Appendix M

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Costs and Benefits Analysis on the Thermal Effect on the Green Deck to the Surrounding Outdoor Environment

(Final Report)

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January 2016

Project title: ***'Costs and Benefits Analysis on the Thermal Effect on the Green Deck to the Surrounding Outdoor Environment'***

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Executive Summary

Objectives

The objectives of this project include:

1. To calculate how many surrounding areas and population are impacted by the ambient temperature change of the Green Deck;
2. To establish a theoretical framework to evaluate the costs and benefits effect of "change of surface temperature" as caused by Green Deck;
3. To identify the tangible and intangible parts of the costs and benefits added to the stakeholders by the "change of surface temperature".

Significance of the project

1. By revealing the monetary value of cost and benefits of "thermal change effect" of Green Deck, the cost-benefit analysis will be more persuasive, all-rounded, and able to ensure this project will improve various groups of stakeholder in Hong Kong society;
2. The analysis will indicate that whether the investment into thermal consideration will socially bring about positive net benefit; and
3. This research will develop a potentially widely-used model for open space construction to monetarily evaluate a project's thermal effect.

Methodology

Generally, cost-benefit analysis is the principal methodology of the present research. Targeting to different sorts of good, different sub-methods of cost-benefit analysis have their own advantages. Based on the objects of the present research, the two basic types of good are tangible goods, which have market price, and intangible goods, which do not have market price. The list of tangible and intangible costs and benefits will be formed through literature review. Then the list will be validated by experts and polished. At last, based on the formula of 'Net Balance=Total Benefit-Total Cost', a cash flow chart will be formed. All the acquired price of future cost and benefit will be discounted into the present value and put into the appropriate part of the form. The net balance will be calculated at last. Furthermore, based on the uncertainty of the future, some other scenario will be tested by sensitive test to provide some other potential possibilities and risk suggestions.

Progress

Recently, a primary framework of cost and benefit from Green Deck's thermal effect

has been formed. The fundamental nine categories of the cost and benefit are listed out. The list is and will be validated by the experts from different relative areas. Meanwhile, the literature review for the tangible goods in Hong Kong context is being conducted. The literature review of revealed preference method is also being conducted. The items whose price cannot be acquired from literature review will be further explored using interview and street survey of stated preference method.

Report dated: 5 Oct 2015

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By Prof. Edwin H.W. Chan

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Executive Summary

Climate change, a trend of local temperatures getting increasingly higher every year, has become a significant challenge for Hong Kong. It can bring a list of harmful impacts to society as a whole and individuals. For instance, Hong Kong should deal with issues of extreme weather events, flooding, decreasing water availability, heat waves, health impacts and threatened ecosystem services brought by high temperatures (Welford et al., 2008).

Besides climate change, the urban heat island effect is a major local factor that greatly influences Hong Kong's temperatures. As a characteristic of cities, the urban heat island effect can increase the temperatures in urban areas normally by 1-3℃, sometimes as much as 12℃ (United States Environmental Protection Agency, 2015). The urban heat island effect also brings about a series of problems, such as health impacts, higher energy consumption and air quality deterioration due to the city getting hotter (Green Power, 2012).

Greenery planting is a mitigation measure to solve the problems caused by high temperatures (Green Power, 2012). Due to a larger greenery coverage than the normal urban area, there exists a *park cool island*, both inside and surrounding an urban park. Such *park cool island*s can reduce the urban heat island effect (Declet-Barreto et al., 2013), lower air temperatures in their surrounding communities and, hence, improve their residents' well-being.

One such area lacking in greenery lies between Hung Hom Station, Polytechnic University and the Cross -Harbour Tunnel entrance. This has become an urban heat island (Arrau & Peña, 2015). To tackle this problem in this location, plans are already prepared to build a multifunctional podium called the Green Deck. Featuring a high

vegetation coverage, one of the functions of the Green Deck is to reduce the temperature of its surrounding communities in such urban heat island area.

This research study aims to economically evaluate the thermal effect of temperature reduction of the Green Deck using cost-benefit analysis. The aim is divided into the following three tasks: (1) describing the size and population of *influenced* surroundings; (2) economically evaluating the net present benefit of the project over a period of 50 years; and (3) discussing the tangible and intangible benefits of different stakeholders from the project.

There are two reasons that make cost-benefit analysis a suitable method for this research. Firstly, cost-benefit analysis is prevalently used to assess environmental impacts of a policy or a construction project by the governments in different regions (Hanley & Spash, 1993), because of its capability to assess impacts of a policy on different groups of stakeholders over a certain length of period. Secondly, it also has a capability to monetarise both tangible and intangible impacts, which help in judging whether a project is desirable for the whole society.

In this research, a geographic information system is used to identify and describe the influenced surrounding area of the thermal effect of the Green Deck. The associated datasets are also used in the following cost-benefit analyses. During each cost-benefit analysis, the structure given by Hanley and Spash (1993) is used. The relationships between temperature and each benefits and the price of each cost or benefit were collected from previous publications.

Three scenarios were taken into consideration that involve the concept of Park Cool Island (PCI). The first one (Scenario 1: Ideal PCI excluding extended deck) took into account the Green Deck only, which has a size of 43,000m^2; the other two (Scenario 2: Ideal PCI included an extended deck; and Scenario 3: Localised PCI) both accounted for the Green Deck and a potentially added greenery area called the Extended Deck, which have a combined total size of 103,000m^2. The theory about calculating the size of a *park cool island* (Jauregui, 1990) was used in the first two scenarios. In these two scenarios, a 1℃'s decrease was assumed to happen within the theoretical *park cool island* outside the Green Deck. For the size of *park cool island* in Scenario 3, our linked research from Chau et al (2015) studying the local situation was used. Their research revealed that the *park cool island* (PCI) of the Green Deck would extend 150m beyond its boundary with an effect to decrease the temperatures by an average of 2℃.

In the above three scenarios, the descriptions of size and population of the *influenced* surroundings are shown as below:

(1) Scenario 1 (Ideal PCI excluding extended deck): 426,568m^2 with 8,122 people;

(2) Scenario 2 (Ideal PCI including extended deck): 871,952m^2 with 23,118 people;

(3) Scenario 3 (Localised PCI): 450,033m^2 with 7,563 people.

In this cost-benefit analysis, the costs are divided into capital cost and recurrent cost of maintaining the vegetation in the Green Deck; four kinds of benefits, which are health benefits, saved energy consumption, increased productivity and increased recreational value, are identified. According to the result of cost-benefit analysis, the benefits of thermal effect from the Green Deck is projected to pay back the investment in greenery of the Green Deck in the first year after completion of construction, and thereafter to maintain a positive net present value of benefit. The annual gross benefit of thermal effect in present value is: HK$248,284,314 in Scenario 1; HK$579,886,405 in Scenario 2; and HK$429,771,502 in Scenario 3. Using a discount rate of 4% recommended by Hong Kong Government, the net benefit in present value over 50 years after the Green Deck being in use is: HK$5,278,209,784 in Scenario 1; HK$12,324,333,607 in Scenario 2; and HK$9,099,537,545 in Scenario 3.

The capital costs and recurrent costs of vegetation in Green Deck are both regarded as the tangible costs of the thermal effect of Green Deck. The main investor of these costs is the Hong Kong Government. For the benefits, the hospitalisation fee of the reduced morbidity and the saved energy consumption are regarded as tangible benefits; meanwhile, the reduced mortality, the restricted active day of the reduced morbidity, the increased productivity and the increased recreational value are regarded as intangible benefits. The stakeholders of these benefits include the Hong Kong Government, the surrounding residents, the industry and commerce in Hong Kong (both companies in the surrounding community and all over Hong Kong) and the surrounding property owners.

1. Introduction

1.1 Background

Large-scale urban regeneration achieves environmental sustainability by adding one Green Deck in the Hung Hom area (Figure 1.1). The Green Deck podium will form a new landscape between Hung Hom station (in green), Polytechnic University (in yellow) and Cross- Harbour Tunnel entrance (in orange). This Green Deck will create an open space in the centre of Hung Hom with recreation areas, waterfront and greenery. It not only encourages the public access to open space but also significantly improves ecological condition, one of which is a reduction in air temperatures in surrounding areas. Green areas produce social, economic and environmental benefits in highly populated urban areas.

Figure 1.1 Proposed Green Deck

Cities all over the world have been warming up in the summer over the recent years. Urban thermal stress is an urban environmental problem that has been attracting public attention in Hong Kong. Under such circumstances, those urban developments that consider the urban thermal environment have become of interest. The existing site of the proposed Green Deck is an example of how Hong Kong conditions are exacerbated by urban heat in summer. As part of the Green Deck initiatives, a series of research projects has been established and those closely related to this proposal are considering the surface temperature and heat mitigation to the surrounding area when promoting this new Green Deck (Figure 1.2).

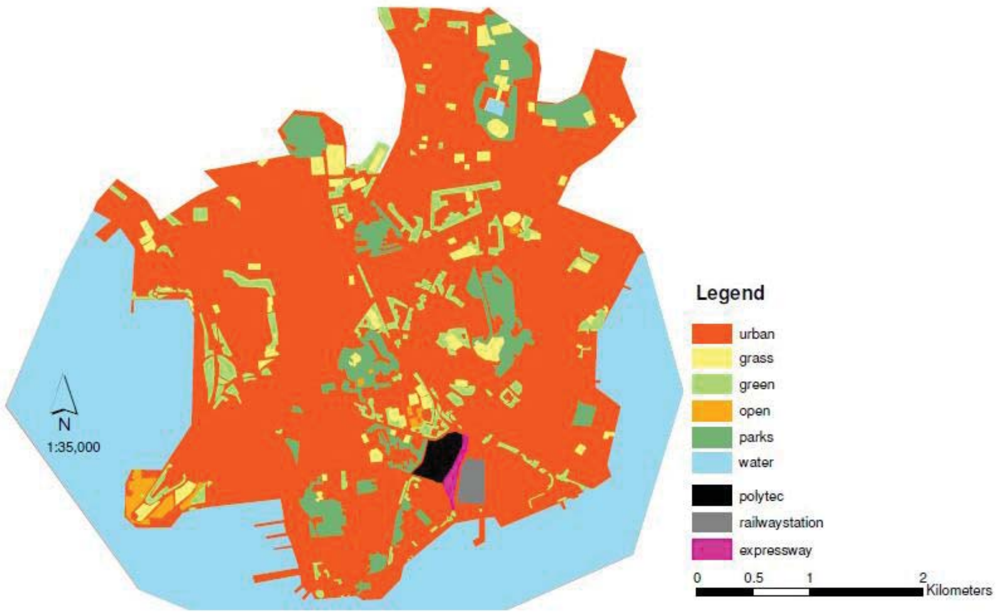


Figure 1.2 Thermal Effect of the Existing Area in Relation to Land Use before Green Deck

1.2 Scope of Study

This study is to investigate the effect of temperature changes to stakeholders at neighbourhood-scale brought about by the proposed Green Deck project, in Hung Hom, Hong Kong. Based on the findings of temperature change identified by the linked project: '*Investigating the Effects of Greenery on Temperature and Thermal Comfort in Urban Parks*', this proposed study aims to conduct cost and benefit analyses on the thermal effect of the Green Deck to the surrounding outdoor environment. With the identified temperature difference, we will address the research question of:

What are the costs and benefits, both tangible and intangible, added to the stakeholders, particularly the citizens by the 'change of surface temperature' effected by the Green Deck?

1.3 Objectives

- To calculate how many surrounding areas and population are impacted by the ambient temperature change of the Green Deck;

- To establish a theoretical framework to evaluate the costs and benefits effect of 'change of surface temperature' as caused by the Green Deck.

- To identify the tangible and intangible parts of the costs and benefits added to the stakeholders by the 'change of surface temperature'.

1.4 Methodology

Cost Benefit Analysis (CBA) has been used as a tool for policy and project analysis throughout the world (Treasury Board of Canada Secretariat, 1998; Tse et al., 2004,; Xu et al., 2011, Yung & Chan). With accurate temperature differences identified, this study applies the cost benefit analysis (CBA) to evaluate the effect of the changes due to the Green Deck. It establishes a theoretical framework to evaluate the effect of ambient temperature changes by including both the tangible and intangible parts of the costs and benefits in the formulas. It attempts to evaluate effects on users, effects on non-users, external effects, and option value/social benefits. The areas of costs and benefits to be covered by this study include:

Tangible Costs and Benefits

(1) The tangible savings in cooling energy consumptions of the surrounding buildings due to the Green Deck:

The potential energy savings due to lowering the mean ambient temperature of the Green Deck will be estimated. The effect of the Green Deck on the temperature variations to the surroundings will be based upon the findings the other linked research. The empirical models developed by Fung et al. (2006) together with the physical characteristics of the buildings surrounding Green Deck will be used for estimating the potential savings in energy consumptions in both domestic and commercial buildings due to the urban temperature variations.

Intangible Costs and Benefits

(2) The health bill savings from the lower mean ambient temperature due to the heat island effect relief and thermal stress reduction. The published findings of healthy bill

data and health effect of temperature will be correlated to the technical data of temperature change.

The above will be triangulated with data collected by interviews with the stakeholders and questionnaire survey with the affected population.

Although this study focuses on the benefits of the Green Deck project, the costs side will be estimated to provide a balanced picture. The land and capital costs related to the temperature improvement will be obtained from the Architect/QS consultants of the Green Deck project. Where the costs are not directly attributed to the three areas of improvement, an estimation based on an appropriate portion of the overall cost of the Green Deck will be provided.

2. Impacted Surrounding

A *park cool island* is projected to exist around the Green Deck. It can reduce the temperature of its surrounding area and bring some related benefits to the surrounding communities of the Green Deck. The prerequisite of assessing the impacts of such *park cool island* is to determine size of the *park cool island* of the Green Deck and the population within it.

In the following part, firstly, a literature review helped us find the theory about calculating the size of the *park cool island* of the Green Deck. Then, using ArcGIS software, the size of the *park cool island* and the population within it will be estimated. The figures collected in this section will be further used for estimating the benefit from thermal effect of Green Deck.

Previous studies have proved the thermal effect of an urban park to reduce ambient temperature can reach beyond the boundary of the park (Chang & Li, 2014). Table 2.1 gives a summary of some previous research. It is widely acknowledged that the distance that a *park cool island* can expand beyond an urban large park is one-park-width (Jauregui, 1990; Shashua-Bar & Hoffman, 2000; Cao et al., 2010). Thus, the area within the 1 park-width buffer zone outside the Green Deck can be regarded as a theoretical *influenced* surrounding area. In reality most parks have an irregular shape, Chang & Li (2014) provided a method to estimate the width of a real urban park by taking the square root of the area of the park. Thus, in this research the square root of the size of the Green Deck is the length of 1 park-width.

For the intensity of the part of a *park cool island* outside a park, according to Yu & Hien (2006), the maximum decrease of temperature in the ambient area of a city park ranges from 1.3-1.5℃. Thus, a maximum 1.4℃ decrease is assumed in this research. Also referring to Yu & Hien's (2006) study, the change of temperature in the ambient area of a city park is relatively a linear one. Thus, an average 0.7℃ decrease is assumed happen in the *park cool island* outside the Green Deck. Due to the limitation of our referred models, the 0.7℃ is rounded off to 1℃ in this study.

Table 2.1 Summary of Size of Urban *Park Cool Island* from Previous Studies

Author	Location	Sample Size	Size of Park	Distance from Boundary	Decrease of Temperature
Jauregui, 1990	Mexico City	1	500 ha	2 km (one-park-width)	2-3 ℃ inner the park
Givoni, 1972	Israel	1	0.5 ha	20-150 m	-
Shashua-Bar & Hoffman, 2000	Tel-Aviv	11	$2700m^2$-$11025m^2$	Small green site: 2-4 park-width; Large green site: 1 park-width	About 1.25℃ on average
Spronken-Smith & Oke, 1998	Vancouver & Sacramento	20	2-53 ha	No more than 1 park-width	1-7 ℃ inner the park
Ca et al., 1998	Tokyo	1	1.2km×1.2km	600m on average	2 ℃ inside the park; maximum 1.5℃ outside the park

According to the theory, the first two scenarios studied in this research are described as below.

(1) According to PolyU's (2015) website, Green Deck will have a size of $43{,}000m^2$. Thus, the *park cool island* beyond Green Deck's boundary is shown in Figure 2.1.

By using ArcGIS, descriptive information about this area was acquired as shown below:

- Area: $426{,}568m^2$
- Population: 8,122

Figure 2.1 Ideal Park Cool Island when Accounting for Green Deck Only

(2) There is also a potential added green area, which is called Extended Deck (DLN, 2014), as shown in Figure 2.2 within the yellow line. Connected to the Green Deck, it will possibly expand the park area of the Green Deck. After adding the Extended Deck, the total park area will reach 103,000m^2. The $park\ cool\ island$ in Scenario 2 is shown in Figure 2.3.

According to the data from ArcGIS, the related information of the area is displayed as following:

- Area: 871,954m^2

- Population: 23,118

Figure 2.2 The Potential Plan of Green Spaces in the Studied Area

Figure 2.3 Ideal Park Cool Island when Accounting for both Green Deck and Extended Deck

However, many other factors also influence *park cool islands*, such as park shape, forest structure, tree shade and water pond (Cao et al., 2010; Ren et al., 2013). These factors may alter largely across different regions, especially under different design guidelines and practices. Thus, the local typical examples should be examined. From our linked project, Chau et al. (2015) provided an estimation from his empirical study of the parks in Hong Kong. The *park cool island* would extend to a 150m buffer area outside the Green Deck. This *park cool island* will cause a 2℃s' decrease in the neighbouring communities of the Green Deck. According to their description, the *park cool island* of the Green Deck is shown in Figure 2.4.

Figure 2.4 Predicted Park Cool Island according to Localised Situation

Data about the area and population of this *park cool island* are shown as below.

- Area: 450,033m^2
- Population: 7,563

The area where the frequent users of the Green Deck are located was also projected in this research. According to Wong's (2009) study, in Hong Kong 59% of frequent users of parks prefer the parks within a distance of 15-minute walk. A circle with a radius of 800 metres, whose centre located at the centre of the Green Deck, is formed. Under Hong Kong traffic condition, it is assumed that people living in this area can reach the Green Deck within 15 minutes. The area is shown as Figure 2.5.

Figure 2.5 Residential Area Assumed within 15-Minute Walk from Green Deck

The descriptive information of the above area acquired from ArcGIS is displayed as following:

- Area: 172,611m^2
- Population: 64,503

Overall, the area of *influenced* surroundings and its population are summarised into Table 2.2.

Table 2.2 Size and Population of Influenced Surroundings

Description	S1. Ideal PCI excluding Extended Deck	S2. Ideal PCI including Extended Deck	S3. Localised PCI	Area where Frequent Users Living
Area	426,568m^2	871,954m^2	450,033m^2	172,611m^2
Population	8,122	23,118	7,563	64,503

3. Cost-Benefit Analysis (CBA)

3.1 Introduction to Cost-Benefit Analysis

While many social policies and projects are worth pursuing, limited availability of resources is pressuring governments to compare projects and prioritize some over others. Cost-benefit analysis is a tool to assess the desirability of projects through monetary values, to make sure the resources used are consumed rationally. The crucial element of CBA, that is, monetization, enables objective and transparent comparison. The fact that every cost and benefit is analysed in detail and explicitly converted into a monetary value, ensures high transparency of the decision process, and helps minimize occurrence of judgmental biases in analysing teams.

Cost-benefit analysis has advantages of taking a long-term view (in the sense of looking at repercussions in the further, as well as the nearer, future) and a wide view (in the sense of allowing for side-effects of many kinds on many persons, industries, regions, etc.) (Prest & Turvey, 1965). Unlike common forms of financial analysis, which focus on cash flows that are expected to be incurred throughout the project's lifetime, cost-benefit analysis assesses projects' impact on the society as a whole, emphasizing externalities rather than operational aspects. This method enhances evaluation of project consequences that affect the whole economy and thus impact large and diverse groups of population.

The above advantages make cost-benefit analysis highly effective for assessment of large-scale projects that affect lives of people through several generations. It is also applicable to a large array of public investment and policies. For instance, Prest & Turvey (1965) demonstrate how cost-benefit analysis is used for evaluating projects in health, transportation, water supply, education, and other areas of focus for public investment and policymaking. For instance, cost-benefit analysis has been adopted as a main tool of social project evaluation by many governments, including USA, Canada, UK and Australia (United States of America, 1982; Treasury Board of Canada Secretariat, 2007; Australian Government Department of Finance, 2006; Prime Minister's Strategy Unit, 2004). For example, a dam in Canada was closed after CBA had demonstrated that future environmental costs exceeded the social benefits (Oldman River Dam Environmental Assessment Panel, 1992). More recently, the UK Government used CBA to analyse investment in different types of childcare (Prime Minister's Strategy Unit, 2004).

Several concepts of cost-benefit analysis will be helpful in understand how it will help in a decision making of a public policy or project. They are cost, benefit, discount rate, net present value, internal rate of return and benefit-cost ratio. These are outlined below.

Cost and Benefit

In cost-benefit analysis, benefits are defined as increases in human wellbeing (utility); meanwhile, costs are defined as human wellbeing one must give up to conduct a project. Thus, if a project or a policy is to qualify on cost-benefit grounds, its social benefits must exceed its social costs (Pearce et al., 2006).

Discount Rate

The Discount Rate is another factor that has a significant impact on the result of a cost-benefit analysis and, further influence on decision making. One principle of cost-benefit analysis is that all costs and benefits should be discounted by a time weight because a unit of money that can be used today is valued more than the same amount that can be used in the future (Brent, 2006). The Social Discount Rate is an index reflecting such difference between the present value of a certain amount of money and the future value of it. In this research, r is used in the formulae to represent the social discount rate.

Only with a proper discount rate, can an accurate net present benefit, net present cost and net present value can be calculated by the formulae below.

$NPB = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t}$ and $NPC = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$ (Mishan, 1973).

$\mathrm{NPV} = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$ (Layard & Glaister, 1994).

The discount rate can be described as society's rate of time preference (Mishan, 1973). With a discount rate value of r, the money values of v in the present will be of value $\frac{v}{(1+r)}$ in the next year (Layard & Glaister, 1994).

Net Present Value, Internal Rate of Return and Benefit-Cost Ratio

Hanley & Spash (1993) mentioned three kinds of outputs from a cost-benefit analysis that will indicate the desirability of a project. These three outcomes are net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (BCR).

Net present value (NPV) is defined as the difference between the present value of the benefits and the present value of the costs (Investopedia, 2016a). It is calculated using the formula (Hanley & Spash, 1993) below.

$$\text{NPV} = \sum B_l(1+i)^{-l} - \sum C_l(1+i)^{-l}.$$

Letter l stands for the period accounted in a cost-benefit analysis; and letter i stands for the discount rate used in the research. When NPV>0, the project is desirable; and when NPV≤0, the project is not desirable.

The internal rate of return (IRR) is the discount rate that can make the NPV of a project equal to 0 (Investopedia, 2016b). The IRR can be calculated by using the function of some data analysing software, such as Excel. When IRR>discount rate, the investment of the project will be paid back and the project is desirable; and when IRR≤discount rate, the project is not desirable.

Benefit-cost ratio (BCR) is the ratio of dividing the discounted benefits by the discounted cost (Hanley & Spash, 1993). According to this definition, BCR is calculated using the formula below.

$$\text{BCR} = \frac{Discounted\ Benefit}{Discounted\ Cost}.$$

When BCR>1, the project is desirable; and when BCR≤1, the project is not desirable.

According to previous studies, there are some guidelines indicating the steps to take to enhance a cost-benefit analysis. Boardman et al. (2006), in their work, indicated that cost-benefit analysis is generally conducted through the following steps.

1. List stakeholders (whose benefits and costs count)

2. List alternative projects

3. List potential impacts (costs and benefits) and select measurement indicators

4. Predict quantitative impacts over a relevant time period

5. Monetize all impacts (convert all costs and benefits into a common currency)

6. Discount for time to find present values

7. Perform sensitivity analysis

8. Recommend an option with the highest value of net social benefits

However, the structure from Hanley & Spash (1993) is more frequently and easily used to evaluate impacts of environmental projects and policies. The detailed steps are displayed as following.

1. Definition of project;

2. Identification of project impacts;

3. Identification of impacts which are economically relevant;

4. Physical quantification of relevant impacts;

5. Monetary valuation of relevant effects.

3.2 Cost-Benefit Analysis Approach used in This Study

In this research, Hanley and Spash's (1993) structure of cost-benefit analysis was used. Each step in this project is briefly described as following.

Step 1. Definition of project

The main objective of this research concerns the thermal effect of the Green Deck. The thermal effect refers to the temperature reduction due to the Green Deck. It is mainly attributed to the existence of vegetation in the Green Deck. Thus, the project in this research is defined as the planting work and the maintenance of vegetation in the Green Deck.

Step 2. Identification of project impacts & Step 3. Identification of impacts which are economically relevant

The direct impact of the above project is a reduction of the temperature within the *park cool island* of the Green Deck. However, this impact can be monetized only if the indirect impacts of such thermal effect are identified. In this research, four indirect impacts, which is also the benefits, are identified, namely health benefit, saved energy consumption, increased productivity and increased recreational value.

Step 4. Physical quantification of relevant impacts

To physically quantify each impact, the relationship between change of temperature and each impact is acquired from previous studies, especially the model in the Hong Kong's situation. Such relationships are converted into numerical formulae to monetise each benefit. The data used in the formulae was acquired from local official or professional publications.

Step 5. Monetary valuation of relevant effects

The monetary value of each impact was acquired by multiplying the physical qualified impact with the price of each item. For the tangible benefits, such price can be directly cited from market. Meanwhile, for intangible benefits, the price should be acquired using either a revealed preference method or stated preference method. Thus, for these impacts without market prices, either the prices from the previous studies were cited or the methods used in the previous studies were adapted to calculate the prices. The previous studies referred to here mean the official or professional publications in Hong Kong.

4. Cost and Benefit Analysis of Thermal Effect from Green Deck

4.1 Costs at Construction Stage and Operation Stage

Compared with most other studies and conventional description of cost-benefit analysis (Prest & Turvey, 1965), this research focuses on a certain function from the project instead of concentrating on all benefits from a whole project. Thus, in this research, the marginal cost of such thermal effect will be used. Marginal cost is defined as the additional part from total cost which leads to an extra unit of output (O'Sullivan & Sheffrin, 2007). In this research, the extra output refers to the thermal effect. To measure marginal cost derives from the concept of 'additionality' in Hanley & Spash's (1965) work, as they explained, the benefit of a project should be the net benefits ignoring any other benefits that would exist without this project. Conversely, when only the thermal effect, as a net benefit of the vegetation planting and maintenance in the Green Deck, is analysed, it is reasonable to only account for the cost of the greenery in the Green Deck. As urban vegetation is mainly attributed to such effect (Doick & Hutchings, 2013), the marginal cost in this research refers to the costs to both planting and maintaining the greenery in the Green Deck, namely the capital cost and recurrent cost of the vegetation in the Green Deck.

To calculate the capital cost and the recurrent cost, the following formulae were established.

$$\text{Capital Cost} = \text{Size of Greening Area} \times \text{Unit Price of Planting Work}/m^2.$$

$$\text{Recurrent Cost} = \text{Size of Greening Area} \times \text{Unit Price of Maintenance Work}/m^2.$$

At the present stage, there is no detailed design plan of the Green Deck. It is assumed that the greening rate of the Green Deck is 60%. Thus, an area of 25,800m^2 needs to be greened when the Extended Deck is excluded. Meanwhile the size of the greenery area will expand to 61,800m^2 when the Extended Deck is included.

The unit prices of planting and maintenance were acquired from the study on green roofs from Architectural Services Department (2007). The sort of intensive green roof is chosen, rather than extensive green roof. According to a comparison between the two kinds of green roof in the report, the intensive green roof is more suitable to become a multi-functional platform as it can provide space for recreational activities. Thus, unit prices used in our estimation are HK\$2000/m^2 for planting work and HK\$7/m^2 for annual maintenance, (this being the same data with the annual recurrent cost of a middle road children's play ground, for annual maintenance work). As a result, the capital and operational cost of the greenery on Green Deck can be summarised into the Table 4.1.

Table 4.1 Capital and Recurrent Cost of the Green Deck

	Extended Deck Excluded	Extended Deck Included
Capital Cost (in HK$)	51,600,000	123,600,000
Annual Maintenance Cost (in HK$)	180,600	432,600

4.2 Benefit from Thermal Effect

Four kinds of benefits of the thermal effect of Green Deck, which can be found on a community level, are identified from previous studies. They are (1) health benefits (Lam et al., 2004; Chan et al., 2013), (2) saved energy consumption (Lam et al., 2004), (3) increased productivity (Park, 2015), and (4) added recreational value (Lin, 2009). In the following part, each benefit will be explained in detail and calculated. The calculation of each benefit will adopt the last three steps given by Hanley & Spash (1993).

1. Definition of each benefit;

2. Establishment of the formulations to physically quantifying each impact;

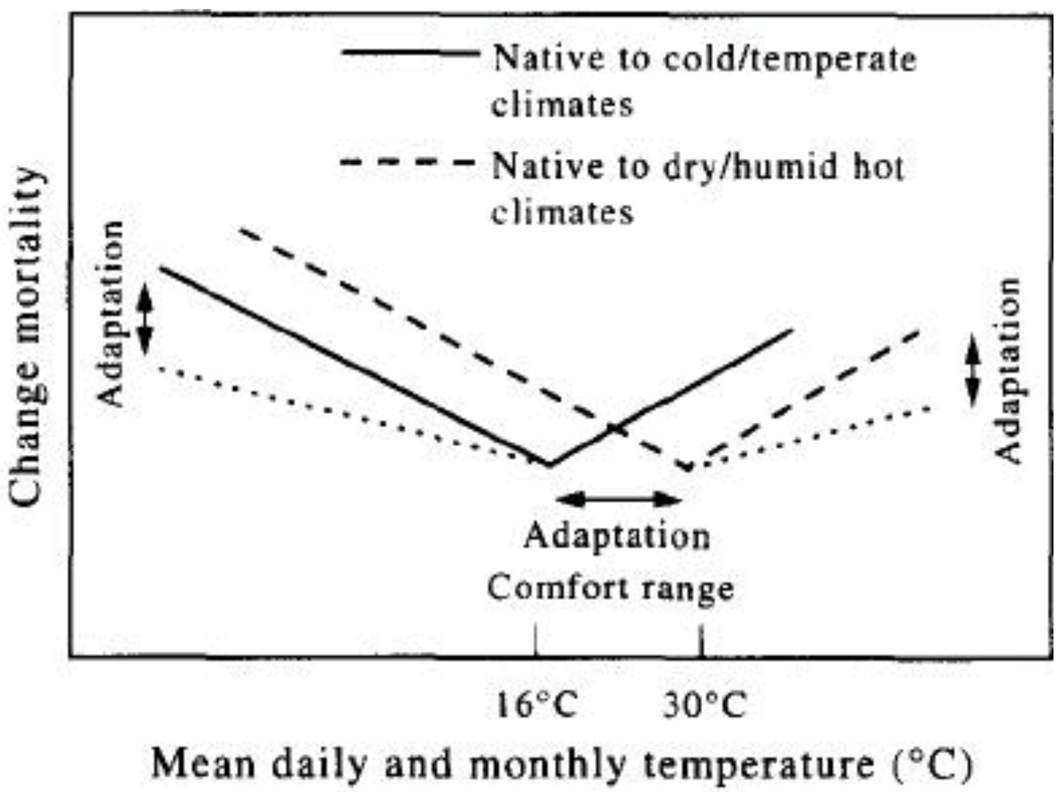
3. Monetarily estimation of each benefit.

4.2.1 Health Benefit

It is well documented that air temperatures have a significant impact on human health. In extremely hot weather, mortality and morbidity become significantly influence by the raise of air temperature. For example, Tol (2002) listed six categories of health issue which are sensitive to climate. They are (1) morbidity and mortality, (2) vectors of infectious diseases, (3) non-vector-borne infectious diseases, (4) air-quality-related disease, (5) flood and storm injuries and deaths, and (6) some health issues indirectly influenced by climate.

Firstly, it is important to define the 'extreme hot weather' which make the health significantly relate to air temperature. Using a meta-analysis, Martens (1998) found the lowest point of temperature-related mortality for natives to dry/humid hot climates is 29℃, as shown by Figure 4.1. The same baseline temperature for morbidity was also found by Chan et al. (2013), in their study about the relationship between temperature and morbidity in Hong Kong. Thus, 29℃ can be regarded as the baseline temperature of the extreme hot weather in Hong Kong. So in this study, the 'health benefit' refers to the reduced mortality and morbidity in the *park cool island* in extreme hot days (above 29℃).

Figure 4.1 Relationship between Mean Daily/Monthly Temperature and Mortality (Martens, 1998)



Reduced Mortality

A general formulation was established to value the reduced mortality.

$$\text{Benefit}_{Mortality} = \text{Reduced Mortality(No.)} \times \text{Statistical Value of Life.}$$

According to the available localised data, the formula of reduced mortality was developed as below.

$$\text{Reduced Mortality} = \text{Reduced Mortality Rate} \times \frac{Studied\ \ Area\ \ Population}{1000}.$$

According to Lam et al. (2004), the increase in mortality rate with each 1℃ increase of air temperature is 6.82. Thus, the numbers of reduced mortality in the three scenarios can be summarised as below.

S1. Ideal PCI excluding extended deck: 55

S2. Ideal PCI including extended deck: 158

S3. Localised PCI: 103

There are different kinds of methods to calculate statistical value of life. They are the revealed preferences method, contingent valuation method, consumer market behaviour method, meta-analysis method, forensic economics method, QALY and VSLY (Brannon 2004), and human capital method (Chau et al., 2007). Based on the data available, the human capital method is chosen to calculate the statistical value of life in Hong Kong. Thus, the statistical value of life in Hong Kong is calculated by discounting the total income of one's whole life. In terms of a numerical formula, the statistical value of life is calculated as below.

$$\text{Statistical Value of Life} = \sum_{i=1}^{40} \frac{Average\ \ Annual\ \ Salary\ \ per\ \ Capita}{(1+Discount\ \ Rate\ )^{i-1}}.$$

According to The Government of the Hong Kong Special Administrative Region of the People's Republic of China's (2015) fact sheet, the median monthly wage in Hong Kong is HK$14,800. Thus, the average annual wage in Hong Kong is HK$177,600. The discount rate is 5% according to Chau et al.'s (2007) study. Thus, the statistical value of life in Hong Kong is about HK$3,199,826. However, according to Andersson & Treich (2008), the human capital method may underestimate the value of statistical life. Thus, the result coming from this method should be regarded as a conservative estimation of value of statistical life.

The annual values of reduced mortality in the three scenarios are shown as below.

S1. Ideal PCI excluding extended deck: HK$175,990,430

S2. Ideal PCI including extended deck: HK$505,572,508

S3. Localised PCI: HK$329,582,078

Reduced Morbidity

A formula was established to calculate the benefit gained from reduced morbidity as below.

$$\text{Benefit}_{morbidity} = \text{Numbers of Reduced Morbidity} \times (Hospitalisation\ Cost + Restricted\ Active\ Day).$$

The part of number of reduced morbidity was further developed into a more detailed formula which contains the available localised data.

$$\text{Number of Reduced Morbidity} = \text{Reduced Rate of Morbidity} \times \text{Total Morbidity (No.)} \times \frac{Studied\ \ Area\ Population}{Hong\ \ Kong\ \ Population}.$$

According to Chan et al. (2013), the morbidity increases by 4.5% with every 1℃ increase of air temperature. Thus, an increase of 2℃ will lead the number of morbidity to increase by 9.2%. From the same study, it is calculated that the average hospitalisation admission per day in summer in Hong Kong is 1,779. According to The Government of the Hong Kong Special Administrative Region of the People's Republic of China (2015), the population of whole Hong Kong is 7,241,700. According to the data from Hong Kong Observatory, the annual number of the days with a temperature above 29℃ is 34.6. Thus, the annual number of reduced morbidity in the three scenarios can be summarised as below.

S1. Ideal PCI excluding extended deck: 3

S2. Ideal PCI including extended deck: 9

S3. Localised PCI: 6

The average cost of hospitalisation is acquired from the website of the Hospital Authority (n.d.). As the fees both burdened by private and public should be taken into account, the public charges of specialist out-patient fee for non-eligible persons, which is $1,110 per attendance, is regarded as the average hospitalisation fee per day.

If considering the whole society, the cost of a restricted active day is defined as the productivity of a person per day. GDP per hour worked is a measure of labour productivity (OECD, 2015). Thus, the GDP per capital per day is used in this research as the restricted active day. GDP per capita per day can be calculated using the following formula.

$$\text{GDP per capita per day} = {}^{GDP\ per\ capita}/_{365}.$$

The figure of GDP per capita is acquired from The World Bank (2016). The figure of US$40,169.5 (equal to HK$311,359.8) of GDP per capita in 2014 in Hong Kong was used. Thus, the restricted active day is HK$853.

Thus, the values of benefit of reduced morbidity due to the thermal effect of Green Deck in the three scenario are listed as following.

S1. Ideal PCI excluding extended deck: HK$5,899

S2. Ideal PCI including extended deck: HK$17,667

S3. Localised PCI: HK$11,778

4.2.2 Saved Energy Consumption

According to Fung et al. (2006), the ambient air temperature has a significant impact on the energy consumption of a building in Hong Kong. For the buildings with different functions, the intensity of such effect varies. The benefit of saved energy consumption is defined as the saved cost of the energy consumed by the buildings within the *park cool island*. Thus, the following formula is established to calculate the economic value of the reduced energy consumption.

$$\text{Benefit}_{energy\ consumption} = \sum_{i=1}^{2}(\sum Reduced\ Energy\ Consumption_i \times Unit\ Price\ of\ Energy\ Consumption_i).$$

The letter i represents the code of two different kinds of buildings. ‘1’ means residential buildings; ‘2’ means commercial buildings.

Based on the data available, the reduced energy consumption can be calculated using the following formula.

$$Reduced\ energy\ consumption = Average\ energy\ consumption \times Reduce\ Rate.$$

According to Fung et al. (2006), the change rate of the energy consumption of different kinds of buildings due to 1℃ and 2℃ increases can be summarised into Table 4.2.

Table 4.2 Change Rate of Energy Consumption due to Temperature Change

Function of Building	Electric	Gas
Residential	Increase 9.2% with 1℃ increase Increase 20.2% with 2℃ increase	Decrease 2.4% with 1℃ increase Decrease 4.8% with 2℃ increase
Commercial	Increase 3.0% with 1℃ increase Increase 6.1% with 2℃ increase	-

The average annual consumption of the buildings with different functions was acquired from previous studies and governmental publications. For residential buildings, according to the Electrical and Mechanical Services Department (2015), the annual electricity consumption of one Hong Kong household is 4,610kWh and the annual gas consumption per household is 8,180MJ, which is calculated using the portion rate of gas consumption. For commercial buildings, most property units in them are used as offices. Thus, Yu et al.'s (2015) model of electricity consumption in an office building is used. According to the model, the annual electricity consumption in a commercial building with office is 135.48kWh per square metre. Comparing to the figure of a pure commercial building in Yu & Chow's (2007) study, which is 259.2kWh/ m^2 /yr, using 135.48kWh per square metre can be regarded as a conservative estimation of the energy consumption of commercial buildings. This conservative estimation helps to avoid exaggeration of the energy saving.

In the studied area, the residential buildings here refer to all kinds of buildings used for living in. The number of property units in most residential buildings can be obtained from the website of the Home Affairs Department. Information about the other types of residential buildings can be acquired from each building's official website (e.g. The PolyU, Hung Hom Hall) or its respective property agency's website (e.g. Centaline). Commercial buildings refer to all the university buildings, hotels, commercial buildings with offices and museums within the park cool island. The information of these buildings and the sources of information are listed in Table 4.3.

Table 4.3 Information of the Buildings within Park Cool Island

Distance Scope	Building Name	Function	GFA/Number of Unit	Source
Within 150m	The Metropolis Residence (residential part) *(excluded from 207m scenario)*	Residential	662	Centaline
	The Metropolis Tower *(excluded from 207m scenario)*	Commercial	25,216m^2	JLL
	The Hong Kong Polytechnic University (Block Z excluded)	Commercial	250,160m^2	PolyU CDO
	Concordia Plaza	Commercial	54,627m^2	JLL
	Harbour Crystal Centre	Commercial	16,350m^2	JLL
	New Mandarin Plaza Tower A	Commercial	19,510m^2	JLL
	New Mandarin Plaza Tower B	Commercial	19,510m^2	JLL
	Chinachem Golden Plaza	Commercial	46,452m^2	JLL
	South Seas Centre Tower 1	Commercial	15,143m^2	JLL
	New World Millennium Hong Kong Hotel	Commercial	16,500m^2	WCWP
150m-207m	South Seas Centre Tower 2	Commercial	15,143m^2	JLL
	East Ocean Centre	Commercial	22,761m^2	JLL

	Hong Kong Science Museum	Commercial	13,500m^2	Hong Kong Science Museum
	Hong Kong Museum of History	Commercial	17,500m^2	LCSD
207m-321m	Fok Lin Building Block A	Residential	128	Home Affairs Department
	Wah Lai Mansion	Residential	99	Home Affairs Department
	Wing Fung Building	Residential	45	Home Affairs Department
	7-9 Wa Fung Street	Residential	30	Home Affairs Department
	Winston Mansion	Residential	58	Home Affairs Department
	Royal Peninsula Block 1-4	Residential	1349	Home Affairs Department
	Hilton Towers	Residential	216	Home Affairs Department
	PolyU Hung Hom Hall	Residential	3,000 people	
	The Hong Kong Polytechnic University Block Z	Commercial	44,900m^2	PolyU
	Peninsula Centre	Commercial	29,822m^2	JLL
	Energy Plaza	Commercial	10,944m^2	JLL
	Empire Centre	Commercial	22,714m^2	JLL
	Tsimshatsui Centre	Commercial	30,036m^2	JLL
	Regal Kowloon Hotel	Commercial	31,746m^2	Regal Reit

According to the data collected above, the total energy consumption of each kind of building in the three scenarios can be summarised as following.

S1. Ideal PCI excluding extended deck:

- Commercial building-electricity: 2,129,994kWh

S2. Ideal PCI including extended deck:

- Residential building-electricity:1,139,610kWh
- Residential building-gas: 527,512MJ
- Commercial building-electricity: 2,950,558kWh

S3. Localised PCI:

- Residential building-electricity: 616,468kWh
- Residential building-gas: 259,928MJ
- Commercial building-electricity: 3,830,229kWh

The price of each kind of energy used in different kinds of buildings is acquired from the publicity from Census and Statistics Department (2015a). The average electricity rate in residential buildings is HK$1/kWh; the average gas rate in residential buildings is HK$0.22/MJ; and the average electricity rate in commercial buildings is HK$1.2/kWh.

As a result, the total saved energy consumptions in the three scenarios are listed as below.

S1. Ideal PCI excluding extended deck: HK$2,555,993

S2. Ideal PCI including extended deck: HK$4,564,228

S3. Localised PCI: HK$5,155,559

4.2.3 Increased Productivity

Environmental temperature has a significant impact on workforce's productivity. Burnett et al. (2008) found a decrease of heat-related illness will lead to a reduction of sick leave and an increase of productivity in work place. Besides such indirect effect through healthy impact, workplace temperature is also related to the task performance (Niemelä, 2002). In this research, the increased productivity is defined as the added value caused by improved task performance due to the thermal effect of the Green Deck. The indirect health impact has been evaluated in the previous part. Furthermore, not all the manual workers within the *park cool island* are taken into account. Only those who work in a poor air-conditioned environment are assumed to be influenced by the thermal effect of Green Deck. In a well air-conditioned workplace in the surrounding area of the Green Deck, the thermal effect of the Green Deck is reflected by the saved electricity consumption which has been accounted for in the previous part and the indoor temperature was assumed not to change too much.

Firstly, a formula as below was established to calculate such benefit.

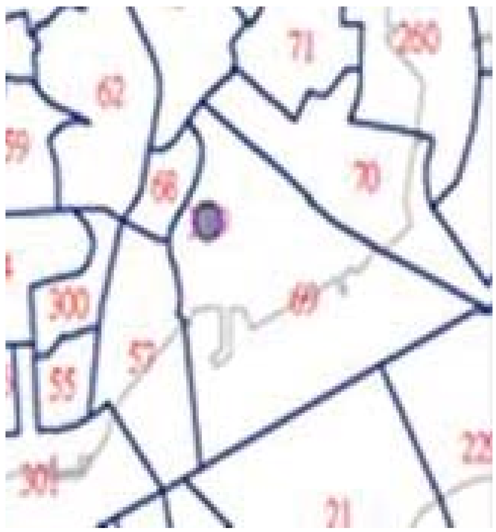
$$\text{Benefit}_{improved\ \ productivity} = \sum_{i=n}^{m}(Improved\ Productivity\ Rate_i \times Number\ of\ Days_i) \times Number\ of\ Workers \times GDP\ per\ Capita\ per\ Day.$$

The letter i means the daily mean temperature.

The increase rate of productivity is acquired from the study of Seppänen et al. (2006). Thus, it is projected that the productivity of the workforces who are working in a poorly air-conditioned area will increase by 2% with 1℃ drop in temperature and 4% with 2℃ drop. A baseline temperature of 25℃, below which changes of temperature have no significant effect on workforce's performance, was also given by Seppänen et al.'s (2006) study.

The total number of manual workers is acquired by adjusting the figures given by ARUP. In the map (Figure 4.2) below, the Area 57, Area 68 and Area 69 are covered by the *park cool island* of Green Deck. From the data given by ARUP, the total numbers employmed in these three areas is estimated to be 49,200. The workers working in a poor air-conditioned environment are assumed to be the bus drivers, logistics workers and some construction field workers working within the *park cool island*. According to the Census and Statistics Department (2015b), the portion of these kinds of employees accounts for 16.2% of the total in Hong Kong. Thus, it is estimated that 7,970 workers in this area are exposed to the poor air-conditioned environment. Due to the limitations of data and difficulties in estimating the real situation of the area, all these 7,970 workers were assumed to work within the *park cool island*s in all the three scenarios. Thus, total of 7,970 workers will be significantly influenced by the thermal effect of the Green Deck.

Figure 4.2 Zoning Map Given by ARUP to Estimate Employment Population



For the other two factors in the formula, the annual number of the days with a daily mean temperature above 25℃ in the following 50 years is estimated using the data from 1st January 2000 to 31st December 2014 from the website of Hong Kong Observatory. As a result, it is estimated that the annual number of the days with a daily mean temperature above 25℃ would be 186. For the value of daily productivity per person, the GDP per capita per day, which is HK$853, has already calculated in the above part of health benefit.

In the three scenarios, the annual benefits of improved productivityis listed as below:

S1. Ideal PCI excluding extended deck: HK$25,290,085

S2. Ideal PCI including extended deck: HK$25,290,085

S3. Localised PCI: HK$50,580,170

4.2.4 Increased Recreational Value

Previous studies have shown that there is a significant relationship between the temperature of the outdoor environment and people's willingness to attend activities in an urban park in the heat (Huang et al., 2014; Zacharias, 2001; Nikolopoulou et al., 2001; Thorsson et al., 2004; Eliasson et al., 2007; Thorsson et al., 2007; Lin, 2009; Lin et al., 2013; Nikolopoulou & Lykoudis, 2007; Kántor & Unger, 2010; Lenzholzer & Koh, 2010). Thus, the Green Deck will provide a suitable place for various activities and encourage more park users to attend recreational activities in it. The increased recreational value in the present research is defined as the added value due to more people using the park for recreational purpose due to a lower temperature in the Green Deck than outside. A formula to calculate such increased recreational value was established as below.

$$\mathrm{BRV} = \sum_{i=n}^{m}(Increased\ Park\ Use\ Rate_i \times Number\ of\ Days_i) \times Number\ of\ Users \times Recreational\ Value.$$

In the formula, the letter i represents the daily temperatures which have a significant impact on people's willingness to attend activity in the park.

The increased park use rates due to a decrease in temperature are calculated according to the study of Lin (2009). In Lin's (2009) study, with a regression analysis, the relationship between temperature and number of people using the park is indicated as following:

$\mathrm{y} = -3.6393\mathrm{x} + 141.89$. (Where y is the number of users and x is degrees C lower in temperature) ?

The baseline temperature, according to Lin (2009), is 25.6℃, below which there is no significant effect on people's willingness to use a park. According to the temperature data used in this research, this baseline temperature is rounded off to 26℃. As the intensity of a *park cool island* inside a park is stronger than that beyond the boundary of the park, it is assumed that there will be a 3℃ lower in the Green Deck than local temperature. Based on the above premises, the increased rate of park users and annual number of days with a certain daily mean temperature are summarised into Table 4.4.

Table 4.4 Annual Number of Days with a Mean Temperature above 26℃ and the Resulting Increased Park Use Rate

Mean Temperature	Increased Park-Use Rate	Annual Number of Days with such Temperatures
27℃	7.7%	30.3
28℃	18.2%	32.8
29℃	30%	37.9
30℃	33.4%	30.6
31℃	37.6%	3.8
32℃	42.9%	0.2

Another main factor in the formula is the number of users. The formula below was established to estimate the daily number of visitors of the Green Deck.

$$\text{Number of Users} = \text{Population of the Area} \times \text{portion of frequent users} \times \text{Possibility Using Green Deck per Day}.$$

According to Wong (2009), 59% frequent park users prefer to use the park within 15-minute walk. Thus, it is assumed that the potential frequent park-users live in a circle area with a radius of 800 metres, the centre point of which is located in the centre of Green Deck. Meanwhile, four neighbouring urban parks, which are Kowloon Park, King's Park, Ho Man Tin Park and Hutchison Park are assumed have the same attractiveness as the Green Deck. The picture of the four parks with the same size circles is shown in Figure 4.3. As the centre of the Green Deck is assumed to remain the same in the three scenarios, the area displayed in Figure 4.3 is applicable to all the three scenarios.

Figure 4.3 Area where the Potential Frequent Park Users are Living

Within the circle of the Green Deck, the frequent park users are assumed to use the Green Deck only in the part uncovered by the other circles; in the part covered by another one circle, the frequent park users are assumed to have $\frac{1}{2}$ of a chance to use the Green Deck; in the part covered by another two circles, the frequent park users are supposed to have $\frac{1}{3}$ of a chance to use the Green Deck.

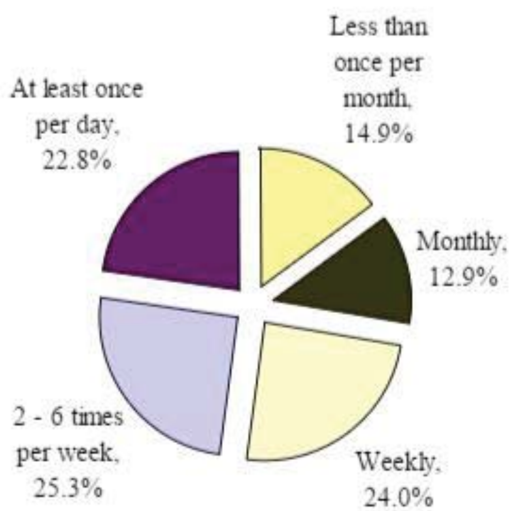
Furthermore, Lo (2009) studied the distribution of the frequency of park use in Hong Kong. The result is shown in Figure 4.4. According to the distribution, it is assumed that 22.8% of Hong Kong residents will use the open space every day; 25.3% of the population will have four sevenths chance to use the park in one day; 24.0% of the population will have one seventh chance to use the park in one day; 12.9% of the population will have one thirtieth chance to use the park in one day; the rest 14.9% residents are regarded as infrequent park users, who contribute little to the number of daily park users of the Green Deck.

Based on the above assumptions, the daily park user numbers of Green Deck is estimated to be 9,250 people per day.

The contingent value of the recreational function of an urban park is estimated according to Lo's (2009) study. In Lo's (2009) study, the contingent value of an urban green space is HK$77.43 per household per month. According to the Census and Statistics Department (2013), the average size of household in Hong Kong is 3 people. According to the factor analysis Lo (2009) conducted to seek the main factors under such contingent value, the weight of the factor of recreation is 0.17. Thus, the daily recreational value of a green open space is HK$13.2 per person ($77.43 x 0.17).

As a result the annual added recreational value is HK$44,441,916.

Figure 4.4 Distribution of Park Use Frequency in Hong Kong



Overall, the costs and benefits in three scenarios are displayed in Table 4.5.

Table 4.5 The Costs and Benefits in the Three Scenarios

Item	Scenario 1	Scenario 2	Scenario 3
Cost			
Capital Cost	HK$51,600,000	HK$123,600,000	HK$123,600,000
Annual Maintenance Cost	HK$180,600	HK$432,600	HK$432,600
Annual Benefit			
Health Benefit	HK$175,996,319	HK$505,590,175	HK$329,593,856
Saved Energy Consumption	HK$2,555,993	HK$4,564,228	HK$5,155,559
Increased Productivity	HK$25,290,085	HK$25,290,085	HK$50,580,170
Increased Recreational Value	HK$44,441,916	HK$44,441,916	HK$44,441,916

4.3 Social Discount Rate

Several perspectives are given to find a proper discount rate figure to use in the cost-benefit analysis. Mishan (1973) mentioned a method depends on three different scenarios of public fund source. This method can best reflect the usage of discount rate in the present research. According to *Mishan's Fund Source Method,* if the government raises the money entirely from the market, it means government uses the money which should be used in private investment. In such situation, *rate of return on private investment expenditure* will be an appropriate social discount rate. On the other hand if the government raises the money entirely by reducing their expenditure on public sector, local *social rate of time preference* is suitable to be used. In a mixed mode, the figure will be calculated by giving a certain value to n in the formula below.

$$r_{mix} \approx \sqrt[n]{p_p \times (1 + r_p)^n + p_g \times (1 + r_g)^n} - 1.$$

In which, p_p stands for the portion of fund raised from private sector; p_g stands for the portion of fund raised from public sector; r_p stands for market rate of return on private investment expenditure; and r_g stands for social rate of time preference. n is the number of years.

Localised opinion about the appropriate discount rate differs in Hong Kong. The figures and the reason to use them can be summarised into Table 4.6.

Table 4.6 Summary of Discount Rate Used in Hong Kong Context

Figure	Stated Reason	Reference
4%	Recommended by HKSAR Government	Economic Analysis Division Financial Services Bureau Government Secretariat, 1999; Economic Analysis and Business Facilitation Unit, 2005; Planning Department, 2007; Transport and Housing Bureau, 2008
6%	Due to a high rate of inflation	Attenborough et al., 1998; Tao et al., 2011
10%	According to the marginal rate of return of private investment	Gwee et al., 2008

The rates of 4%, 6% and 10% are three significant recommendations of Hong Kong's social discount rate. The rate of 4% is the one mostly preferred by the HKSAR Government and was used in different public policy studies by different departments. While using 6%, scholars may take the high local inflation rate into account. The rate of 10% as an assumption of social discount rate considers a wider range of stakeholders by paying accounting for their micro-economic reality.

According to the following four reasons, the NPV discounted by 4% is regarded as the primary result of this research. These reasons include:

(1) The investment of the greenery in the Green Deck will mainly be made by related departments of the HKSAR Government, as indicated in the next chapter

(2) Echoing our previous study, our local government is of the greatest importance and the greatest influence in the project of the Green Deck;

(3) At the current stage, the main stakeholder involved in the process of the Green

Deck's construction is the related departments of the HKSAR Government, by which more authorised guidelines and support will be given;

(4) The essence of the Green Deck project is a planning and development work. Thus, in Hong Kong's cases, it should be led by the Government.

However, the other two discount rates will be used to provide persuasive results of NPV for different especially for different stakeholders. And using a social discount rate, which can reflect the expectations and situation of the private sector, will encourage the engagement from different sectors to support and participate in the construction of the Green Deck. Furthermore, at this stage, it is still uncertain about what portion of participation may be expected from the respective public and private sectors in the Green Deck. Under such uncertainty, a social discount rate of 10% will provide a lower-end result to refer.

According to the value of costs and benefits and the judgement of the discount rate used in this research, a cash flow table (Table 4.7) was formed as below revealing the net present value with a discount rate of 4%. For the other possible discount rates of 10% and 6%, the cash flow tables are put in the Appendix 1 and Appendix 2.

Table 4.7 Net Present Value with a Discount Rate of 4% (in HK$) (Only the Investment of Greenery Accounted for)

Year	Scenario 1	Scenario 2	Scenario 3
0	-51,600,000	-123,600,000	-123,600,000
1	186,961,263	433,567,120	289,225,867
2	416,347,093	969,304,735	686,173,816
3	636,910,391	1484,437,057	1,067,854,536
4	848,990,486	1,979,756,598	1,434,855,228
5	1,052,913,653	2,456,025,387	1,787,740,509
…			
10	1,960,743,365	4,576,289,418	3,358,723,084
…			
25	3,824,296,051	8,928,673,659	6,583,566,642
…			
50	5,278,209,784	12,324,333,607	9,099,537,545

According to the above tables, the results in all the three scenario show the same overall picture that the greenery work will be paid back in the first year after its accomplishment due to an outstanding amount of benefit from the 'health benefit' section. The net benefit will maintain positive after the first year until the 50th year of the utility of the Green Deck.

Going one step further, due to such a large amount of positive net benefit, it is explored in this research to what extent the benefit of the thermal effect can pay back the total investment of the Green Deck during a 50-year utility. The capital cost and recurrent costs are taken and adopted from one of the related research projects of the Green Deck from Hsu et al. (2015). Thus, the design and consultation cost is projected to be HK$240,000,000 for the Green Deck only and, multiplying the area ratio of the Green Deck in the two scenarios, HK$574,883,721 when the Extended Deck is included. The annual capital cost is assumed to be HK$1,200,000,000 for the Green Deck only and HK$2,874,418,605 when the Extended Deck is included. The construction period is projected to be 5 years. The annual recurrent cost is projected to be HK$1,600,000 for the Green Deck only and HK$3,832,558 when the Extended Deck is included. As the return on investment of our investors is the main concern in this section of this research, the social indirect cost will not be taken into account in the following part of this research.

The net present values of the three scenarios with the discount rate of 4% are displayed in Table 4.8. As the cost-benefit analysis is conducted in the stage of design and consultation, and given the 5-year construction period, the year of -5 is regarded as the present. The net present value tables with the discount rates of 10% and 6% are also given in the Appendix 1 and Appendix 2.

Table 4.8 Net Present Value with a Discount Rate of 4% (in HK$) (All the Investment of Green Deck Accounted)

Year	Scenario 1	Scenario 2	Scenario 3
-5	-240,000,000	-574,883,721	-574,883,721
-4	-1,393,846,154	-3,338,747,764	-3,338,747,764
-3	-2,503,313,609	-5,996,309,344	-5,996,309,344
-2	-3,570,109,240	-8,551,657,017	-8,551,657,017
-1	-4,595,874,269	-11,008,722,088	-11,008,722,088
0	-5,582,186,797	-13,371,284,655	-13,371,284,655
1	-5,387,228,601	-12,916,020,933	-13,034,658,921
2	-5,199,768,796	-12,478,267,353	-12,710,980,331
3	-5,019,518,985	-12,057,350,450	-12,399,750,917
4	-4,846,201,858	-11,652,622,659	-12,100,491,865
5	-4,679,550,775	-11,263,461,321	-11,812,742,777
…			
10	-3,937,649,760	-9,530,984,185	-10,531,734,959
…			
25	-2,414,708,165	-5,974,631,735	-7,902,138,761

…			
50	-1,226,533,710	-3,200,022,944	-6,239,657,501
Benefit-Cost Ratio	78.1%	76.2%	56.5%

From a comparison between Scenario 1 and Scenario 2, it is shown that with the increase of the size of the Green Deck, the benefit-cost ratio will become lower, although the net present benefit will become larger. And, the localised benefit-cost ratio is 56.5% as shown in Scenario 3. The remaining 43.5% of the investment should be paid back by other functions of the Green Deck, in order to make it a more desirable environmental project.

5. Discussion: Tangible and Intangible Costs and Benefits for Different Stakeholders

A typical issue that arises when discussing tangible and intangible costs is the problem of definition. This is because the definition of ‘tangible’ and ‘intangible’ is always evolving, and so any discussion becomes controversial. Recognising this problem, Murphy & Simon (2002) reviewed and listed a wide range of definitions of ‘tangible’ and ‘intangible’ in their work. Among these definitions, the one given by Merriam-Webster (2015) might be relatively the most suitable one in this research. A tangible asset is something capable to be appraised at an actual or approximate value. However, using present evaluation techniques, even the intangible assets can be appraised with a monetary value. Thus, some modification should be made on this definition.

According to another cited definition from Remenyi et al. (1993), the tangible assets have a direct impact on a company’s profit. In this research, we also consider the benefit of residents in the surrounding area of the Green DeckThus, the term ‘company’s profit’ needs to be substituted with term ‘the collective stakeholders’ financial situation.

In this research, tangible means to have a market value that can directly reflected in the stakeholders’ financial record; however, intangible means the impacts do not have a market value and influence the stakeholders’ financial situation indirectly.

5.1 Tangible Costs

In this research, the tangible costs refer to the investment in planting and maintaining the vegetation in the Green Deck and Extended Deck, if it is accounted for. Both of those costs are regarded as tangible costs. The main investor to pay these costs is the related department of government, namely the Leisure and Cultural Services Department, if the Green Deck is regarded as a Government Land (Greening, Landscape & Tree Management Section, Development Bureau, 2015).

5.2 Intangible Costs

Despite the discussion above concerning the definitions of tangible and intangible costs and assets, in this particular study, there are two reasons to not consider them in the argument here. According to Hsu et al’s (2015) research, the intangible costs of the Green Deck include the traffic and carbon emission issues during the construction stage and carbon emission issues in operation and maintenance stages.

Firstly, the tree planting work is supposed to be conducted on an existing platform to be built above the ground. Thus, planting work in the Green Deck cannot be regarded as the direct cause of the temporary traffic congestion in the construction of the Green Deck. Thus, the cost of traffic congestion can be neglected in this study.

Secondly, earlier research studies about cost-benefit analysis of tree planting seldom takes carbon emissions as an indirect or intangible cost of tree planting (International Institute for Sustainable Development, 1996; eXtension, 2015; McPherson et al., 2007). It is well documented that, in fact, urban vegetation has a significant ability to sequester carbon. Thus, the emitted carbon can be balanced by the natural carbon dioxide-absorbing nature of the vegetation itself. So, such cost can be ignored in this research.

5.3 Tangible Benefits

Tangible benefits refer to well-being or goods with a definite market price. In this research, the saved hospitalisation fee of the reduced morbidity and the saved energy consumption belong to the above-mentioned kind of tangible benefits. For reduced morbidity, the stakeholders who gain benefits are the residents in the surrounding area and the Hong Kong Government that partially pays these kind of hospitalisation fees. Meanwhile, for saved energy consumption, the main stakeholders are the property owners, both residential buildings and commercial buildings, in the surrounding communities.

5. 4 Intangible Benefits

The remaining benefits are relatively intangible because they do not have market prices and cannot be represented by a priced good which can be exchanged in the market. These benefits are the reduced mortality, the reduced restricted days arising from the reduced morbidity, the increased productivity and the increased recreational value. These four benefits are elaborated below.

For reduced mortality, the main stakeholders are the individuals living around the Green Deck; for reduced restricted days, the main stakeholders are the industry in Hong Kong; for increased productivity, the stakeholders are the companies which do not have air-conditioned indoor environment in the surrounding communities of the Green Deck; for increased recreational value, the main stakeholders are the residents who live within 15-minute walk from the boundary of the Green Deck.

According to the above discussion, a summary of the tangible and intangible costs and benefits of different stakeholders is displayed in the following tables (Table 5.1, Table 5.2 and Table 5.3).

Table 5.1 Stakeholders and Their Costs and Benefits in Scenario 1 Ideal PCI excluding extended deck

Cost	Tangible or Intangible	Stakeholder	Private or Public	Amount in NPV over 50 Years
Capital and recurrent cost	Tangible	The Hong Kong Government	Public	HK$55,479,683
Benefit	**Tangible or Intangible**	**Stakeholder**	**Private or Public**	**Amount in NPV over 50 Years**
Reduced mortality	Intangible	Surrounding residents	Private	HK$3,780,658,908
Reduced morbidity (Hospitalisation fees)	Tangible	Surrounding residents	Private	HK$71,536
	Tangible	The Hong Kong Government	Public	
Reduced morbidity (Restricted active day)	Intangible	Industry in Hong Kong	Private	HK$54,973
Saved energy consumption	Tangible	Surrounding property owners	Private	HKS54,908,318
Increased productivity	Intangible	Surrounding companies (with a poor air-conditioning environment)	Private	HK$543,286,279
Increased recreational value	Intangible	Surrounding residents (within 15-minute walking distance)	Private	HK$954,709,452

Table 5.2 Stakeholders and Their Costs and Benefits in Scenario 2 Ideal PCI including extended deck

Cost	Tangible or Intangible	Stakeholder	Private or Public	Amount in NPV over 50 Years
Capital and recurrent cost	Tangible	The Hong Kong Government	Public	HK$132,893,193
Benefit	**Tangible or Intangible**	**Stakeholder**	**Private or Public**	**Amount in NPV over 50 Years**
Reduced mortality	Intangible	Surrounding residents	Private	HK$10,860,801,954
Reduced morbidity (Hospitalisation fees)	Tangible	Surrounding residents	Private	HK$214,607
	Tangible	The Hong Kong Government	Public	
Reduced morbidity (Restricted active day)	Intangible	Industry in Hong Kong	Private	HK$164,919
Saved energy consumption	Tangible	Surrounding property owners	Private	HK$98,049,589
Increased productivity	Intangible	Surrounding companies (with a poor air-conditioning environment)	Private	HK$543,286,279
Increased recreational value	Intangible	Surrounding residents (within 15-minute walking distance)	Private	HK$954,709,452

Table 5.3 Stakeholders and Their Costs and Benefits in Scenario 3 Localised PCI

Cost	Tangible or Intangible	Stakeholder	Private or Public	Amount in NPV over 50 Years
Capital and recurrent cost	Tangible	The Hong Kong Government	Public	HK$132,893,193
Benefit	**Tangible or Intangible**	**Stakeholder**	**Private or Public**	**Amount in NPV over 50 Years**
Reduced mortality	Intangible	Surrounding residents	Private	HK$7,080,143,046
Reduced morbidity (Hospitalisation fees)	Tangible	Surrounding residents	Private	HK$143,071
	Tangible	The Hong Kong Government	Public	
Reduced morbidity (Restricted active day)	Intangible	Surrounding companies	Private	HK$109,946
Saved energy consumption	Tangible	Surrounding property owners	Private	HK$110,752,665
Increased productivity	Intangible	Surrounding companies (with a poor air-conditioning environment)	Private	HK$1,086,572,558
Increased recreational value	Intangible	Surrounding residents (within 15-minute walk distance)	Private	HK$954,709,452

It can be seen from the above discussion and the tables presented, that, overall, the benefits accruing to the Government and the industry in Hong Kong are relatively small. The thermal effect can largely benefit residents, companies and property owners in the surrounding communities. Reflecting Chan et al's (2014) previous study on public engagement of the Green Deck, key stakeholders, such as end-users, community and business, should be kept satisfied and shaped as stakeholders of high importance and high influence. Promotion of such thermal effect and the benefits it bringing to these stakeholders would be a suitable entry point to achieve this goal.

6. Conclusions and Recommendations

6.1 Conclusions

In this research, the thermal effects of the Green Deck in both theoretical and localised situations are explored. Answers to the three questions as the aims of this research are summarised in the tables below (Table 6.1, Table 6.2 and Table 6.3).

Table 6.1 Research Results in Scenario 1

Scenario 1 Ideal PCI excluding the Extended Deck				
				
Area and Population				
Area			426,568m^2	
Population			8,122	
Costs				
Item	**Tangible or Intangible**	**Stakeholders**	**Annual**	**NPV over 50 years**
Capital Cost	Tangible	Hong Kong Government	HK$51,600,000	
Recurrent Cost			HK$180,600	HK$3,879,683

Benefits				
Item	**Tangible or Intangible**	**Stakeholders**	**Annual**	**NPV over 50 years**
Health Benefit	Tangible and Intangible*	Surrounding Residents/Hong Kong Government/Hong Kong Industry	HK$175,996,319	HK$3,780,785,417
Saved Energy Consumption	Tangible	Surrounding Property Owners	HK$4,564,228	HK$54,908,318
Increased Productivity	Intangible	Surrounding Companies (with a poor air-conditioning environment)	HK$25,290,085	HK$543,286,279
Increased Recreational Value	Intangible	Surrounding Residents (within 15-minute walk)	HK$44,441,916	HK$954,709,452

Table 6.2 Research Results in Scenario 2

Scenario 2 Ideal PCI including the Extended Deck

Area and Population

Area	871,954m^2
Population	23,118

Costs

Item	Tangible or Intangible	Stakeholders	Annual	NPV over 50 years
Capital Cost	Tangible	Hong Kong Government	HK$123,600,000	
Recurrent Cost			HK$432,600	HK$9,293,193

Benefits				
Item	**Tangible or Intangible**	**Stakeholders**	**Annual**	**NPV over 50 years**
Health Benefit	Tangible and Intangible*	Surrounding Residents/Hong Kong Government/Hong Kong Industry	HK$505,590,175	HK$10,861,181,480
Saved Energy Consumption	Tangible	Surrounding Property Owners	HK$4,564,228	HK$98,049,589
Increased Productivity	Intangible	Surrounding Companies (with a poor air-conditioning environment)	HK$25,290,085	HK$543,286,279
Increased Recreational Value	Intangible	Surrounding Residents (within 15-minute walk)	HK$44,441,916	HK$954,709,452

Table 6.3 Research Results in Scenario 3

<table>
<tr><td colspan="5">Scenario 3 Localised PCI</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td colspan="5">Area and Population</td></tr>
<tr><td colspan="2">Area</td><td colspan="3">450,033m^2</td></tr>
<tr><td colspan="2">Population</td><td colspan="3">7,563</td></tr>
<tr><td colspan="5">Costs</td></tr>
<tr><td>Item</td><td>Tangible or Intangible</td><td>Stakeholders</td><td>Annual</td><td>NPV over 50 years</td></tr>
<tr><td>Capital Cost</td><td rowspan="2">Tangible</td><td rowspan="2">Hong Kong Government</td><td colspan="2">HK$123,600,000</td></tr>
<tr><td>Recurrent Cost</td><td>HK$432,600</td><td>HK$9,293,193</td></tr>
</table>

Benefits				
Item	**Tangible or Intangible**	**Stakeholders**	**Annual**	**NPV over 50 years**
Health Benefit	Tangible and Intangible*	Surrounding Residents/Hong Kong Government/Hong Kong Industry	HK$329,593,856	HK$7,080,396,063
Saved Energy Consumption	Tangible	Surrounding Property Owners	HK$5,155,559	HK$110,752,665
Increased Productivity	Intangible	Surrounding Companies (with a poor air-conditioning environment)	HK$50,580,170	HK$1,086,572,558
Increased Recreational Value	Intangible	Surrounding Residents (within 15-minute walk)	HK$44,441,916	HK$954,709,452

*For the health benefit, the hospitalisation fee of the reduced morbidity is a tangible benefit. Meanwhile the reduced mortality and the restricted active days of the reduced morbidity are intangible benefits.

Besides the above results, according to the two cash-flow tables in the previous chapter, this research also indicates another important finding.

When considering the cost to planting and maintaining the vegetation only, the investment will be paid back in the first year after the Green Deck is in use, with a net benefit equal to present value of HK$189,961,263 in Scenario 1, HK$433,567,120 in Scenario 2, and HK$289,225,867 in Scenario 3. After a 50-year period, the respective net present value become HK$5,278,209,784 in Scenario 1, HK$12,324,433,607 in Scenario 2, and HK$9,099,537,545 in Scenario 3.

When considering the total investment of Green Deck, it is shown that in Scenario 1 the thermal effect will pay back 78.1% of total investment, 76.2% in Scenario 2, and 56.5% in Scenario 3 over a 50-year period. A comparison between Scenario 1 and Scenario 2 shows that with an increase of the size of park, also the increase of greenery area, the amount of net benefit will increase, however, the portion of thermal effect paying off the total investment will decrease. Furthermore, with the recent local practice, an ideal return rate is still difficult to achieve.

6.2 Recommendations

Supported by the results of this research, the following three recommendations are given.

(1) The research proved that the Green Deck can improve the environmental condition of its surrounding area by mitigating the high temperatures brought by the urban heat island effect. Such improvement can not only pay back the investment to provide the thermal effect, but also attract very substantial net benefit. Thus, the Green Deck, with enough landscaping work of vegetation, is a desirable and feasible mitigation measure of this urban heat island in its surrounding area.

(2) It is shown that, with the increase of the park size, the net present value of thermal effect is increasing. Thus, from the perspective of the thermal effect only, the plan including the Extended Deck is more desirable. However, for the benefit (thermal effect)-cost ratio (total investment), it will decrease when the Extended Deck is included. Thus, it indicates that to expand the open space covered by a large portion of greenery in this area has a high effectiveness but low efficiency in respect to thermal effect. The decision to include the External Deck in the future plan should be made based on three points. Firstly, the budget should be sufficient. Secondly, after adding other kinds of benefits, the benefit-cost ratio in the scenario including the Extended Deck is larger than the scenario excluding the Extended Deck. Lastly, the thermal effect has a higher priority or weight than other benefits to make the inclusion of the External Deck a more desirable option than that which excludes the External Deck.

(3) In previous chapter, we use the discount rate of 4% assuming the government invests in the project totally; meanwhile, we also use the discount rate of 10% assuming purely private investment mode respectively. According to a comparison between net present values with different discount rates the larger portion of the capital and recurrent cost that is invested by the government, the higher the net present values will be. Thus, it is expected that the Hong Kong Government, other than private end-users, should invest more in planting work and maintaining the vegetation in the Green Deck.

4. Another observation is that as the surrounding residents, companies and surrounding property owners are all beneficiaries of the thermal effect, the promotion of the thermal effect could be a suitable entry point to enhance the engagement of the public with the idea of construction and operation of the Green Deck.

6.3 Limitations and Research in the Future

The main limitation of the present research is the calculations of different results of the thermal effect being based on a theoretical model and data for the whole of Hong Kong. Thus, some inaccuracy is inevitable. In the future, a more systematic survey could be conducted in Hung Hom (as well as other locations of interest) to improve the accuracy of such kind of regional studies.

One further point of interest to scholars and those engaged in formulating public policy, a lot of important data that is needed for this kind of policy research is not officially published, such as the value of statistical life. Policy or public project research such as this one has to collected data from varies studies with different opinions and unofficially sources. Thus, if possible, more efforts should be made by government units/research institutes to establish of an official platform providing well-acknowledged data for policy or public project studies. This will encourage more scholars to be involved in policy and public project research in Hong Kong.

Lastly, at the present stage, the detailed construction plan of the Green Deck has not been published. However, a framework to evaluate the costs and benefits of the thermal effect of the Green Deck has been established in this research. In the future, the updated figures can be put into the framework to calculate a more accurate net present value of the thermal effect of the Green Deck, as we go forward.

References

Hong Kong. Architectural Services Department. (2007). *Study on Green Roof Application in Hong Kong: Final Report*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Arrau, C. P. & Peña, M. A. (2015). *The Urban Heat Island (UHI) Effect*. [Online]. Available from: http://www.urbanheatislands.com/home. [Accessed 9th January 2016].

Attenborough, N., Sandbach, J., Saadat, U., Siolis, G., Cartwrogjt, M., Dunkley, S. & SOFRES FSA. (1998). *Feasibility Study & Cost Benefit Analysis of Number Portability for Mobile Services in Hong Kong: Final Report for OFTA*. London: National Economic Research Associates.

Australian Government. Department of Finance. (2006). *Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies*. Parkes, ACT: Australian Government Department of Finance. [Online]. Available from: http://www.finance.gov.au/sites/default/files/Intro_to_CB_analysis.pdf. [Accessed 8th January 2016].

Boardman, N. E. (2006). *Cost-benefit Analysis: Concepts and Practice*. (3rd eds.). Upper Saddle River, NJ: Prentice Hall.

Brannon, I. (2004). What is a Life Worth? *Regulation*. 27(4): 60-63.

Brent, R. J. (2006). Applied Cost-Benefit Analysis. (2nd eds). Cheltenham; Northampton, MA.: Edward Elgar.

Burnett (page 30) ?

Ca, V. T., Asaeda, T. & Abu, E. M. (1998). Reductions in Air Conditioning Energy Caused by a Nearby Park. *Energy and Buildings*. 29(1): 83-92.

Cao, X., Onishi, A., Chen, J. & Imura, H. (2010). Quantifying the Cool Island Intensity of Urban Park Using ASTER and IKONOS Data. *Landscape and Urban Planning*. 96(4): 224-231.

Hong Kong. Census and Statistics Department. (2013). *Hong Kong Monthly Digest*

January 2013 Feature Article: Hong Kong Domestic Household Projections up to 2041. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Hong Kong. Census and Statistics Department. (2015a). *Hong Kong Energy Statistics: 2014 Annual Report*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Hong Kong. Census and Statistics Department. (2015b). *2014 Report on Annual Earning and Hours Survey*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Chang, C. R. & Li, M. H. (2014). Effects of Urban Park on the Local Urban Thermal Environment. *Urban Forestry & Urban Greening*. 13(4): 672-681.

Chau, C. K., Hui, W. K. & Tse, M. S. (2007). Evaluation of Health Benefits for Improving Indoor Air Quality in Workplace. *Environment International*. 33(2): 186-198.

Chau, C. K., Chan, E. H. W., Yung, E. H. K. & Philipp, C. (2015). *The Effect of Greenery on Temperature and Thermal Comfort in Green Deck*. Hong Kong: The Hong Kong Polytechnic University.

Declet-Barreto, J., Brazel, A. J., Martin, B. C., Chow, W. T. L. & Harlan, S. L. (2013). Creating the Park Cool Island in an Inner-City Neighborhood: Heat Mitigation Strategy for Phoenix, AZ. *Urban Ecosystems*. 16(3): 617-635.

DLN. (2014). *Campus Masterplan Studies of The Hong Kong Polytechnic University: Landscape Deck over Cross Harbour Tunnel Toll Plaza*. Hong Kong: DLN.

Doick, K & Hutchings, T. (2013). *Air Temperature Regulation by Urban Trees and Green Infrastructure*. Surrey: Forest Research. [Online]. Available from: http://www.forestry.gov.uk/pdf/FCRN012.pdf/$FILE/FCRN012.pdf. [Accessed 18th December 2015].

Hong Kong. Economic Analysis and Business Facilitation Unit. (2005). *Regulatory Impact Assessment on Labelling Scheme on Nutrition Information*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Hong Kong. Economic Analysis Division Financial Services Bureau Government Secretariat. (1999). *Economic Assessment on Building a Walt Disney Theme Park in Hong Kong*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Hong Kong. Electrical and Mechanical Services Department. (2015). *Hong Kong Energy End-Use Data 2015*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Eliasson, I., Knez, I., Westerberg, U., Thorsson, S. & Lindberg, F. (2007). Climate and Behaviour in a Nordic City. *Landscape and Urban Planning*. 82(1-2): 72-84.

eXtension. (2015). Cost-Benefit Approach to Urban Forests. [Online]. Available from: http://articles.extension.org/pages/58138/cost-benefit-approach-to-urban-forests. [Accessed 10th January 2016].

Fung, W., Lam, K., Hung, W., Pang, S. & Lee, Y. (2006). Impact of urban temperature on energy consumption of Hong Kong. *Energy*. 31(14): 2623-2637.

Givoni, B. (1972). *Comparing Temperature and Humidity Conditions in an Urban Garden and in its Surrounding Areas*. Haifa: Technion.

Hong Kong. Green Power. (2012). Report on Urban Heat Island Effect in Hong Kong. Hong Kong: Green Power. [Online]. Available from: http://www.greenpower.org.hk/html/download/concern/gp_urban_heat_island_report_2012.pdf. [Accessed 9th January 2015].

Hong Kong. Greening, Landscape & Tree Management Section, Development Bureau. (2015). *Introduction to Greening, Landscape and Tree Management Section*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Gwee, E., Currie, G. & Stanley, J. (2008). Evaluating Urban Railway Development Projects—An International Comparison. In: *31st Australasian Transport Research Forum*. Gold Coast. Canberra: Australian Government Department of Infrastructure and Regional Development.

Hanley, N. & Spash, C. L. (1993). *Cost-Benefit Analysis and the Environment*. Cheltenham; Northampton: Edward Elgar.

Hong Kong. Hospital Authority. (n.d.). *Fees and Charges*. [Online] Available from: https://www.ha.org.hk/haho/ho/cs/v3/serviceguide_feenchg-en.htm. [Accessed 5th January 2016].

Hsu, M. S. C., Chan, A. P. C., Fan, H. Q. & Pratt, S. (2015). *Cost-Benefit Analysis of the Green Deck Development: Final Report*. Hong Kong: The Hong Kong Polytechnic University.

International Institute for Sustainable Development. (1996). *Offsetting* CO_2 *Emissions: Tree Planting on the Prairies*. Winnipeg: International Institute for Sustainable Development (ISSD).

Investopedia. (2016a). *Net Present Value—NPV*. [Online]. Avaliable from: http://www.investopedia.com/terms/n/npv.asp. [Accessed 27th January 2016].

Investopedia. (2016b). *Internal Rate of Return—IRR*. [Online]. Available from: http://www.investopedia.com/terms/i/irr.asp. [Accessed 27th January 2016].

Jauregui, E. (1990). Influence of a Large Urban Park on Temperature and Convective Precipitation in a Tropical City. *Energy and Buildings*. 15(3-4): 457-463.

Kántor, N. & Unger, J. (2010). Benefits and Opportunities of Adopting GIS in Thermal Comfort Studies in Resting Places: An Urban Park as an Example. *Landscape and Urban Planning*. 98(1): 36-46.

Lam, K. S., Hung, W. T. & Fung W. Y. (2004). *Tender AM02-316: Provision of Service for Characterizing the Climate Change Impact in Hong Kong*. Hong Kong: Environmental Protection Department, the Government of the Hong Kong Special Administrative Region.

Layard, R. & Glaister, S. (1994). *Cost-Benefit Analysis*. (2nd eds). Cambridge; New York: Cambridge University Press.

Lenzholzer, S. & Koh, J. (2010). Immersed in Microclimatic Space: Microclimate Experience and Perception of Spatial Configurations in Dutch Squares. *Landscape and Urban Planning*. 95(1-2): 1-15.

Lin, C. H., Lin, T. P. & Hwang, R. L. (2013). Thermal Comfort for Urban Park in Subtropics: Understanding Visitor's Perceptions, Behavior and Attendance.

Advances in Meteorology. Article ID 640473.

Lin, T. P. (2009). Thermal Perception, Adaptation and Attendance in a Public Square in Hot and Humid Regions. *Building and Environment*. 44(10): 2017-2026.

Lo, Y. H. A. (2009). *An Exploratory Study of the Multiple Values and Roles of Urban Green Spaces in Hong Kong*. A thesis submitted in partial fulfilment of the requirements of The University of Hong Kong for the Degree of Master of Philosophy. Hong Kong: The University of Hong Kong.

Martens, W. J. M. (1998). Climate Change, Thermal Stress and Mortality Change. *Social Science & Medicine*. 46(3): 331-344.

McPherson, E. G., Simpson, J. R., Peper, P. J., Gardner, S. L. & Xiao, Q. F. (2007). *Northest Community Tree Guide: Benefit, Costs, and Strategic Planting*. Washington, D.C.: United States Department of Agriculture.

Merriam-Webster. (2015). *Tangible*. [Online]. Available from: http://www.merriam-webster.com/dictionary/tangible. [Accessed 27th January 2016].

Mishan, E. J. (1973). *Elements of Cost-Benefit Analysis*. New York: Praeger.

Murphy, K. E. & Simon, S. J. (2002). Intangible Benefit Valuation in ERP Projects. *Information Systems Journal*. 12(4): 301-320.

Niemelä, R., Hannula, M., Rautio, S., Reijula, K. & Railio, J. (2002). The Effect of Air Temperature on Labour Productivity in Call Centres—A Case Study. *Energy and Buildings*. 34(8):759-764.

Nikolopoulou, M., Baker, N. & Steemers, K. (2001). Thermal Comfort in Outdoor Urban Spaces: Understanding the Human Parameter. *Solar Energy*. 70(3): 227-235.

Nikolopoulou, M. & Lykoudis, S. (2007). Use of Outdoor Spaces and Microclimate in a Mediterranean Urban Area. *Building and Environment*. 42(10): 3691-3707.

OECD. (2015). *Productivity*. [Online]. Available from: https://data.oecd.org/lprdty/gdp-per-hour-worked.htm. [Accessed 27th January 2016].

O'Sullivan, A. & Sheffrin, S. M. (2007). *Economics: Principles in Action*. Boston: Pearson Education Inc.

Oldman River Dam Environmental Assessment Panel. (1992). *Oldman River Dam: Report of the Environmental Assessment Panel*. Hull: Federal Environmental Assessment Review Office.

Park, J. (2015). The Labor Productivity Impacts of Climate Change: Implications for Global Poverty. [Online]. Available from: http://www.worldbank.org/content/dam/Worldbank/document/Climate/Climate%20and%20Poverty%20Conference/D2S3_Park_Labor%20Productivity%20Impacts%20from%20Climate%20Change%20-%20Feb%2010%202015%20v13short.pdf. [Accessed 27th January 2016].

Pearce, D. W., Atkinson, G. & Mourato, S. (2006). *Cost-Benefit Analysis and the Environment: Recent Developments*. Paris: Organisation for Economic Co-operation and Development.

Hong Kong. Planning Department. (2007). *Hong Kong 2030 Planning Vision and Strategy: Economic and Financial Assessment Final Report*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Hong Kong. HK PolyU, The,. (2015). *Green Deck—An Innovative Solution to Enhance the Environment*. [Online]. Available from: http://www.polyu.edu.hk/cpa/greendeck/. [Accessed 14th December 2015].

Prest, A. R. & Turvey, R. (1965). Cost-Benefit Analysis: A Survey. *The Economic Journal*. 75: 683-735.

United Kingdom. Prime Minister's Strategy Unit. (2004). *Strategy Survival Guide Overview*. Surrey: The National Archives. [Online]. Available from: http://webarchive.nationalarchives.gov.uk/+/http:/www.cabinetoffice.gov.uk/strategy/downloads/survivalguide/downloads/ssgv2.1_overview.pdf. [Accessed 9th January 2016].

Remenyi, D., Money, A., Sherwood-Smith, M. & Irani, Z. (2000). *The Effective Measurement and Management of IT Costs and Benefits*. Offord:

Butterworth-Heinemann.

Shashua-Bar, L. & Hoffman, M. E. (2000). Vegetation as a Climatic Component in the Design of an Urban Street: An Empirical Model for Predicting the Cooling Effect of Urban Green Areas with Trees. *Energy and Buildings*. 31(3): 221-235.

Seppänen, O., Fisk, W. J. & Lei, Q. H. (2006). *Effect of Temperature on Task Performance in Office Environment*. Berkeley: Ernest Orlando Lawrence Berkeley National Laboratory.

Sponken-Smith, R. A. & Oke, T. R. (1998). The Thermal Regime of Urban Parks in Two Cities with Different Summer Climates. *International Journal of Remote Sensing*. 19(11): 2085-2104.

Tao, R., Liu, S., Hung, C. & Tam, C. M. (2011). Cost-Benefit Analysis of High Speed Rail Link between Hong Kong and Mainland China. *Journal of Engineering, Project, and Production Management*. 1(1): 36-45.

Canada. Treasury Board of Canada Secretariat. (1998). *Benefit-cost analysis guide*. [Online] Available from: http://www.tbs-sct.gc.ca/fm-gf/tools-outils/guides/bca2-gaa-eng.asp. [Accessed 19th November 2015].

Canada. Treasury Board of Canada Secretariat. (2007). *Canadian Cost-Benefit Analysis Guide: Regulatory Proposals*. [Online]. Available from: https://www.tbs-sct.gc.ca/rtrap-parfa/analys/analys-eng.pdf. [Accessed 8th January 2016].

Hong Kong. The Government of the Hong Kong Special Administrative Region of the People's Republic of China. (2015). *Hong Kong: The Facts*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

The World Bank. (2016). *GDP per Capita (Current US$)*. Washington, DC: The World Bank. [Online]. Available from: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD. [Accessed 5th January 2016].

Thorsson, S., Honjo, T., Lindberg, F., Lindberg, F., Eliasson, I. & Lim, E. M. (2007).

Thermal Comfort and Outdoor Activity in Japanese Urban Public Places. *Environment and Behavior*. 39(5): 660-684.

Thorsson, S., Lindqvist, M. & Lindqvist, S. (2004). Thermal Bioclimatic Conditions and Patterns of Behaviour in an Urban Park in Göteborg, Sweden. *International Journal of Biometeorology*. 48(3): 149-156.

Tol, R. S. J. (2002). Estimateds of the Damage Costs of Climate Change: Part 1: Benchmark Estimates. *Environmental and Resource Economics*. 21(1): 47-73.

Hong Kong. Transport and Housing Bureau. (2008). *Legislative Council Panel on Transport Hong Kong—Zhuhai—Macao Bridge*. Hong Kong: The Government of the Hong Kong Special Administrative Region of the People's Republic of China.

Tse, M. S., Chau, C. K., & Lee, W. L. (2004). Assessing the Benefit and Cost for a Voluntary Indoor Air Quality Certification Scheme in Hong Kong. *Science of Total Environment*. 320(2-3): 89-107.

United States. Environmental Protection Agency. (2015). *Heat Island Effect*. [Online]. Available from: http://www.epa.gov/heat-islands. [Accessed 28th January 2016].

United States. Department of Energy. (1982). *The National Environmental Policy Act of 1969, as Amended*. Washington, DC: U.S. Department of Energy. [Online]. Available from: http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/Req-NEPA.pdf. [Accessed 8th January 2016].

Welford, R., CSR Asia & Hong Kong University. (2008). *Climate Change Challenges for Hong Kong: An Agenda for Adaptation*. Hong Kong: CSR Asia & The University of Hong Kong. [Online]. Available from: http://www.csr-asia.com/report/report_cc_challenges_hk.pdf. [Accessed 9th January 2015].

Wong, K. K. (2009). Urban Park Visiting Habits and Leisure Activities of Residents in Hong Kong, China. *Managing Leisure*. 14(2): 125-140.

Xu, Y., Chan, E. H. W. & Qian, Q. K. (2011). Application of Benefit-Cost Analysis (BCA) to Evaluate Environmental Regulations. *16th International Symposium on*

Advancement of Construction Management and Real Estate (CRIOCM 2011). Chongqing, Friday 23rd to 25th September 2011. pp. 135-141.

Yu, C., Pan, W., Zhao, Y. S. & Li, Y. G. (2015). Challenges for Modeling Energy Use in High-Rise Office Buildings in Hong Kong. *Procedia Engineering*. 121: 513-520.

Yu, P. C. H. & Chow, W. K. (2007). A Discussion on Potentials of Saving Energy Used for Commercial Buildings in Hong Kong. *Energy*. 32(2): 83-94.

Yung, E. H. K & Chan, E. H. W. (2012). Critical Social Sustainability Factors in Urban Conservation: The Case of the Central Police Station Compound in Hong Kong. *Facilities*. 30(9-10): 396-416.

Zacharias, J., Stathopoulos, T. & Wu, H. (2001). Microclimate and Downtown Open Space Activity. *Environment and Behavior*. 33(2): 296-315.

Appendix 1. With a Discount Rate of 10%

Net Present Value when Only the Investment of Greenery is Accounted for

Year	Scenario 1	Scenario 2	Scenario 3
0	-51,600,000	-123,600,000	-123,600,000
1	173,948,831	403,176,186	266,708,092
2	378,993,222	882,063,628	621,533,631
3	565,397,215	1,317,415,848	944,102,302
4	734,855,389	1,713,190,593	1,237,346,549
5	888,908,276	2,072,985,816	1,503,932,227
…			
10	1,472,889,919	3,436,892,787	2,514,501,691
…			
25	2,200,447,339	5,136,125,373	3,773,526,390
…			
50	2,408,302,296	5,621,576,977	4,133,215,561

Net Present Value when All the Investment of Green Deck is Accounted for

Year	Scenario 1	Scenario 2	Scenario 3
-5	-240,000,000	-574,883,721	-574,883,721
-4	-1,330,909,091	-3,187,991,544	-3,187,991,544
-3	-2,322,644,628	-5,563,544,110	-5,563,544,110
-2	-3,224,222,389	-7,723,137,352	-7,723,137,352
-1	-4,043,838,536	-9,686,403,935	-9,686,403,935
0	-4,788,944,123	-11,471,191,739	-11,471,191,739
1	-4,649,697,259	-11,146,024,360	-11,230,760,309
2	-4,523,109,201	-10,850,417,652	-11,012,186,282
3	-4,408,029,148	-10,581,684,281	-10,813,482,622
4	-4,303,410,918	-10,337,381,217	-10,632,842,930
5	-4,208,303,436	-10,115,287,522	-10,468,625,029
…			
10	-3,847,771,253	-9,273,377,682	-9,846,109,981
…			
25	-3,398,599,830	-8,224,478,698	-9,070,545,462

…			
50	-3,270,276,615	-7,924,820,078	-8,848,975,417

Appendix 2. With a Discount Rate of 6%

Net Present Value when Only the Investment of Greenery is Accounted for

Year	Scenario 1	Scenario 2	Scenario 3
0	-51,600,000	-123,600,000	-123,600,000
1	182,460,107	423,054,533	281,436,700
2	403,271,529	938,766,356	663,546,793
3	611,584,192	1,425,286,944	1,024,028,014
4	808,105,571	1,884,268,631	1,364,104,637
5	993,503,099	2,317,270,222	1,684,931,640
…			
10	1,774,464,931	4,141,230,444	3,036,371,690
…			
25	3,119,998,137	7,283,764,362	5,364,792,091
…			
50	3,858,976,160	9,009,670,113	6,643,579,931

Net Present Value when All the Investment of Green Deck is Accounted for

Year	Scenario 1	Scenario 2	Scenario 3
-5	-240,000,000	-574,883,721	-574,883,721
-4	-1,372,075,472	-3,286,599,386	-3,286,599,386
-3	-2,440,071,200	-5,844,821,712	-5,844,821,712
-2	-3,447,614,339	-8,258,239,000	-8,258,239,000
-1	-4,398,126,735	-10,535,047,762	-10,535,047,762
0	-5,294,836,543	-12,682,980,557	-12,682,980,557
1	-5,120,933,836	-12,276,885,326	-12,382,710,409
2	-4,956,874,678	-11,893,776,618	-12,099,436,685
3	-4,802,101,888	-11,532,353,308	-11,832,197,322
4	-4,656,089,821	-11,191,387,921	-11,580,084,716
5	-4,518,342,589	-10,869,722,462	-11,342,242,635
…			
10	-3,938,101,136	-9,514,750,531	-10,340,365,265
…			
25	-2,938,392,686	-7,180,244,987	-8,614,212,699

…			
50	-2,389,344,494	-5,898,115,135	-7,666,195,361