regarded as a risk assessment with the main purpose of determining the variables that are critical in altering the outcome of the CBA (CEEU, 2012; Boardman et al., 2017). This is usually carried out by adjusting the variables by a certain amount that is significant enough to observe the changes in the NPV or IRR. In this study, three major parameters are selected to test the significance of NPV – ‘The number of estimated annual visitors to Green Deck’, ‘Average food and beverage expense of each visitor’, and ‘Property (hedonic) value increased by the Green Deck project’. These three parameters are adjusted from +20% to -20% with a step of 5% at a time to test which one is the most sensitive to the NPV. The result is shown in Fig. 5-3.

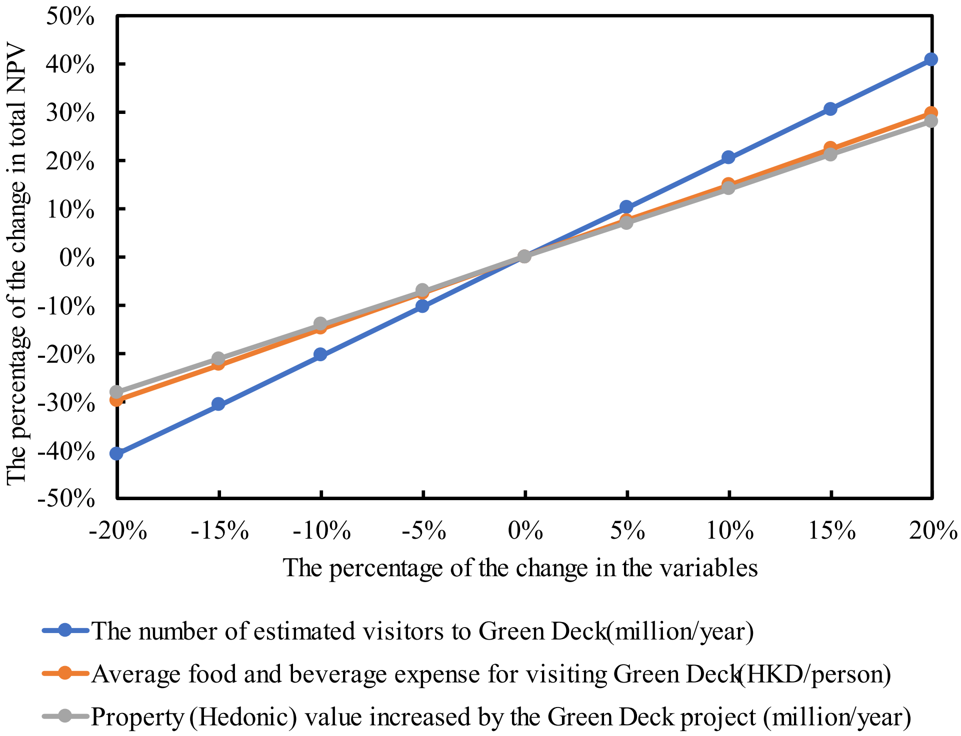


Fig. 5-3 Sensitivity of NVP to changes in different variables.

The parameter of the number of estimated annual visitors to the Green Deck shows the largest slope among the other variables, having a 20% and 40% change in NPV when the number of visitors changes by 10% and 20% respectively. The parameter of average food and beverage expense of each visitor has the second-largest impact. The parameter of property (hedonic) value increased by the Green Deck project is the least critical variable among the three with the flattest sensitivity curve. A ±20% change would only result in a 28% change in NPV.

The changes in the number of estimated annual visitors to the Green Deck are set as two different scenarios. Scenario 1 describes a decrease in the number of visitors by 20%, and Scenario 2 represents an increase in the number of visitors by 20%. Table 5-3 shows that for Scenario 1, the NPV would reach as low as HK$1.97 billion. While for Scenario 2, it would be as high as HK$4.69 billion. The B/C ratio ranges from 1.21 to 1.49, which are all larger than one. The IRR of Scenario 1 is the lowest, which is 4.9%, but it is still greater than the 4% discount rate.

Table 5-3 Value of NPV, B/C ratio, and IRR of the Green Deck with the change in the number of visitors

Indicator	Base Case Scenario	Scenario 1	Scenario 2
Net Present Value (HK$ billion)	3.33	1.97	4.69
Benefit-Cost Ratio	1.35	1.21	1.49
Internal Rate of Return	5.5%	4.9%	6%

Chapter 6. Discussion and conclusion

This study presented the CBA of the Green Deck development proposed by PolyU, which can serve as a reference in the decision-making process. Both tangible and intangible costs and benefits are taken into account to compute the NPV, B/C ratio, and IRR to decide whether the Green Deck project is considered an acceptable and beneficial investment to society.

The base case scenario shows a B/C ratio that is larger than 1, a positive NPV, and an IRR that is bigger than the discount rate (**Error! Reference source not found.**). Based on these decision rules, the Green Deck project is hence considered economically feasible. For other sustainable infrastructure development in Asia, Tong et al. (2021) reported a B/C ratio of 1.01 for developing a waste recycling system in Vietnam. Solar photovoltaic system installation for commercial buildings in India was discovered to have a B/C ratio of 1.11 (Goel and Sharma, 2022). Shen et al. (2019) computed that the B/C ratio of public housing prefabrication in China is 1.81. Comparatively speaking, the B/C ratio of Green Deck development is viable.

Referring to Fig. 5-1, the NPV reaches zero at around the year 2058, which means that the Green Deck development has a payback period of approximately 42 years since 2016. For most green infrastructures, it is not uncommon that the discounted payback period tends to extend to more than 10 years (Valderrama et al., 2013). Ding et al. (2014) suggested that the payback period could be as long as 20-30 years for infrastructure projects in Asia, and Flyvbjerg (2007) even reported a payback period of 55 years for the Copenhagen Metro construction project. Comparatively speaking, the payback period of the Green Deck development is within a reasonable range.

Sensitivity analysis is carried out to test the significance of the variables to the NPV. Three variables were chosen, and the result shows that the number of visitors is the most significant variable that impacts the NPV among the selected variables. Changing the number of visitors from -20% to +20%, the NPV of the Green Deck development would range from HK$1.97 billion to HK$ 4.69 billion. It is not surprising that the number of visitors has the greatest influence on the NPV as visitor expenditure shares the highest proportion among all the benefits in terms of present value (Fig. 5-3). As seen in the table, the largest benefit is from visitor spending, consisting of 53%. Marketing strategies (e.g., collaborations with surrounding art and cultural institutions) are advised to target attract more visitors to increase the net present value.

In conclusion, this study gives a preliminary and brief estimate of the costs and benefits of the Green Deck development. It is noted that due to the lack of information, there are a number of limitations including a general estimation by solely considering the average wage rate as the time cost of the road users, and a brief estimation of the number of passengers on each vehicle for calculating the cost of temporary congestion during the Green Deck construction. Also, although the Hong Kong Government suggested using a 4% discount rate for infrastructure projects, there is no consensus on the choice of discount rate yet (ranging from 3-8% in different countries). Despite the limitations, this ex-ante CBA could provide a reference on whether the Green Deck development is economically feasible and at the same time serve as a tool in the decision-making process.

Appendix. User guide for the Excel tool

A.1. Introduction

A separate Excel tool is provided as one of the deliverables to reproduce the cost and benefit analysis result of this report. This tool supports users to revise the input values of the parameters to update the result. By adopting this tool, users are expected to obtain:

1. Tangible and intangible costs and benefits of the Green Deck development.

2. Financial metrics of Green Deck development (e.g., total net present value, benefit and cost ratio, payback year, and internal rate of return).

This appendix aims to help users grasp this tool by providing a quick starting guide and several examples.

A.2. Getting started

1. The Excel tool contains three sheets: input_variables, computational_process, and result.

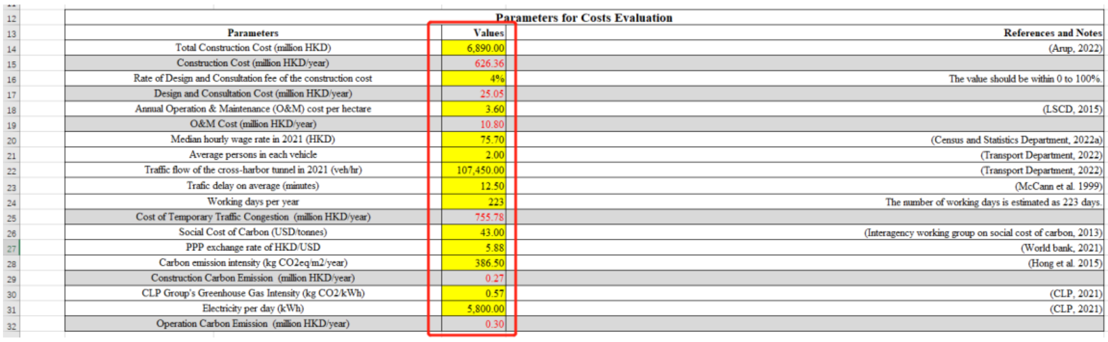
    - Input_variables: input variables for conducting cost and benefit analysis
    - Computational_process: discounting process that users may not need to interact with when using this tool
    - Result: output of the cost and benefit analysis

2. To view the cost and benefit analysis result, click the result sheet. The outputs include:

    - Itemized annual costs and benefits
    - Benefit and cost ratio
    - Payback year
    - Total net present value
    - Internal rate of return
    - Sensitivity analysis result

Results will update automatically with the change in the values of the input variables.

3. To update the result, click the Input_variables sheet and revise the values of the parameters in a **yellow shade**. The parameters in red with grey shade and figures will be updated automatically.



Parameters for Costs Evaluation		
Parameters	Values	References and Notes
Total Construction Cost (million HKD)	6,890.00	(Arup, 2022)
Construction Cost (million HKD/year)	626.36	
Rate of Design and Consultation fee of the construction cost	4%	The value should be within 0 to 100%.
Design and Consultation Cost (million HKD/year)	25.05	
Annual Operation & Maintenance (O&M) cost per hectare	3.60	(LSCD, 2015)
O&M Cost (million HKD/year)	10.80	
Median hourly wage rate in 2021 (HKD)	75.70	(Census and Statistics Department, 2022a)
Average persons in each vehicle	2.00	(Transport Department, 2022)
Traffic flow of the cross-harbor tunnel in 2021 (veh/hr)	107,450.00	(Transport Department, 2022)
Trafic delay on average (minutes)	12.50	(McCann et al. 1999)
Working days per year	223	The number of working days is estimated as 223 days.
Cost of Temporary Traffic Congestion (million HKD/year)	755.78	
Social Cost of Carbon (USD/tonnes)	43.00	(Interagency working group on social cost of carbon, 2013)
PPP exchange rate of HKD/USD	5.88	(World bank, 2021)
Carbon emission intensity (kg CO2eq/m2/year)	386.50	(Hong et al. 2015)
Construction Carbon Emission (million HKD/year)	0.27	
CLP Group's Greenhouse Gas Intensity (kg CO2/kWh)	0.57	(CLP, 2021)
Electricity per day (kWh)	5,800.00	(CLP, 2021)
Operation Carbon Emission (million HKD/year)	0.30	

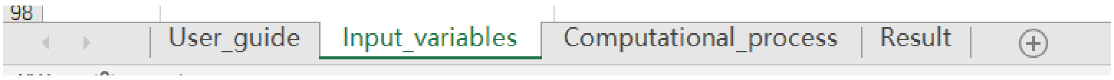
4. To revise the sensitivity analysis result, click the Input_variables sheet and find the "variables for sensitivity analysis". Change the variables through the drop-down lists.

A.3. Examples

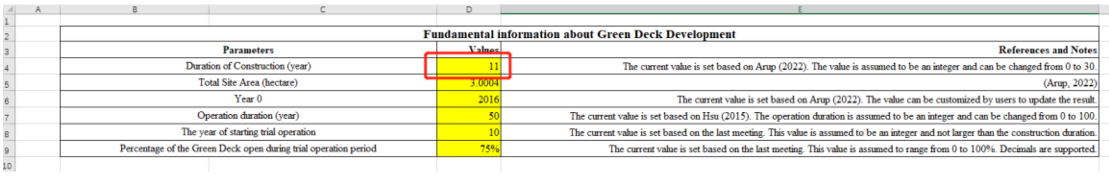
A3.1. Revise the duration of the construction period

This example shows the detailed steps to revise the duration of the construction period and then to view the change in the cost and benefit analysis result.

Step 1: Go to sheet “Input_variables”.



Step 2: Find the parameter of “Duration of Construction (year)”. Type in an integer from 0 to 30. The maximum construction year supported in this tool is assumed to be 30 years.



Fundamental information about Green Deck Development		
Parameters	Values	References and Notes
Duration of Construction (year)	11	The current value is set based on Arup (2022). The value is assumed to be an integer and can be changed from 0 to 30.
Total Site Area (hectare)	3.0004	(Arup, 2022)
Year 0	2016	The current value is set based on Arup (2022). The value can be customized by users to update the result.
Operation duration (year)	50	The current value is set based on Hsu (2015). The operation duration is assumed to be an integer and can be changed from 0 to 100.
The year of starting trial operation	10	The current value is set based on the last meeting. This value is assumed to be an integer and not larger than the construction duration.
Percentage of the Green Deck open during trial operation period	75%	The current value is set based on the last meeting. This value is assumed to range from 0 to 100%. Decimals are supported.

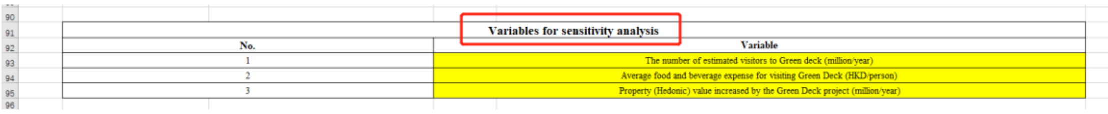
Step 3: Go to sheet “Result” to view the change in the tables showing Benefit-Cost Ratio, payback year, total net present value, Internal Return Rate, etc. The figures will also update automatically.

A3.2. Change the parameters for sensitivity analysis

This example shows the detailed steps to change the parameters for sensitivity analysis.

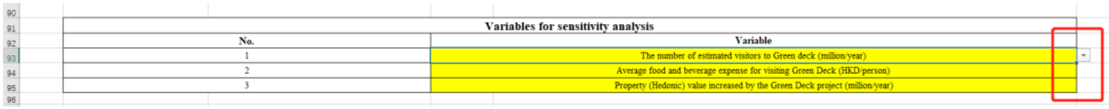
Step 1: Go to sheet “Input_variables”.

Step 2: Scroll down and find the section “Variables for sensitivity analysis”.



Variables for sensitivity analysis	
No.	Variable
1	The number of estimated visitors to Green deck (million/year)
2	Average food and beverage expense for visiting Green Deck (HKD/person)
3	Property (Hedonic) value increased by the Green Deck project (million/year)

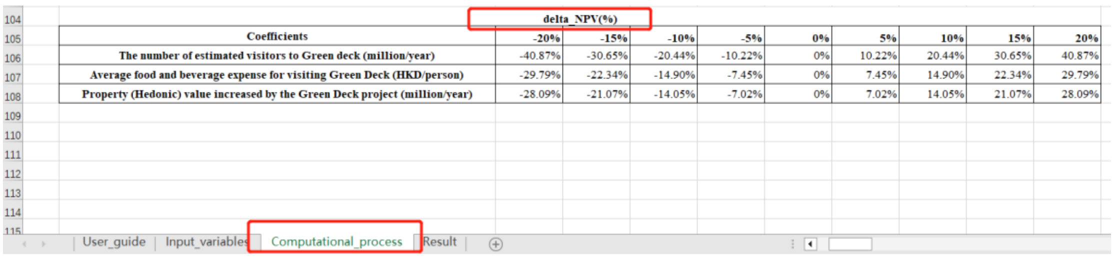
Step 3: Use the drop-down menu to select the parameters for sensitivity analysis.



Variables for sensitivity analysis	
No.	Variable
1	The number of estimated visitors to Green deck (million/year)
2	Average food and beverage expense for visiting Green Deck (HKD/person)
3	Property (Hedonic) value increased by the Green Deck project (million/year)

Step 4: Go to sheet “Result” to view the change in the total net present value in Fig. 3. The figure updates automatically based on the parameters selected by users.

Step 5: To view the concrete values of the change in the total net present value, please go to sheet “Computational_process”. Find the section on “sensitivity analysis” and scroll down to the last table. The values represent the change in the total net present value with the variations of the selected parameters.



	delta_NPV(%)								
Coefficients	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
The number of estimated visitors to Green deck (million/year)	-40.87%	-30.65%	-20.44%	-10.22%	0%	10.22%	20.44%	30.65%	40.87%
Average food and beverage expense for visiting Green Deck (HKD/person)	-29.79%	-22.34%	-14.90%	-7.45%	0%	7.45%	14.90%	22.34%	29.79%
Property (Hedonic) value increased by the Green Deck project (million/year)	-28.09%	-21.07%	-14.05%	-7.02%	0%	7.02%	14.05%	21.07%	28.09%

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