Valuation of Wetland Flood Protection Services in the New Territories of Hong Kong using a Stated Preference Approach

by

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Abstract

Valuation of ecosystem services has recently been emphasized to arouse the attention of policymakers on natural capital. Stated Preference (SP) approach is a well-established method to estimate the Willingness to Pay for valuing ecosystem services. Flooding is a concern for the people in Hong Kong – a coastal city. Adopting SP's Choice Experiment approach and a randomized intercept survey, this research examined whether residents of Yuen Long District (YLD) in Hong Kong recognized the flood protection service provided by the Mai Po mangrove wetlands in YLD. By using Latent Class Modelling analysis, we found that most respondents supported the adoption of mangrove wetlands and green infrastructure (GI) for flood risk management and were willing to pay for the ecosystem services. Respondents that had past experiences with flooding, seemed to have greater concern on flooding and sea level rise and more willing to pay for flood risk management options.

Keywords: Mangroves; Stated Preference Approach; Discrete Choice Experiment; Latent Class Modelling; Willingness-To-Pay; Ecosystem Services; Hong Kong; Flood Protection Services

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Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1. Background

As a major Asian city with a large coastal population and economic assets, Hong Kong's trade, supplies, economy and social capital is greatly affected by heavy storms and flooding (Chan et al., 2013). Historically, Hong Kong has always been susceptible to heavy rainfall and typhoons due to its geographical location. Yet, in recent years, evidence of the intensity and frequency of coastal flooding, enhanced by climate change and rising sea levels, has become more concrete and concerning (Solomon et al., 2007; Webster et al., 2005; Lin et al., 2012). Figure 1.1 shows a flooding incident in Hong Kong in 2018.

Figure 1.1: Storm surge flooding from Typhoon Mangkhut in Hong Kong, 2018
(Photo. Extracted from: https://www.ejinsight.com/eji/article/id/1946196/20180917-Hong-Kong-begins-recovery-clean-up-efforts-after-Mangkhut-havoc)

As sea surface temperatures gradually increase owing to global warming, a more favourable environment is created for the formation of intense tropical storms. Between 1970 and 2004, the global sea surface temperature (SST) increased by 0.5 °C, with research verifying that SST > 26 °C is a requirement for tropical storms to occur (Lighthill et al., 1994). The sea water temperature at the nearby region of Hong Kong is higher than 26 °C in summer time. Figure 1.2 shows the average sea water temperature for the past seven years.

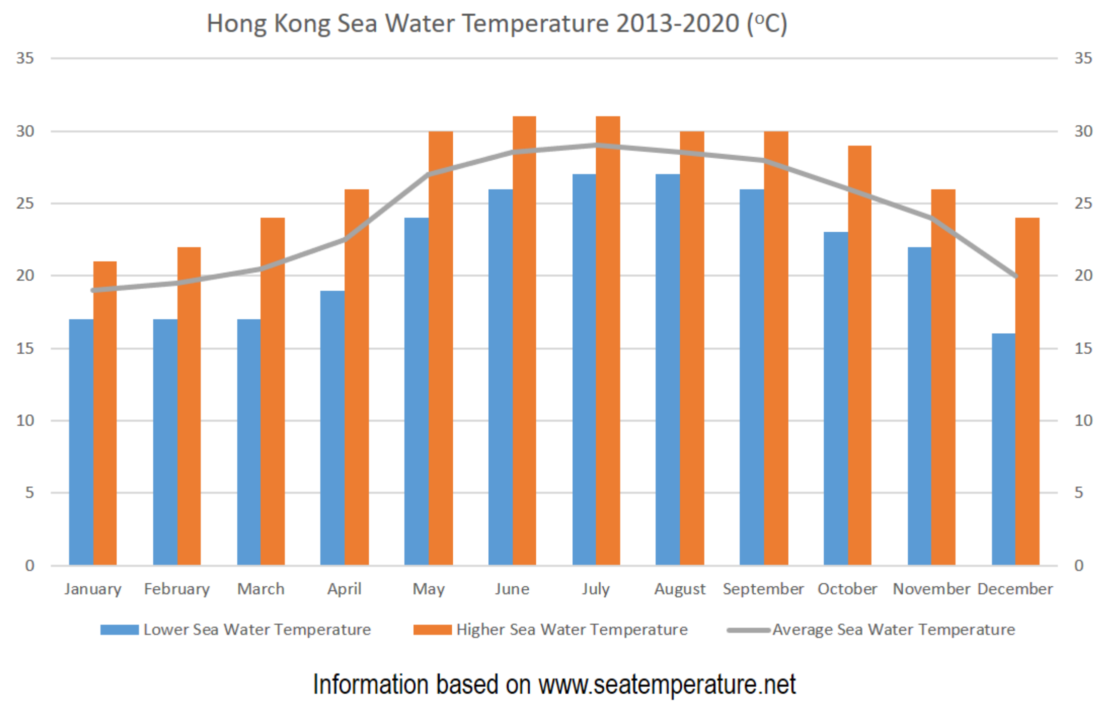

Figure 1.2: Sea Water Temperature Range in Hong Kong

Therefore, it is expected that the potential for more frequent and intense storms will continue to climb, as a result of global warming (Holland, 1997). Over the past 30 years, studies have shown that the intensity of tropical cyclones has already increased, with category 4 (maximum wind speed 201-251 km/h) and category 5 (>252 km/h) scale hurricanes almost doubling in terms of number from 1970 to 2004 (Webster et al., 2005). While these projections have estimated a 2-11% increase in the intensity of tropical storms by 2100, these projections also suggest a 20% increase in precipitation within a 100 km radius of the storm centres (Knutson et al., 2010).

Accompanying the rise in SST, sea level rise (SLR) is another major concern for coastal cities. Currently, the projection of global average SLR is around 20-25 cm by 2050, and 40-75 cm by 2100 (Church et al., 2013). Globally, it is predicted that by 2100, 0.3% to

9.3% of GDP will be lost to flooding annually, with 0.2% to 4.6% of the global population expected to be subjected to floods every year (Hinkel et al., 2014). SLR is also shown to augment storm surge levels in coastal areas, further strengthening the already frequent and intensified tropical storms discussed above. A modelling study shows that the combination of SLR and climate change could cause New York City to experience a 100-year surge (based on historical records) every 2-30 years, and a 500-year flood every 25-240 years, by 2100 (Lin et al., 2012).

The Civil Engineering and Development Department (CEDD) of the Hong Kong Special Administrative Region currently uses a hard-engineered flood risk management system to avoid and mitigate the adverse effects of flooding. This is done through a combination of land reclamation, seawalls and breakwaters to prevent storm surge overtopping, with a 1 in 100-200 year return period (CEDD, 2012a; 2012b). To manage runoff and storm surge within the urban district, 2,345 km of urban storm water drainage has also been constructed in Hong Kong (Chui et al., 2006). The two approaches have been able to cope with the majority of the typhoons and tropical storms that have struck Hong Kong in the past several decades.

The drainage system alone has received an investment of approximately 13 million Hong Kong Dollars (~1.67 million US Dollars [USD]) annually from 2011 to 2016 (Chan et al., 2018). According to information published by the Drainage Service Department of Hong Kong (DSD) (https://www.dsd.gov.hk/EN/Home/index.html), the number of flooding blackspots (areas that have a more frequent record of floods) has decreased by over 90% in the past 14 years, showcasing the emphasis the Government places on combating flooding. Figure 1.3 shows the flooding blackspot situation from 1995 to 2019.

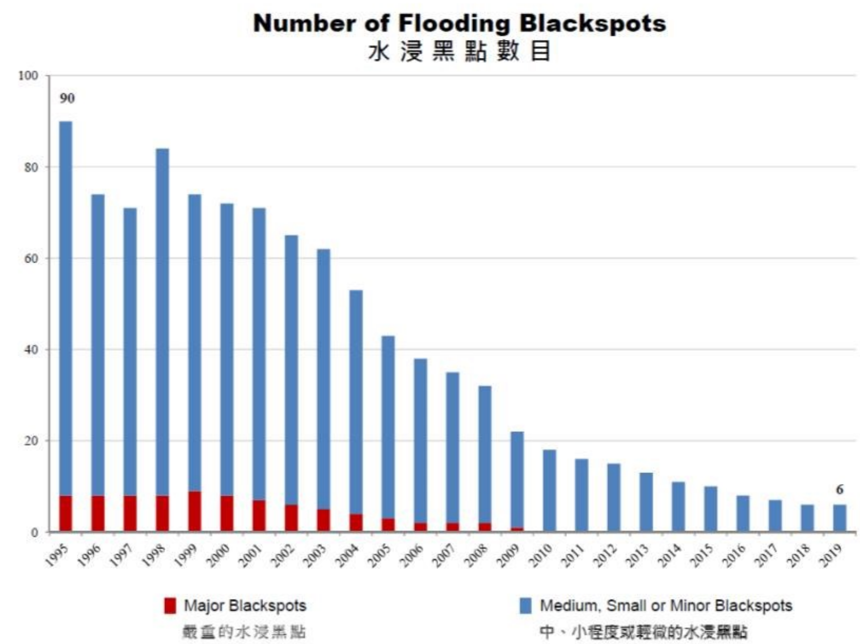

Figure 1.3. Number of Flooding Blackspots in Hong Kong (DSD, 2019)

However, these defences can still be surpassed. For example, Typhoon Hato in 2017 created a +3.62 m surge capable of breaking the 1 in 200 years return barrier system, causing flooding in urban residential and commercial areas and bringing an estimated economic loss of 110 million USD to the local economy (Choi et al., 2018). Figure 1.4 shows the flooding situation caused by Typhoon Hato in Hong Kong's urban district.

Figure 1.4: Flooding caused by Typhoon Hato in 2017
(Photo. Extracted from: https://hongkongfp.com/2017/11/06/)

For the past 60 years, the Hong Kong Observatory has recorded an average of +31 mm in SLR every 10 years in Hong Kong's Victoria Harbour (Figure 1.5). Based on a recent study that modelled the potential effect of SLR on Hong Kong, continuation of this trend could lead to the potential displacement of ~20,000-100,000 people in response to a 40-75 cm SLR by 2100. This shows that Hong Kong's current standards and approaches, which rely heavily on urban drainage and structural coastal defence, may not be able to withstand the higher frequency and strength of tropical storms associated with climate change. A description of Hong Kong's flooding problems provided by the DSD can be found in Appendix I.

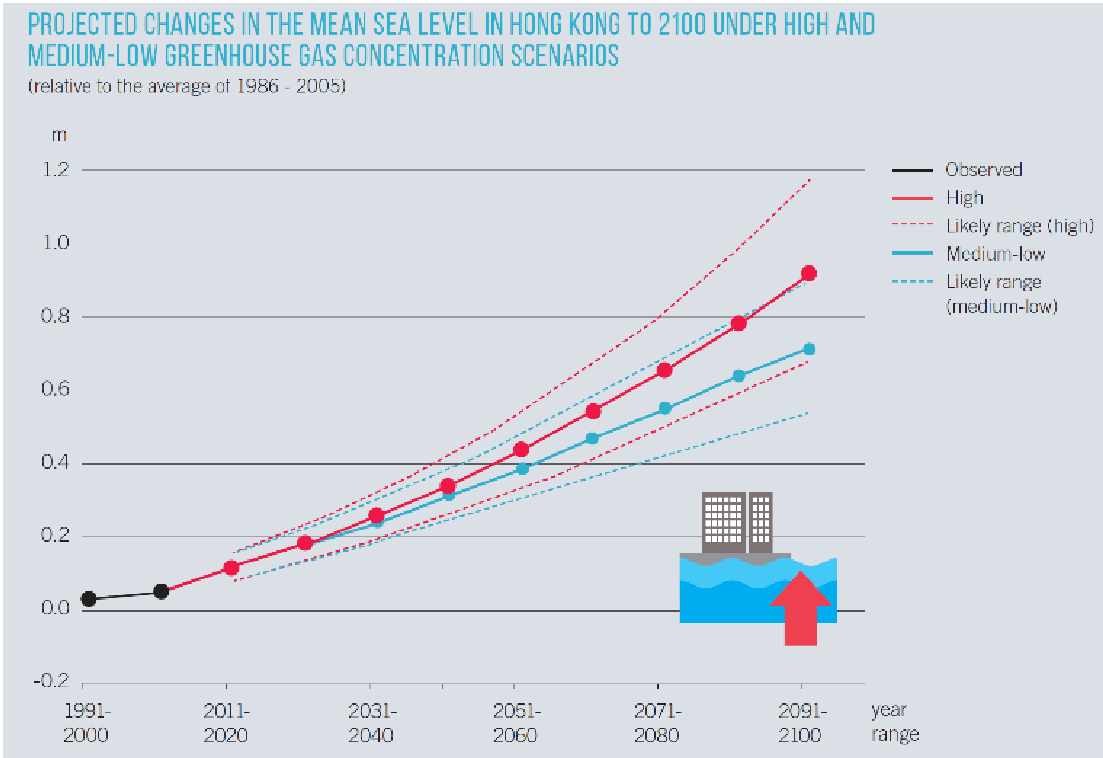

Figure 1.5: Projected Sea Level Rise
(Figure extracted from the Hong Kong Action Plan 2030+[1])

To reduce dependence on conventional measures, green infrastructure like wetlands could be utilised to assist in reducing storm water impact. Natural wetlands, such as mangroves, are capable of lowering wave energy and dissipating storm surges, thus reducing impact on property and infrastructure (Barbier et al., 2008). Both short period (Mazda et al., 1997; Moller et al., 1999) and long period (Zhang et al., 2012) wave energy attenuation by mangrove forests has been documented.

Alternatively, engineered wetlands, such as storm water detention ponds (or 'wet ponds'), can catch rainfall and surface runoff for temporary retention in a permanent pool of water, to be released at a controlled rate. Sediment loading is also slowed, leading to more deposit in the forebay, preventing erosion. During major storms, wet ponds can also utilise unused capacity to contain incoming waters, delaying the advance of the flood (Hossain et al., 2005; Walker, 1998).

[1] Environment Bureau (2017), "Adapting to Climate Change", Hong Kong Action Plan 2030+, published by Hong Kong Special Administrative Region Government.

A large wetland area called Mai Po is located along the northwest edge of Hong Kong's territory. Figure 1.6 shows the location of Mai Po. The Mai Po wetland can serve as a reservoir to alleviate flooding affecting the northwest areas.

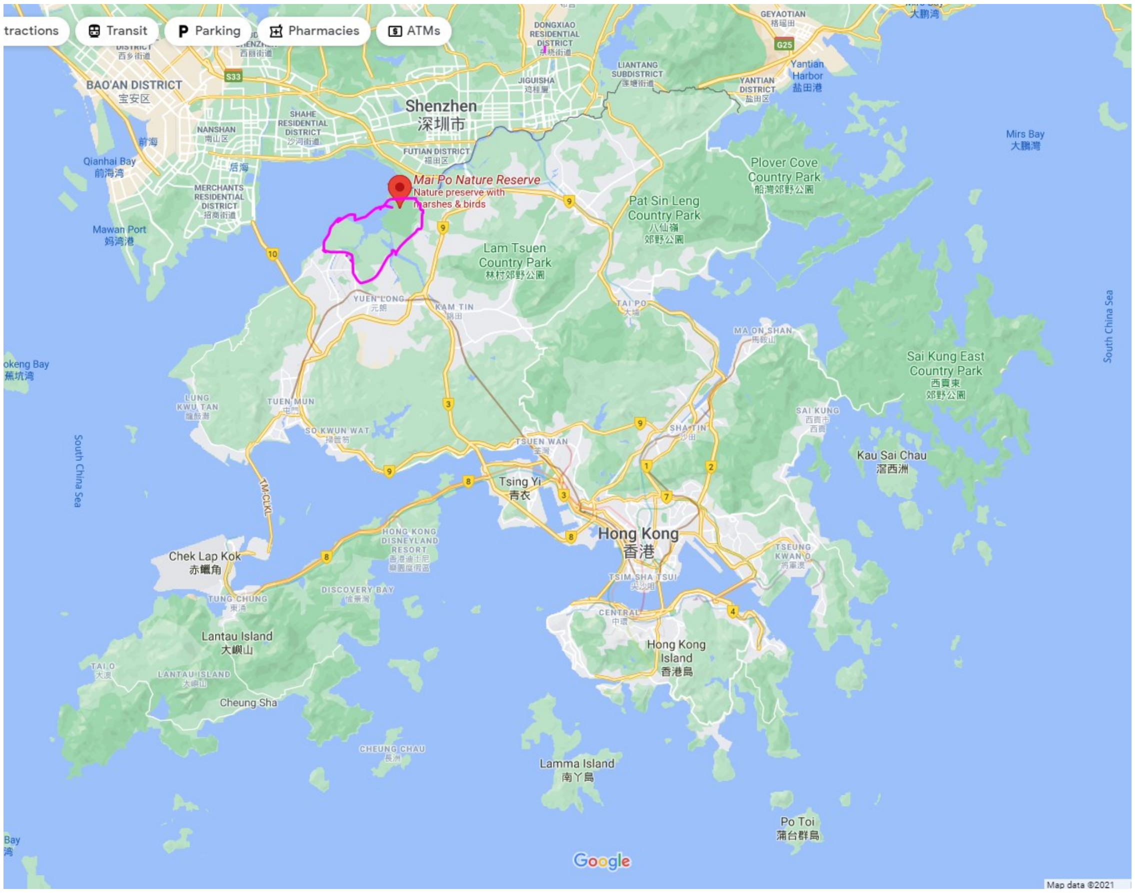

Figure 1.6: Location of Mai Po (from Google Maps)

1.2. Survey Background

Based on the information provided in section 1.1, a study investigating flood prevention in the Mai Po wetland and the northern New Territories of Hong Kong (Figure 3.1) is necessary. This is an area with unique geography and large swaths of coastal wetlands. At the mouth of the Shenzhen River, the wetlands consist mostly of mangroves and fish farms, which act as wet ponds and 'shelter' for various habitable areas (Figure 1.7 and 1.8).

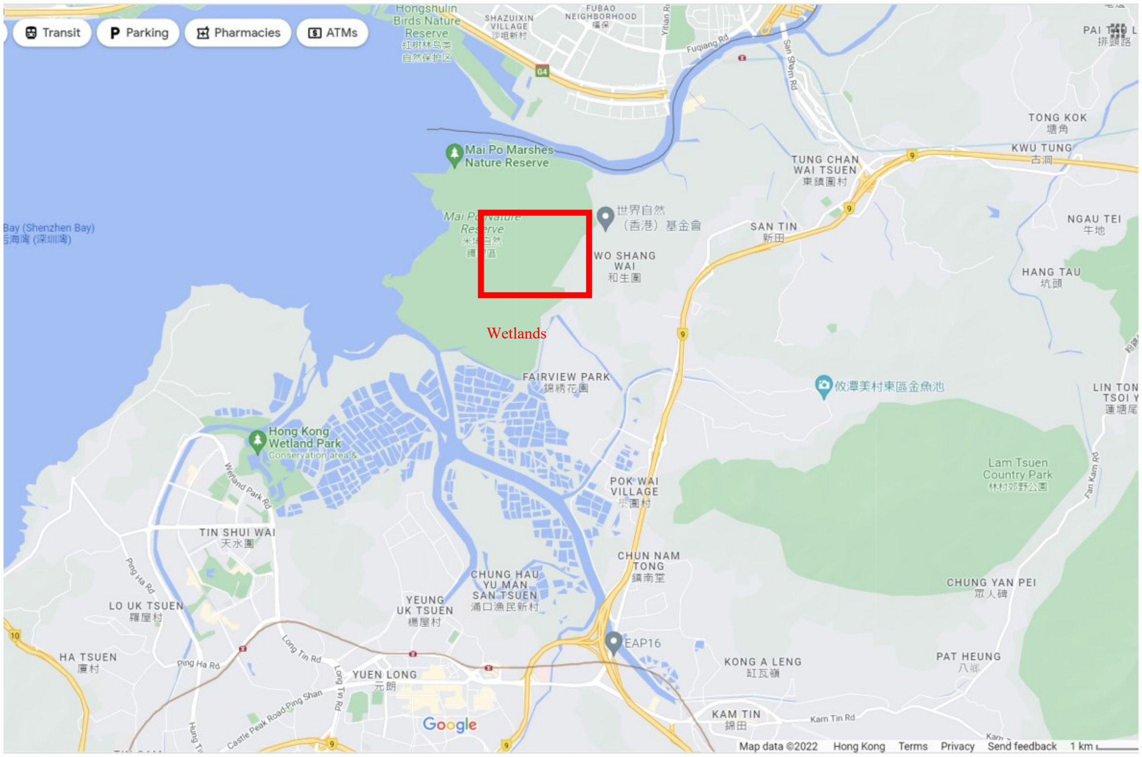

Figure 1.7: Location Map of Mai Po Wetland (from Google Map)

Figure 1.8: Mai Po Wetland
(Photo. Extracted from https://www.wwf.org.hk/en/wetlands/mai-po/)

Fish farming can be perceived negatively for its environmental impact on nearby marine ecosystems, increasing water pollutants, anoxic sediments and nutrient levels, as well as decreasing the oxygen level of the water column (Wu et al., 1994; Wu, 1995; Ervik et al., 1997). However, fishponds can also be perceived as providing a benefit through storm protection by acting like wet ponds to detain storm water and serve as buffer to store flooding water. For example, the fishponds near Mai Po, outlined in blue in Figure 1.9, might have lowered the impact of storm surges to the residential areas at the vicinity by acting as buffers .

The residents in these areas suffered from flooding (Figure 1.10 shows previous flooding incidents), which made their opinion valuable for this study. A stated preference approach was adopted to investigate the willingness to pay of nearby residents on flood protection services by mangrove wetlands. Accordingly, a survey was designed and conducted through face-to-face encounters in the Yuen Long District, located at the vicinity of the Mai Po wetland and fish ponds, as the main tool for data collection. The method of choice was used to investigate respondent perceptions of different scenarios, and allowed researchers to estimate relative values based on trade-offs.

Figure 1.9: Satellite Image of the Landscape Around the Mai Po Area in Hong Kong (from Google Earth)

Figure 1.10: Flooding in the Yuen Long District (near Mai Po)
(Photo. Extracted from
https://www.dsd.gov.hk/30A_monograph/eng/chapter_c2.php)

1.3. Flooding Prevention Works by Drainage Services Department (DSD)

Heavy rain storms and typhoons frequently trigger serious flooding in particular in the Yuen Long District (Figure 1.10 and 1.11 show flooding events at Yuen Long District). To prevent flooding, the DSD has implemented a range of projects to improve drainage in the territory, reducing the risk of flooding. These drainage improvements have also revitalised water bodies and created green spaces, which in turn, promote biodiversity.

Figure 1.11: Flooding in the Yuen Long District
(Photo. Extracted from
https://www.dsd.gov.hk/30A_monograph/eng/chapter_c2.php)

The DSD has pointed out that filling fish ponds and low lying areas in the flood plains to form large, paved storage yards has increased surface flows and blocked drainage paths (Leung, 2005). The fish ponds near Mai Po are designated by the Hong Kong Town Planning Board as wetland conservation or wetland buffer areas, and filling fish ponds may on one hand cause blockage of drainage paths in nearby areas, but may on the other hand serve as buffer reservoir to temporarily store flooding water.

Hong Kong has adopted conventional urban stormwater management, meaning that pathway and receptor management is prioritised through hard engineering to control floods. In urban areas, three underground cisterns – Tai Hang Tung, Sheung Wan and Happy Valley – with a total storage capacity of 160,000 m^3 have been constructed to temporarily store storm water (DSD, 2015). In the northwest part of Hong Kong, i.e., the area near Mai Po, the Yuen Long Bypass Floodway (Environment Bureau of HK Government, 2015) has been restored.

Apart from the aforementioned hard engineering projects to prevent flooding, the Mai Po wetland and the nearby fish farms, which are part of the wetland conservation area, can serve as buffer areas to provide coastal protection. The Mai Po is a sub-tropical ecosystem that includes a mangrove forest growing in intertidal zones, an interface between land and sea (Wang et al., 2019) providing coastal protection and other eco-services (Giri et al., 2011). However, Mai Po, similar to other mangrove forests around the world, has been suffering great habitat loss due to human activities and global climate change (Duke et al., 2007). There are many buildings and high-rises in adjacent areas, and human settlement and associated activities can affect the wetland's existence. It is, therefore, worth studying how willing nearby residents are to preserve the wetland and the associated fish farms. The following survey investigates this willingness, based on the stated preference approach.

1.4. Aim and Objectives

This study will focus on Mai Po and the northern New Territories of Hong Kong, both areas with unique geography and large swaths of coastal wetlands. A major part of the wetlands at the mouth of the Shenzhen River consists of mangroves and fish farms, which act as wet ponds and 'shelter' for various residential areas in the Yuen Long District. In some cases, fish farming is negatively perceived for its environmental impacts on nearby marine ecosystems by increasing water pollutants, anoxic sediments and nutrient levels, as well as decreasing the oxygen level of the water column (Wu et al., 1994; Wu, 1995; Ervik et al., 1997). However, fish ponds in the vicinity of Mai Po are an integral part of the wetland, serving as a buffer zone and providing storm protection.

It is hypothesised that:

(1) residents in the northwest part of Hong Kong support the use of the Mai Po wetland to protect nearby residential areas against flooding; and

(2) residents are willing to pay for additional flood mitigation alternatives.

The objective of this study is to test the above hypotheses through a survey of the opinions of residents of the Yuen Long District. During the course of this study, the following questions were also explored:

1) How do households located near coastal wetlands, such as those in Hong Kong, value the flood protection service of the wetlands? Does the prospect of SLR alter the perceived value of this ecosystem service or affect preferences for flood management?
2) Are residents willing to pay for alternatives to supplement conventional flood mitigation measures, including improving the wetlands to control flooding? Which alternative flood mitigation measures are most preferred by local residents?

1.5. Research Approach

A discrete choice-based model using spatial/geographic information (based on the Geographic Information System [GIS]) was used for this study. The Choice Experiment (CE) approach is based on choice-based analysis that has been applied in many research studies involving resource management (Viscusi et al., 2008; Hoyos, 2010), public policy (Vossler et al., 2012) and transportation (Hensher et al., 2000). It is a more comprehensive valuation technique than the contingent valuation method (CVM), where respondents are normally asked about their willingness to pay for a particular scenario. In CEs, respondents are asked to choose between different levels of bundled attributes. Price is merely considered as one of the attributes. This approach may be capable of determining the willingness to pay for each attribute, as compared to the composite value of the whole good obtained with CVM studies. Nevertheless, in real world scenarios, respondents may be uncertain of their choice (Li and Mattsson, 1995).

Identification of key and relevant attributes is important to the success of CE. Selection of attributes may initially be carried out through a comprehensive literature review. After selecting the attributes and preparing the survey questions, pre-testing the questionnaire is particularly important where there are cultural and language differences between the researchers and respondents.

Johnson et al. (2013) reported on the theoretical requirements for designs identifying CE preference attributes (parameters), and summarised and compared a number of available approaches for constructing experimental designs. Figure 1.12, extracted from Johnson et al. (2013), shows the key stages of developing CE via experimental design approach.

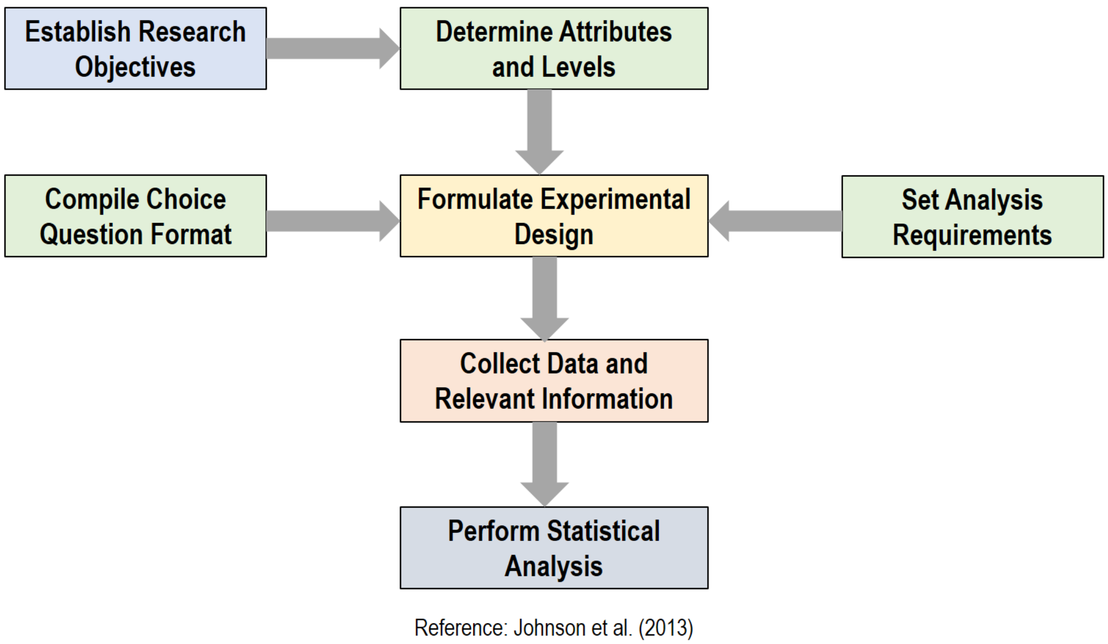

Figure 1.12: Key Stages of Developing Choice Experiment (Adapted from Johnson et al. (2013))

In constructing the experimental design that was used in formulating the CE exercise, the following three components formed the basis:

a) Attributes and Levels: Individual features of the study that can elicit trade-offs for the survey. Each attribute and level should distinctively and individually outline the possible values, outcomes and interventions/disturbances.
b) Choice Question Format: Of the different attribute combinations and levels, how would a series set of alternatives choices be presented to respondents for the best result?

c) Analysis Requirement: Information about the intended specifications for the choice model should be enclosed.

The CE was embedded in a face-to-face survey, after the screening process, the introduction and an explanation of the CE took place. This was taken to reduce biases in the CE, by giving respondents enough information to make rational choices without exhausting them with too many questions.

To find out whether living in an area with varying flood risk potential affects selection from the choice set, the approximate GPS coordinates of respondent addresses were collected using Google Maps, by asking them to point out the closet crossroads to their house. This spatial data was then compared with a flood risk topography map outlining Yuen Long District to analyse the correlation between this coefficient and the choices respondents are making.

1.6. Summary of Chapters

Chapter 1 introduces the background and motivation of the study. The scope of work and the aims and objectives of the study are included, and the methodology is briefly outlined.

Chapter 2 presents a literature review. Discussion on the use of CE as a way to carry out stated preference assessment, as well as previous research related to the use of CE in various studies, were reviewed.

Chapter 3 presents the details and theoretical background of the CE. This includes how the CE is structured for discovering whether residents of the New Territories in Hong Kong perceive a flood protection service provided by wetlands – the Mai Po mangrove area – and the estimated value of this service.

Chapter 4 presents the results of the surveys and problems encountered. Analysis of the data will also be presented in this chapter.

Chapter 5 presents the discussion and insights based on the analysis in Chapter 4.

Chapter 6 is the conclusion. The results of the study are summarised, and insights and limitations of the study are presented. A brief discussion of future work will also be included.

Chapter 2

Literature Review

2.1 Valuation of Ecosystem Services

The valuation of ecosystem services is commonly used to emphasise the significance of gains and losses from ecosystem change (Costanza et al., 1997; Guo et al., 2000; Hein et al., 2006). Although the valuation of ecosystem services and the methods used have been criticised (Toman, 1998; Plummer, 2009), this approach is accepted and applied in many instances (Marre et al., 2016; Richardson et al., 2015).

There are many methods to value ecosystem services. One approach is the use of stated preference methods that estimate willingness to pay (WTP). This approach has been widely used for valuing goods and services, even in the absence of market prices. Even non-market values directly yield a measure of value (Bateman et al, 2002). WTP is the maximum sum of money the individual would be willing to pay rather than do without an increase in some good such as an environmental amenity (Freeman III et al, 2014). In the case of Hong Kong, there have been very few stated preference surveys conducted that were designed to value ecosystem services (Chau et al., 2010; Lo & Jim., 2010) and none have looked at the flood protection services provided by coastal wetlands.

Chen et al. (2018) carried out two duplicate CE surveys in Brussels, Belgium and Guangzhou, China on the restoration of heavily modified and polluted river stretches in densely-populated urban settings, in order to compare the heterogeneity of the two groups of respondents. The study used a generalised multinomial logit model to analyse observed preference heterogeneity and unobserved scale heterogeneity simultaneously, while a latent class model (LCM) was used to present linkages between preference heterogeneity and individual characteristics. The results showed that respondents who could not recognise and appreciate the services provided by the urban river ecosystem tended to opt for the status quo more often. In addition, even though the preference heterogeneity of the respondents from the two regions were fairly similar across different attributes, respondents in Guangzhou displayed higher scale heterogeneity and thus, were much more uncertain when making selections in their Discrete Choice Experiment survey questions (Chen et al., 2018).

At a conservation site in Western Australia, CE was adopted to investigate preferences for ways to manage foxes and feral cats, which are considered invasive predators threating biodiversity (Subroy et al, 2018). In addition, Hansen et al. (2018) adopted CE to investigate development pressures on biodiversity and ecosystem services in the Upper Green River Basin in southwestern Wyoming from a recent energy boom. There are also many other studies concerning biodiversity and ecosystem services (Ruto and Garrod, 2009; Broch and Vedel, 2012; Kaczan and Swallow, 2013; Torres et al., 2013; Cranford and Mourato, 2014; Costedoat et al., 2016). CE has also been used to investigate Canadian consumer acceptance of gene edited versus genetically modified potatoes (Muringai et al., 2020).

Rid et al. (2018) also demonstrated that CE may offer great potential for in-depth analysis for participatory planning, such as allowing individuals to select their most preferred option from a range of planning alternatives. They found that presenting respondents with digitally generated film sequences and compared to a presentation of still images was reasonable.

When using CE, various implementation issues should be carefully considered. Mangham et al. (2009) indicated that conducting CE in the developing country context can involve issues not encountered in developed countries. For example, legal matters relating to information collection, the right to conduct the survey, respondents' cultural behaviour and so on, may all be issues affecting implementation of the 'experiment'.

A discrete choice experiment, also referred to as 'choice experiment' (CE), is a type of stated preference method and is regarded as a method for estimating WTP for a service or a good (Louviere and Woodworth, 1983; Louviere et al, 2000).

Veronesi et al. (2014) considered that climate change would lead to extreme rain events in Switzerland, causing an increase in the risk of wastewater flooding and leading to missed legal water quality targets. A study was commissioned to determine residents' willingness to pay to reduce ecological and health risks from combined sewer overflows in rivers and lakes. A discrete CE was conducted on a large representative sample of the population in Switzerland, which found that about 71% of respondents were willing to pay a higher annual local tax to reduce the risk. The study also showed that climate change perception had a significant effect on the willingness to pay to reduce the risks.

Latent class modelling is a technique used in stated preference studies to group people by preferences instead of observed characteristics. In order to bring the importance of services provided by natural capital to policymakers' attention, valuation of ecosystem services with respect to the preferences of different groups of people has been an increasingly popular exercise, used to emphasise the significance of gains and losses from ecosystems (Costanza et al., 1997; Guo et al., 2000; Hein et al., 2006).

There are many methods for valuing ecosystem services. One approach is the use of stated preference methods that estimate WTP. Contingent valuation is a method of estimating the value a person places on a service or good. A simple approach is asking people to directly indicate their WTP for a service or a good. Contingent valuation is regarded as a simple, flexible, nonmarket valuation method that is widely used in cost–benefit analysis and environmental impact assessments (Venkatachalam, 2004). This approach has been widely used for valuing alternative choices of goods and services, even when they do not have market value. Even these non-market value preferences yield a measure of value (Bateman et al, 2002).

Contingent valuation is always integrated with the state preference approach, in which respondents of the corresponding survey are provided with a set of descriptions of alternatives and asked to express their preferences in decreasing order, or by giving a rating value for each preference (Louviere et al., 2000). This approach has been widely used in many fields, especially in valuing ecosystem services (Olsen et al., 2020).

In the case of Hong Kong, there have been very few stated preference surveys designed to value ecosystem services (Chau et al., 2010; Lo & Jim., 2010), and none have looked at the flood protection services provided by coastal wetlands. Two duplicate stated preference surveys conducted in Brussels, Belgium and Guangzhou, China compared respondents' preferences and influencing factors toward restoration of heavily modified and polluted river stretches in densely-populated urban settings (Chen et al., 2018).

One of the factors affecting the validity of the stated preference approach is ensuring respondents understand the attributes of their choice. It is necessary to describe clearly the choices that the respondents are asked to select. Recent studies have widely used images, videos and virtual reality to portray complex attributes to survey respondents (Rossetti and Hurtubia, 2020).

2.2 Wetland Ecosystem Services and Flooding in Hong Kong

A wetland is an ecosystem that is permanently or seasonally flooded by water. Wetlands provide important and diverse benefits to people around the world, such as providing drinking water, mitigating flood risk, regulating local climate and underpinning human wellbeing in towns and cities (Ramsar, 2013). Such benefits can be classified as ecosystem services. The concept of an ecosystem service provides a crucial bridge between biodiversity/ecosystem function and human wellbeing (Reid and Huq, 2005).

The Hong Kong Government stated in a report (Environment Bureau, 2016):
'Our city receives many "ecosystem services", in forms ranging from life's necessities such as food from our lands and seas, oxygen production and climate regulation from our trees, to non-material cultural enrichment, such as aesthetic and spiritual values, recreation and education opportunities.'

Hong Kong is located in a sub-tropical region and every year, faces heavy rainfall and typhoons. During an entire year, rain falls an average of 138 days, accumulating up to 2400 mm (https://www.hko.gov.hk/en/climate_change/proj_hk_rainfall.htm) of rain water. Flood prevention, especially in urban areas, should be seriously considered by the Hong Kong Government.

The government has commissioned several extensive projects for constructing flood prevention measures in Hong Kong. Particularly in the northwest (Yuen Long District), the DSD has initiated drainage improvement works for decades. The key improvement project was construction of main drainage channels, namely the Yuen Long Bypass Floodway (Figure 2.1).

The DSD plans to continue to initiate drainage improvement work for flood prevention. A report published by the DSD (Sustainability Report 2017-18, River Revitalisation for the Good of Water: https://www.dsd.gov.hk/Documents/SustainabilityReports/1718/en/text/river_revitalisation.html) indicated that apart from the fundamental purpose of drainage, the improvement work aims to increase river biodiversity. The channel (river) was integrated into the surrounding environment by introducing green elements, with the goals of fostering a water-friendly culture and promoting Hong Kong's sustainability to cope with the threats of flooding due to climate change. This message implied that the Hong Kong Government has basically dealt with flooding through the construction of physical flood prevention measures, although they have taken the ecosystem into consideration.

The Environmental Report (https://www.dsd.gov.hk/Documents/EPR/EPR2003/TC/4_2.htm) published by the DSD states that it is government policy to support drainage projects that establish large tracts of vegetated river banks, and preserve meandering river channels, wetland features and mangrove habitats. To reduce flood risk in Yuen Long and other lower lying areas, the Yuen Long Bypass Floodway was constructed to divert storm water from south east of

Yuen Long into the Kam Tin River. This project created two key ecological features – a wetland and in-channel shallow ponds – and addressed both flood prevention and ecosystem priorities. Nevertheless, research on ecosystem services in Hong Kong is still limited (Environment Bureau, 2016). In particular, there is no study on the opinion of residents in the Yuen Long District on the wetland and its flood prevention function.

2.3 Spatial Information

This study also employed geographically weighted choice models for modelling spatially clustered preferences (Budzinski et al, 2018). For example, an analysis of the spatial effects of choice on WTP for forest management in Poland indicated that the higher the ecological value of forests in a respondent area, the higher the preference to extend areas of national forest protection, i.e., there was more willingness to pay for forest protection (Czajkowski et al., 2017). In another study, Campbell et al. (2009) reported findings from a CE survey designed to estimate the economic benefits of policy measures to improve rural landscapes in the Republic of Ireland, analysing the spatial dependence of these estimates. Another study in United Kingdom used the CE approach to examine how the value of environmental goods and services is influenced by an individual's residence (Badura et al., 2020).

Chapter 3

Approach and Methodology

3.1 Study Design

3.1.1 Initial discussion

As an initial step, background information on Hong Kong's wetlands (mangrove and fish ponds) was collected from local experts and the intention and structure of our study was also discussed. The experts in Hong Kong included:

a) Hong Kong government officials (such as the Drainage Services Department, (https://www.dsd.gov.hk/EN/Home/index.html), Hong Kong Special Administrative Region Government, which deals with flood defence[2]);

b) members of non-governmental organisations (NGOs), such as the World Wildlife Fund-Hong Kong (WWF-HK) (https://www.wwf.org.hk/en/); the WWF-HK is responsible for managing the Mai Po Nature Reserve; and

c) professors from University of Hong Kong (Department of Geography, University of Hong Kong https://www.geog.hku.hk/).

Feedback from the aforementioned experts concerning the flooding experience in Hong Kong and the structure on the survey was obtained in order to refine the study's design, as well as the survey itself.

3.1.2 The questionnaire

Having collected the comments and feedbacks from the experts and discussed with the staffs of WWF-HK, a set of questionnaire was prepared for interviewing the target respondents. The questionnaire (Appendix II) was structured in the following parts:

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[2] One of the core business (https://www.dsd.gov.hk/EN/CoreBusiness/Flood_Prevention/index.html) of the Drainage Services Department is "flood prevention". The flood prevention strategies are shown on the department's website: https://www.dsd.gov.hk/EN/Flood_Prevention/Flood_Prevention_Strategy/index.html.

(1) Screening – An initial screening of the respondents to see whether they live in Yuen Long District or not.

(2) Introduction and housing information – where introductory questions and housing questions such as how long they have lived in Yuen Long District for and which type of housing they lived in.

(3) Awareness of local flooding – this section set to ask respondents their concern on flooding, SLR and their past experience with local flooding.

(4) Flood risk management alternatives – this section introduced mangrove wetland management, green infrastructure and adaptation strategies as flood risk management alternatives (details to be given in section 4.2.4 below). Respondents were then asked whether they consider each alternatives important as a flood control method or not.

(5) The choice experiment – A block of 6 choice questions with different flood mitigation programs bundled with different attributes and levels for the choice experiment as described below (section 3.1.3 below).

(6) Awareness of coastal wetland and mangroves – this was set to ask the respondents if they were familiar with the wetland, in particular Mai Po Natural Reserve.

(7) Attitude towards conservation and the environment – A section set to collect the attitude of the respondents on environmental issues.

Dunlap (2008) established a survey-based metric measurement for NEP. Originally, it was designed to measure the environmental concern of groups of people using 15 statements, and respondents of the survey gave the strength of their agreement or disagreement for each statement. Responses to these 15 statements were statistically analysed for environmental concern. The New Environmental Paradigm (NEP) scale is a measure of endorsement of a "pro-environmental" view. It is considered that people's attitudes can be explained by underlying values or a paradigm.

In order to simplify the data collection process and attribute to the NEP idea, we attempted to measure the "Attitudes Towards Environment" (ATE) in this study.

We adopted a 5 level Likert Scale to evaluate 8 statements in section F of the questionnaire. The number of variables were then processed using Principal Component Analysis approach (implemented in SPSS) and the outcome became a super variable of ATE which was then used in data analysis.

(8) Demographic information – this was set to collect the demographic information of the respondents, including their age, income level, education level and etc.

3.1.3 The choice experiment (CE)

The CE exercise presented different proposed government flood prevention measures (programs), each with a different investment and protection plan for the studied area (Mai Po). Respondents were asked to choose their preferred program from each set presented to them in repeated tasks. The programs were described by four attributes and a special context variable attribute whose levels were varied under each program. The attributes selected for use in this study were:

a) Government **Adaptation Strategies**, including actions to reduce potential flood and storm damage. Examples in Hong Kong include awareness campaigns, early warning systems, evacuation plans and development restrictions in low-lying areas.
b) **Green infrastructure** combining natural and green engineered structures that can divert or retain storm water. Examples in Hong Kong include flood retention ponds, green river channels with constructed wetlands, green roofs and permeable pavements.
c) Increases of **Mangrove wetland** area protected in Mai Po, which affects the amount of ecosystem service that can be provided by the mangroves. Examples in Hong Kong include the Mai Po Nature Reserve in the Yuen Long District and the Ting Kok mangrove forest at Tolo Harbour.
d) **Payment vehicle** ($1,000 to $50 HKD): One-time payment by each household in Yuen Long District to a hypothetical flood control trust fund set up by an NGO and supported by the Government.

In essence, the choice task required participants to make trade-offs among the various flood protection attributes ((a), (b) and (c) above), with mangroves serving as a pro-environmental option, investment in engineered defence as a conventional option and green infrastructure falling somewhere in between. Each possible choice included an amount for the annual payment per household that would be required to fund the proposed combination of attributes (attribute e? above). Responses also can be used to test how participants perceive the other ecological benefits that mangroves provide, aside from flood protection, and to what extent these influence their choices.

More specifically, respondents were shown two different programs and the existing situation, and asked to pick which option they would prefer most. Before answering the question, respondents were asked to consider if they would contribute to additional costs, as one-time per-household payment, from their own household budgets to fund the programs (Tables 3.1 and 3.2 show examples of the programs the respondents could select from in different scenarios.). The Choice Cards were delivered in 3 blocks, each with a series of 6 choice questions embedded in the middle of the questionnaire, with a total of 18 choice sets, and each respondent would only see one block of choice questions in their survey.

There was also a special context variable of **Sea Level Rise (SLR)** that had only been shown on latter half of the choice cards. This presented a scenario emphasizing that SLR could occur in the future. The SLR scenario was not shown for the first 3 choice cards, and starting from the 4th and up to the 6th choice cards, a “yellow bubble” on top of the choice cards (Table 3.2) with the SLR scenario statement was shown to the respondents. The intent was to observe whether respondents would make different decisions under the influence of the presentation of this external factor when comparing to the choices they made in the first 3 choice cards.

Before conducting the CE, the respondents were shown an information package card (Figure 3.2) which contains brief explanation on the three flood mitigation alternatives shown in the CE. This was to convey basic knowledge to the respondents so that they could make informed decisions even if they had no previous knowledge on the subject. Surveyors would explain the information card verbally as well to assist the respondent. An example choice card was also provided alongside the information card to guide the respondents through the CE and help them familiarize the process.

The administrators of the survey were to rotate across the block of choice sets after conducting 10 surveys with each block to increase the variety of attribute combinations exposed to the respondents for them to react to.

Once the CE attributes and choice set design were determined, a questionnaire was developed (shown in Appendix II), including a Chinese version, as the field interviews/surveys were conducted in Chinese (Cantonese)[3]. A pre-test was arranged with local residents in the research area, who were recruited randomly. The pre-test volunteers were local residents of the Yeung Long District who know Cantonese well and were representative of normal pedestrians in the study area, who could test and provide feedback about the translation, clarity, wording and interpretation of the survey.

3.2 Data Collection

The field surveys were conducted from June to August in 2019 (about three months), resulting in 511 completed responses for a 95% confidence level, in which arithmetic mean (as a statistical value) of the population is within the margins of error which were established for the survey based on the said sample, calculated using Salant and Dillman (1994)'s significance table and based on a population of 3.6 million in the New Territories District. With the support of the World Wildlife Fund Hong Kong (WWF-HK), two 'surveyors' were recruited, who were college students with the ability to learn and conduct the survey appropriately. The team of 3 surveyors including myself, conducted the surveys in the areas shown in Figure 3.1. Surveyors randomly approached pedestrians in crowded areas, such as parks, shopping malls and community hubs, where people may have time to respond to a survey, requesting responses to the survey. Surveyors were assigned to conduct surveys at different sites in the vicinity of the wetlands in the Tin Shui Wai area

[3] Cantonese, a dialect commonly used in Hong Kong

and Yuen Long Town Center area of the Yuen Long District. All surveyors worked separately at various survey sites, and rotated between sites every two to three days to lower biases.

Data were coded according to question type and response and entered into spreadsheets daily and coded according to question type and response. The first 20 to 30 surveys were used as pilot tests and modifications. In addition, at the end of each survey, the GPS coordinates for the approximate addresses of each respondent and elevation of respondent residences were collected using Google Maps after getting the respondents' consents. The data were recorded based on the GIS System (ArchGIS) and converted into digitised spatial data to examine the spatial effects on respondents' preferences.

Figure 3.1: Field Surveys Conducted Areas (Tin Shui Wai area and Yuen Long area are in the Yuen Long District)

Figure 3.2: Information Package Card about the flood mitigation alternatives presented to respondents before CE

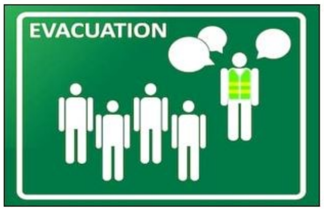
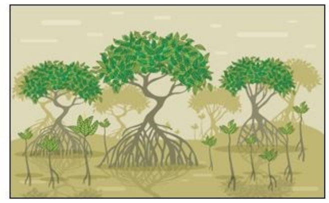
Adaptation Strategies	*Green Infrastructure*	*Mangroves Management*
		
Adaptation strategies include actions to reduce potential flood and storm damages. Examples in Hong Kong include awareness campaigns, early warning systems, evacuation plans and development restrictions in low-lying areas.	**Green infrastructure** combines natural and engineered structures that can divert or retain storm waters. Examples in Hong Kong include flood retention ponds, green river channels with constructed wetlands, green roofs and permeable pavements.	**Mangrove forests** can reduce storm damages by lowering flood energy and dissipating waves. Examples in Hong Kong include the Mai Po Nature Reserve in Yuen Long District and Ting Kok mangrove forest in Tolo Harbour. ◦

Table 3.1: Programs Shown to Respondents

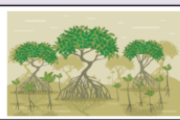
Choose your preferred flood risk management program for Yeung Long District over a 10 year period, assuming these are additional to existing activities and spending [Please remember that this is only a hypothetical exercise and that we will not be collecting any money from you]				
Characteristics of the programs		**Program A**	**Program B**	**Existing Situation**
Mangrove Management		Increasing 80 Hectare of mangrove areas through restoration	Increasing 40 Hectare of mangrove areas through restoration	No restoration to increase mangrove areas
Green Infrastructure		20 additional green infrastructure projects	40 additional green infrastructure projects	No additional green infrastructure projects
Adaptation Strategies		Scale of strategies will expand to implement in all areas potentially affected in 10 years time.	Scale of strategies will expand to implement in all areas affected currently.	Maintaining strategies at current scale (only implementing to seriously affected areas)
One-time payment by each household in Yuen Long		$750	$250	$0
Select your preferred option →		○	○	○ 1

Table 3.2: Programs Shown to Respondents (SLR Scenario)

Now assume that Hong Kong's sea level will rise significantly in future. Choose your preferred flood risk management program for Yeung Long District over a 10 year period assuming they are additional to existing activities and spending.

Characteristics of the programs		Program A	Program B	Existing Situation
Mangrove Management		Increasing 80 Hectare of mangrove areas through restoration	Increasing 40 Hectare of mangrove areas through restoration	No restoration to increase mangrove areas
Green Infrastructure		20 additional green infrastructure projects	40 additional green infrastructure projects	No additional green infrastructure projects
Adaptation Strategies		Scale of strategies will expand to implement in all areas affected currently.	Scale of strategies will expand to implement in all areas affected currently.	Maintaining strategies at current scale (only implementing to seriously affected areas)
One-time payment by each household in Yuen Long		$250	$100	$0
Select your preferred option →		○	○	○ 2

3.3 Challenges

The surveys were conducted during the summer of 2019 in areas near Mai Po. Surveys were successfully conducted in some residential areas, such as the Tin Shui Wai District, and other residential areas near the Mai Po wetland, and most people interviewed lived in that area. However, it was noted that most people lived in well-developed areas, with modernised shopping malls and high-rise residential buildings, with the roads were also well constructed (Figure 3.4), with good drainage systems. It was not surprising that respondents living in this area had few concerns about flooding.

Figure 3.3: Residential areas and roads at Tin Shui Wai area (Photo extracted from https://zh.wikipedia.org/wiki/File:Tin_Shui_Road.JPG)

Surveys were also planned to conduct in the villages, i.e. interviewing the respondents living in the 'villages' (Figure 3.4). However, these surveys were not successful due to social events that took place in mid-2019 in Hong Kong. At that time, people living in the 'villages' near Mai Po wetland obstructed outside visitors to approach and enter the villages. In view of this safety issue, efforts to conduct surveys in the 'villages' (i.e. interviewing respondents in the villages) were abandoned. However, we were able to intercept some people, who were residents of the villages, at the survey points in Tin Shui Wai area and Yuen Long Town Center area, and successfully interviewed them. The limited data collected for this group of people were included in the CE analysis. In addition, a separate analysis on the responses of this group of people was also presented in Chapter 4.

Figure 3.4: Hang Hau Tsuen, ‘village’ near the coast of Yuen Long District (Photo taken by Yui Chi Edwin Lo)

3.4 Data Analysis

The data were used to estimate the economic value of coastal wetlands in the Yuen Long District, based on the preference choices from the CE. The results were analysed using a regression model (the latent class model) and GPS coordinates for the approximate addresses of each respondent were converted into digitised spatial data for performing the regression analysis. The Random Utility Model was the basis for this analysis. The random utility model describes demand for a particular service as a choice among alternative services. The consumer maximises utility, choosing among alternatives defined by component attributes and the levels of those attributes. The utility of an alternative depends on the attributes associated with the alternative, as well as the attributes associated with the consumer (age, gender, education level, etc.). The CE constructs the random utility function of selection, transforming the selection problem into a utility comparison problem, maximising utility to represent the respondent's choice of the best program in the selection set.

To statistically analyse the CE data and to test for heterogeneity in preferences, I used Latent Class Modeling (LCM). Lazarsfeld and Henry (1968) introduced LCM as a way of formulating latent attitudinal variables separately from survey items. Different from factor analysis, which assumes continuous latent variables, LCM applies to categorical latent variables. LCM considers that an individual's choice behaviour is determined by not only choice related attributes but also, latent heterogeneity due to variation in individually specified characteristics (e.g., demographics), which are unobserved by the investigator (Greene and Hensher, 2003). Specifically, the model calibrates the respondents into a discrete number, Q of latent segments/classes, while a parameter vector for each segment is estimated. Thus, the unobserved preference heterogeneity can be captured and accommodated. The posterior probability that each respondent belongs to any of the segments is determined by the respondent's choice observations and characteristics.

In this study, I applied standard latent class analysis to the choice experimental data to model the different preferences of the residents in Yuen Long District about the flood risk management approaches. The choice of different flood risk management approaches was differentiated by different attribute levels.

To implement the latent class analysis, I used Latent GOLD[4], a statistical package developed by Jeroen Vermunt and Jay Magidson (author of SPSS CHAID and SPSS GOLDMinR). It implements latent class analysis within an interactive graphics environment. Its three modules support latent class cluster analysis, latent class factor analysis and latent class mixture regression. The data format of Latent GOLD is compatible with SPSS .sav files, as well as with ASCII files. The user guide can be found on the following website:
https://www.researchgate.net/publication/254809109_Latent_GOLD_choice_user's_guide.

3.5 Summary

This chapter described the methods I used in this study, including the concept and design of the choice experiment, the data collection approach and the analysis methods. In this study, CE was implemented, and the details and locations of the surveys were provided. Problems with the process were identified. Although the respondents were not ideal, 511 people were surveyed, and the sample size with respect to the area population was good.

[4] Latent GOLD: https://www.statisticalinnovations.com/latent-gold-5-1/

Chapter 4

Results

4.1 Survey Data Analyses and Processing

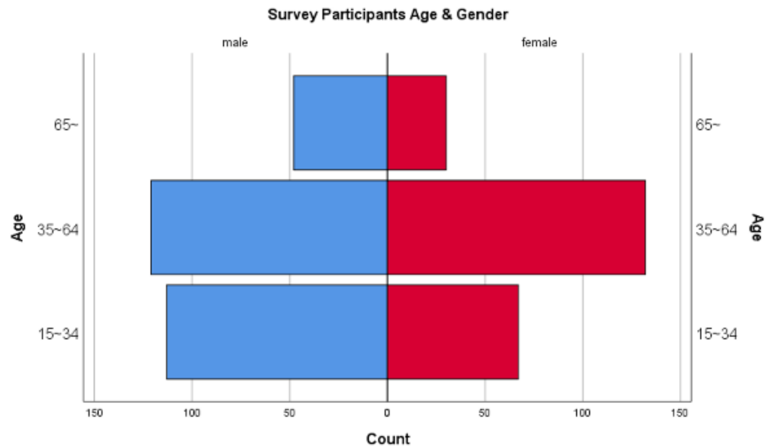
In Chapter 3, I discussed how the survey data were collected. In this section, I discuss the characteristics of the survey data, the locations of the respondents and the relationship of respondents' views with their locations.

4.1.1 Characteristics of the Survey Data

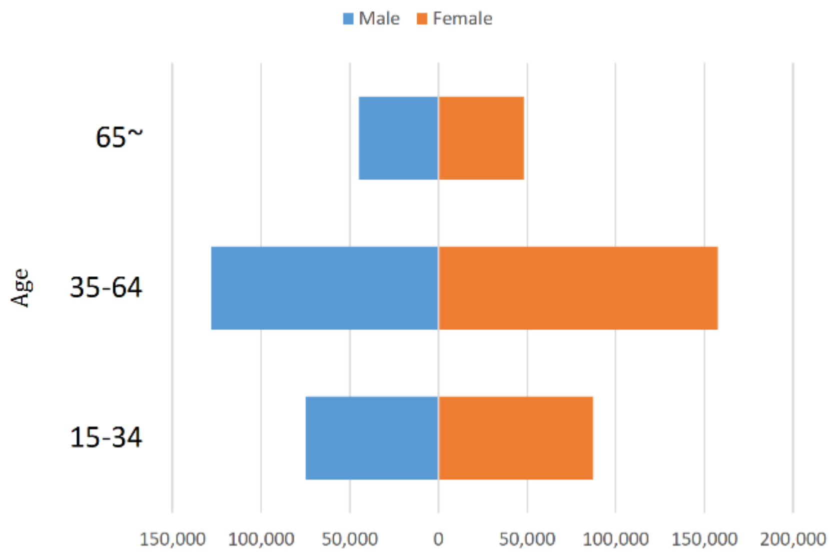
There were 511 respondents in total for this survey, of which 463 provided usable answers to the questionnaire after we removed respondents that only chose "status-quo" for all choice experiment questions. Figure 4.1 shows that the age and gender distribution of the respondents is similar to that of the population in Yuen Long District. According to census information, over 50% of the population falls into the age group of 34 to 65. This matches the age distribution of the respondents shown in Figure 4.1. The detailed age distribution in Yuen Long District is given in Appendix III.

Figures 4.2 and 4.3 show the distribution of education level and income level for the respondents and for the Yuen Long District; the distribution patterns here are also similar between the two groups.

Moreover, over 50% of the population falls into the income group of 10,000 to 19,999 Hong Kong Dollars, which matches the income distribution pattern of the respondents shown in Figure 4.3. A detailed income distribution in the Yuen Long District is given in Appendix III. This indicates that the survey sample characteristics align well with the information provided by the Hong Kong Census for the Yuen Long District.



Age and gender distribution of the respondents



Age and gender distribution of the peopl in Yuen Long District

Figure 4.1: Age and Gender Distribution

(Census data sourced from HK Government Census and Statistics Department)

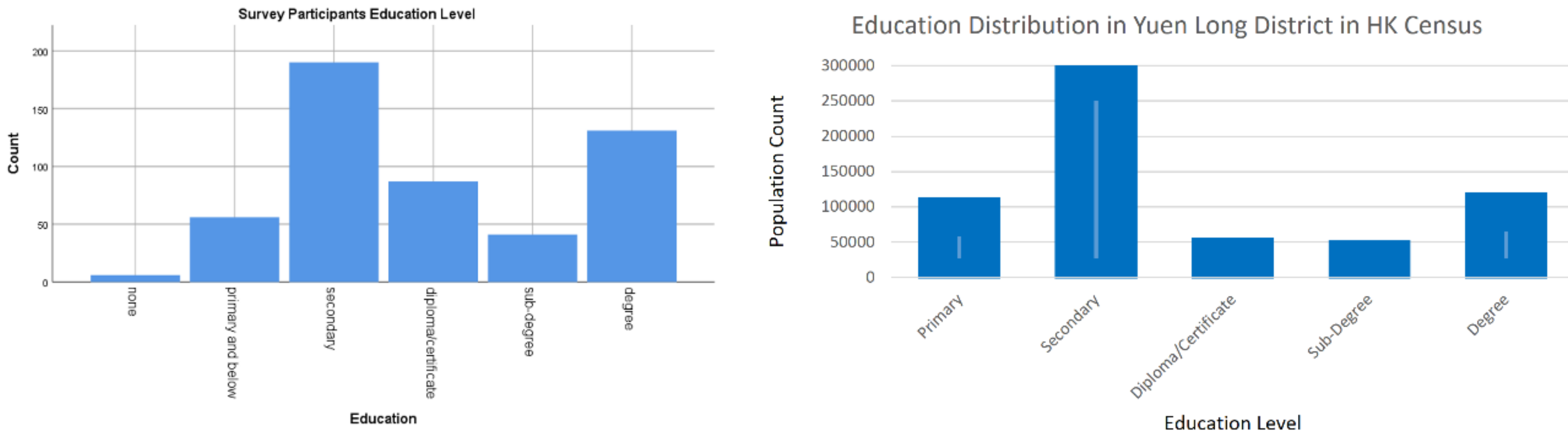


Figure 4.2: Distribution of Education Level

(Census data sourced from HK Government Census and Statistics Department)

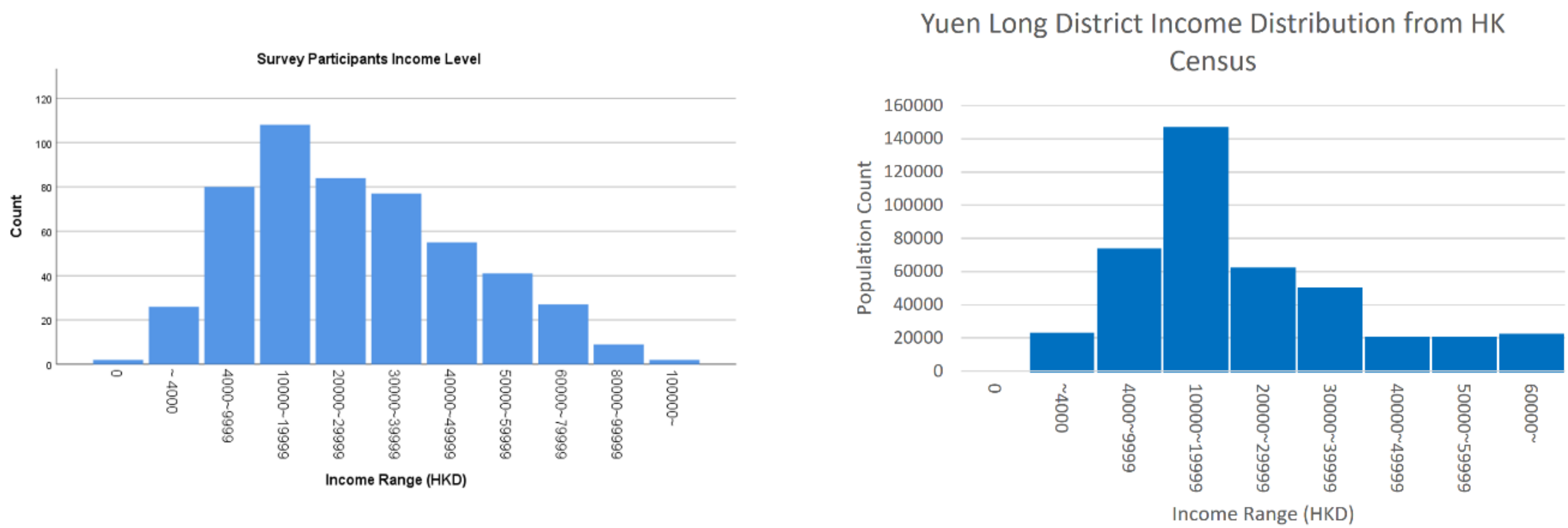


Figure 4.3: Distribution of Income Level

(Census data sourced from HK Government Census and Statistics Department)

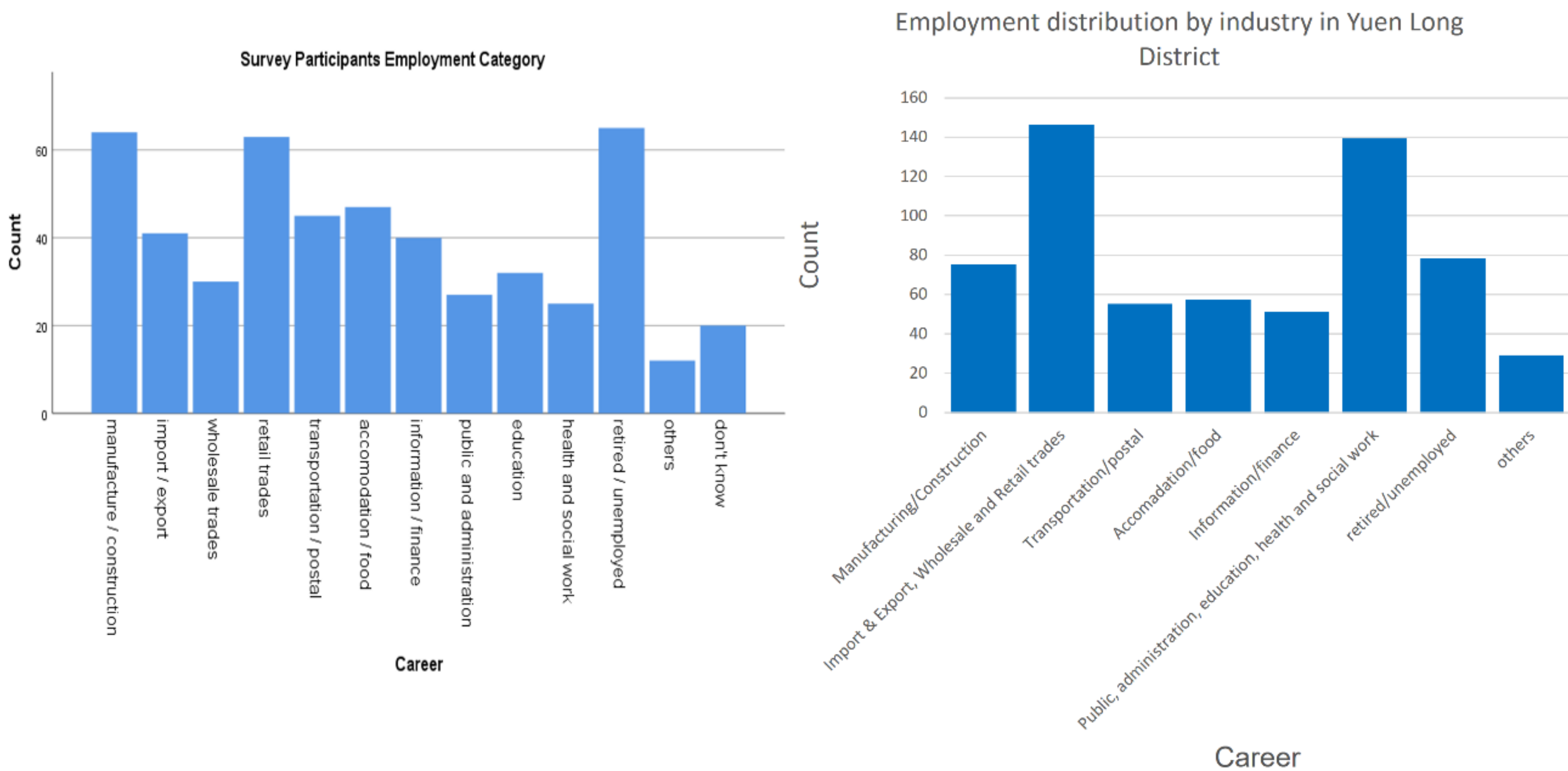


Figure 4.4: Employment Categories of Respondents and Residents of the Yuen Long District

(Census data sourced from HK Government Census and Statistics Department)

4.1.2 Geographical Locations

The geographical locations and elevations of the respondents were recorded on a GIS map. The majority of the respondents were located in the Tin Shui Wei area and the Yuen Long Centre area. The geographical locations of the respondents, along with corresponding photographs of the developed environment, are shown in Figure 4.5. The majority of recorded elevations for the respondents were from 0 – 6 m above sea level. The geographical locations of the respondents, along with their corresponding elevations, are shown in Figure 4.6 below.

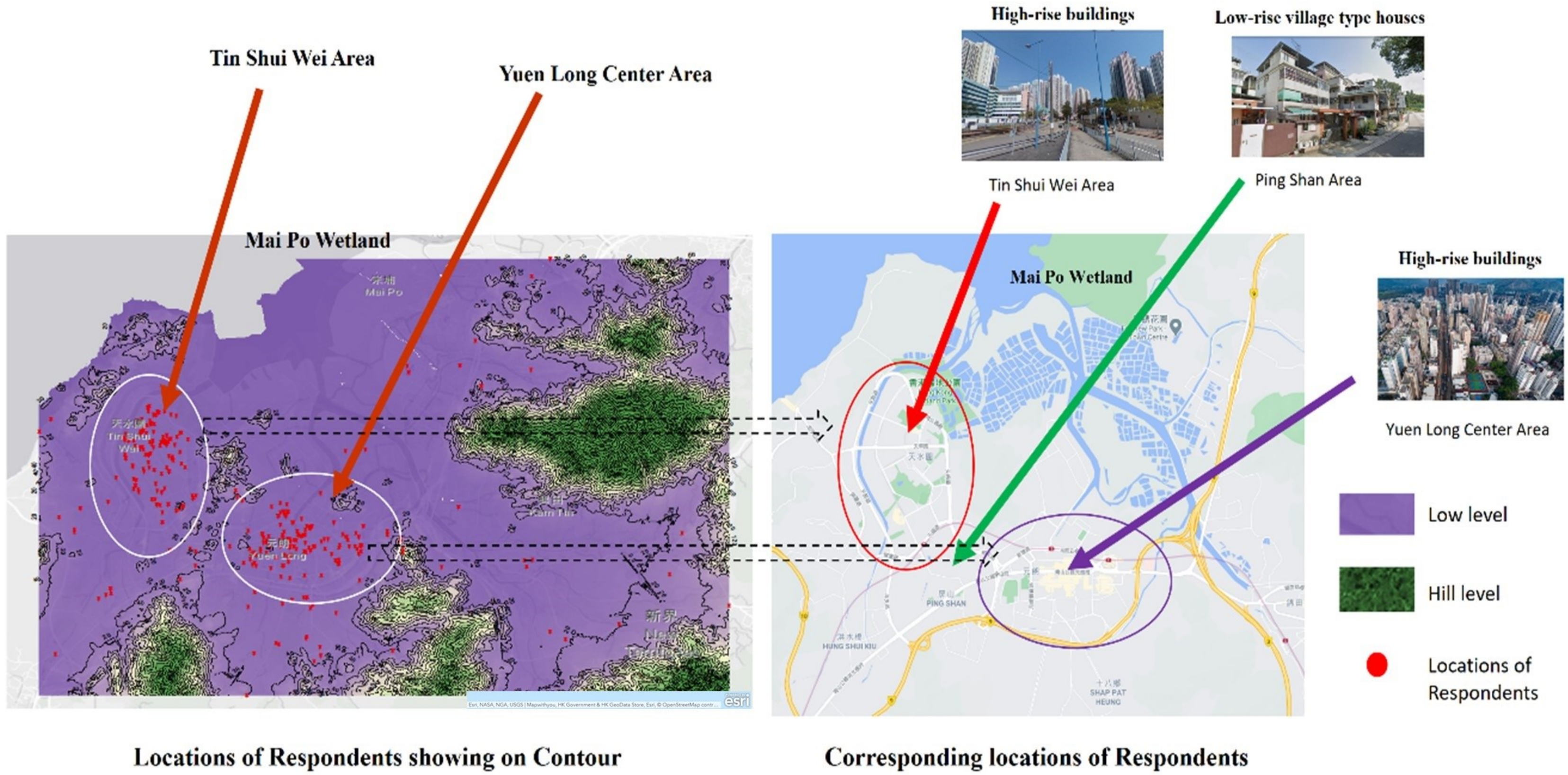


Figure 4.5: Geographical Locations of Respondents shown using ArcGIS

Figure 4.6: Geographical Locations of Respondents with Corresponding Elevations

4.1.3 Distance from Mai Po

To check if there was correlation between respondents' answers and their geographic location, I used the simple Pearson correlation coefficient. It is adopted as this is a simple and direct method to measure the linear correlation/ association between two sets of data. The distance from Mai Po is a set of continuous data and the other sets are ordinal data with different level of concerns and experience. The Pearson correlation approach is considered appropriate with raw data of this nature and the data require no manipulation. The disadvantage of this method is the assumption that the association may be linear. To investigate the effect of distance, two measurements of distance were taken: (a) measurement of the shortest distance to the nearest point in Mai Po, and (b) measurement to the centroid of Mai Po.

a) **Measurement of the shortest distance** from each point to the **nearest point** in the Mai Po area in kilometres is denoted as '**S_Dist**'; Figure 4.7 shows the measurement.

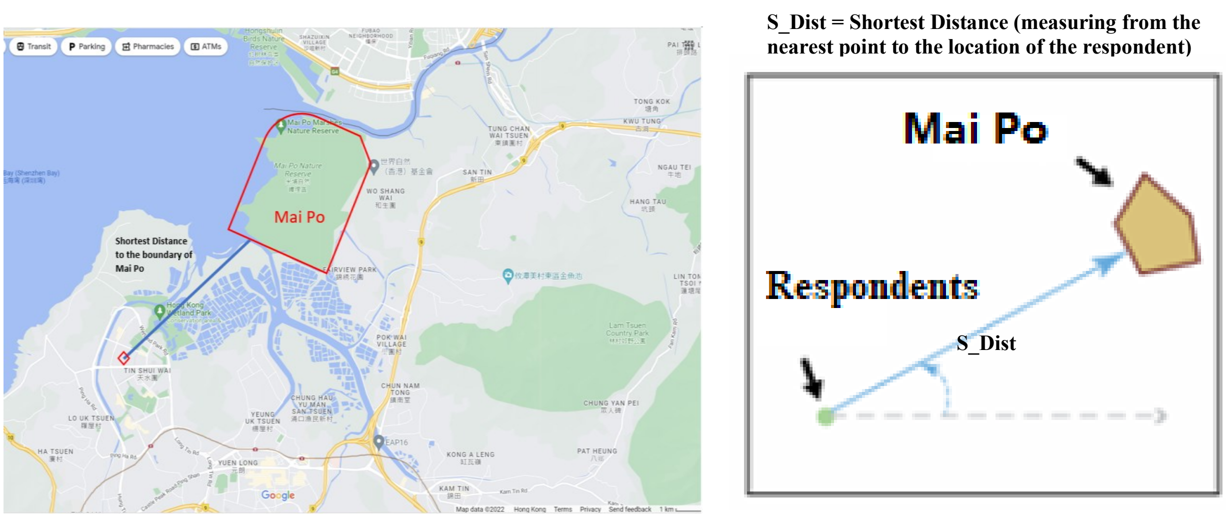


Figure 4.7: Shortest Distance Measurement

The flooding experience, which was asked in the questionnaire in the 5-level Likert Scale, of the respondents had a positive weak linear relationship (Pearson correlation[5]) to the amount of distance from Mai Po at a 95% confidence level (Table 4.1, column "B4"). The Likert Scale responses were

[5] The Pearson correlation coefficient is a measure of the strength of a linear association between two variables and is denoted by ***r***. It can take a range of values from +1 to -1. A value of 0 indicates there is no association between the two variables. A value > 0 indicates a positive association; a value < 0 indicates a negative association. The stronger the association between the two variables, the closer ***r*** will be to either +1 or -1, depending on whether the relationship is positive or negative. The strength of the association can be considered as follows: 0.1 to 0.3 (or -0.1 to -0.3) as **weak association**; 0.3 to 0.5 (or -0.3 to -0.5) as **moderate association**; and 0.5 to 1.0 (or -0.5 to -1.0) as **strong association**.

converted into a numeric figure to use in the calculation of correlation. The finding showed that people located closer to Mai Po had negative flooding experience. Therefore, the flooding experience may not be from Mai Po itself. In other words, there may have other reasons than closeness to Mai Po affecting flooding experience. The results also showed that the "flooding concern" (B1), "sea level rise" (B2) and "concern on flooding damage" (B5) did not correlate to the closeness to Mai Po. One of the possible reason for this finding was that most respondents were living in high-rise residential towers in modernized urban environment.

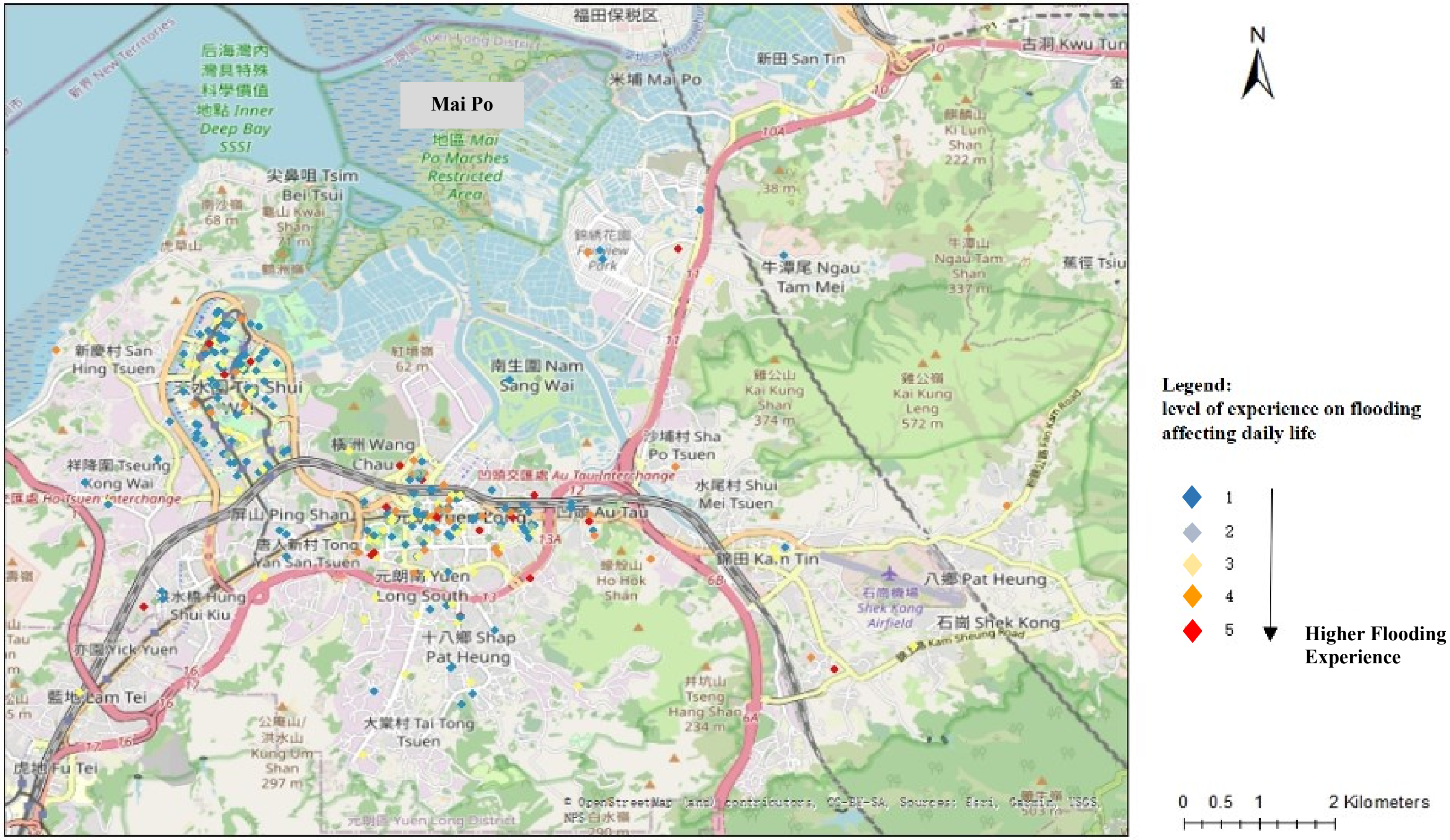
Table 4.1: Effect of Distance from nearest point of Mai Po on Respondents' Survey Answers

		S_Dist	Cent_Dist	B1	B2	B4	B5
S_Dist	Pearson Correlation	1	.989**	.070	.060	.103*	.058
	Sig.		.000	.116	.176	.019	.192
	Sample Size	511	511	511	511	511	511

B1 – concerning flooding in Hong Kong
B2 – concerning rise in sea level
B4 – flooding experience
B5 – concerning flooding damage

B1, B2, B4 and B5 correspond to the description in the questionnaire in Appendix II

The geographical locations of the respondents in relation to their flooding experience is shown in Figure 4.8 below. No obvious pattern can be noted in the figure. The locations of respondents closer to Mai Po did not lead to higher levels of flooding experience. In other words, even though people living closer to the coast, they did not experience more flooding. Perhaps, the wetland serving as a buffer zone minimized the flooding effect on the residents.



Remark: Locations of respondents closer to Mai Po did not lead to higher levels of flooding experience.

Figure 4.8: Geographical Locations of Respondents Detailing Level of Flooding Experience

During the site inspection, it was observed that some wetland areas are not located in the designated Mai Po Natural Reserve. There are many fish ponds located near the Mai Po Nature Reserve. Figure 4.9 shows the measurement of the distance from Mai Po Nature Reserve and the adjacent wetland areas (Fish Ponds). Additional analysis (Table 4.2) was performed by taking these wetland areas into consideration. Similar results were obtained, in that people who are located closer to the wetland have negative flooding experience, i.e., reasons other than closeness to Mai Po appear to affect flooding experience.

Table 4.2: Effect of Distance from nearest point of Mangrove Wetlands

		B1	B2	B4	B5
S_Dist (E)	Pearson Correlation	.073	.050	.201*	.092
	Sig.	.100	.258	.000	.038
	Sample Size	511	511	511	511

S_Dist (E) – Shortest distance to the wetlands (Mai Po Nature Reserve + Fish Ponds)
B1 – concerning flooding in Hong Kong
B2 – concerning rise in sea level
B4 – flooding experience
B5 – concerning flooding damage

Figure 4.9: Locations of Mai Po Nature Reserve and Adjacent Wetlands (Fish Ponds) (Map based on Google Map and Photos extracted from www.wwf.org.hk)

b) **Measurement of distance from the centroid** of the Mai Po area (centre of the area) is denoted as 'Cent_Dist' (Figure 4.10).

Figure 4.10: Distance Measurement from the Centre of the Area (Mai Po and the Fish Ponds) (Map based on Google Map and Photos extracted from www.wwf.org.hk)

When using the centre of Mai Po (centroid) and the fish ponds as the reference point for measurement, a similar association was found, in that the flooding experience of respondents had a positive weak linear relationship (Pearson correlation) to the distance from Mai Po at a 99% confidence level (Table 4.3). A similar conclusion could be reached, in that the flooding experience may not be from Mai Po and there may have reasons other than closeness to Mai Po.

Table 4.3: Effect of Distance from Centroid of Mai Po on Respondents' Survey Answers

		S_Dist	Cent_Dist	B1	B2	B4	B5
Cent_Dist	Pearson Correlation	.989**	1	.076	.059	.128**	.064
	Sig.	.000		.085	.182	.004	.146
	Sample Size	511	511	511	511	511	511

S_Dist – Shortest distance to the wetlands (Mai Po Nature Reserve + Fish Ponds)
Cent_Dist – Distance from the center of area of the wetlands (Mai Po Nature Reserve + Fish Ponds)
B1, B2, B4 and B5 correspond to the description in the questionnaire in Appendix II
B1 – concerning flooding in Hong Kong
B2 – concerning rise in sea level
B4 – flooding experience
B5 – concerning flooding damage

4.1.4 Elevation

Next, I tested whether elevation was correlated with responses to four questions (B1, B2, B4 and B5 in Appendix II). The Pearson correlation coefficient, *r*, was checked to determine if the 'elevation' of respondents had any correlation with:

(i) concern about flooding in Hong Kong (B1),
(ii) concern about sea level rise (B2),
(iii) respondents' experience with flooding (B4), and
(iv) concern about flooding damage (B5).

The field of 'elevation' was calculated by extracting the value of each pixel from a digital terrain model at a point location. As all the r-value < 0.1, there appeared to be no correlation (Table 4.4 refers). The finding indicates that **the elevation positions of respondents do not affect their beliefs on flooding or flooding experience**. This is logical, as most people in Hong Kong live in high-rise buildings, which are structurally stable in flooding conditions. The safety of residents is not affected if they stay at home, and flooding might only affect roads and ground floor shops. This means that in general, people may not have serious concerns about flooding.

Table 4.4: Effect of Elevation of Respondents on Respondents' Survey Answers

		Elevation	B1	B2	B4	B5
Elevation	Pearson Correlation	1	.083	.019	.057	.041
	Sig.		.061	.670	.201	.358
	Sample size	511	511	511	511	511

B1 – concerning flooding in Hong Kong
B2 – concerning rise in sea level
B4 – flooding experience
B5 – concerning flooding damage

4.1.5 Attitudes Towards Flood Protection Measures

Most flood and storm risk management in Hong Kong has emphasised engineering and drainage projects. Various alternative protection measures are also in use, but on a limited basis. Considering the possible increase in damages due to future sea level rise, more emphasis on alternative measures may be justified. Respondents were asked to judge the importance of flood and storm protective measures, green infrastructure and the use of mangrove forests.

In the survey, the respondents were asked to judge (Questions: C1, C2 and C3 in Appendix II):

(i) the importance of actions to reduce potential flood and storm damages (C1),

(ii) the importance of green infrastructure (natural and engineered) for diverting and retaining storm waters (C2), and

(iii) the importance of Mangrove forests to reduce flood/ storm damages (C3).

Initially, the correlation of (i) to (iii) above with the respondents' elevation was tested using the Pearson Correlation Coefficient. Table 4.5 shows that all the $r < 0.1$. This implies that the **respondents' judgements about the importance of these factors have no correlation with their elevation positions.**

Table 4.5: Effect of Elevation of Respondents on Respondents' Judgement

		Elevation	C1	C2	C3
Elevation	Pearson Correlation	1	-0.27	-0.004	0.032
	Sig.		0.542	0.934	0.464
	Sample size	511	511	511	511

C1 – Importance of actions to reduce potential flood/ storm damages
C2 – Importance of Green infrastructure (natural and engineered) for diverting/ retaining storm waters
C3 – Importance of Mangrove forests to reduce flood/ storm damages

4.1.6 View of Respondents Living in the Local 'Villages'

As mentioned in Chapter 3 above, surveyors were not able to visit **five** villages near the Mai Po wetland where we had planned to collect data. The names of the villages are San Hing Tsuen, Hung Shui Kiu, Tong Yan San Tsuen, Wang Chau and Nam Sang Wai and their locations and images are shown in Figure 4.11 and Figure 4.12 respectively. As these villages are located near Tin Shui Wai, some residents in these villages shop frequently in some of the shopping malls in Tin Shui Wai. Therefore, surveyors were able to intercept 38 village residents and responses were collected opportunistically and further analysed. The locations where the respondents live are shown in Figure 4.12. Even though these data were limited, they still provide certain insights.

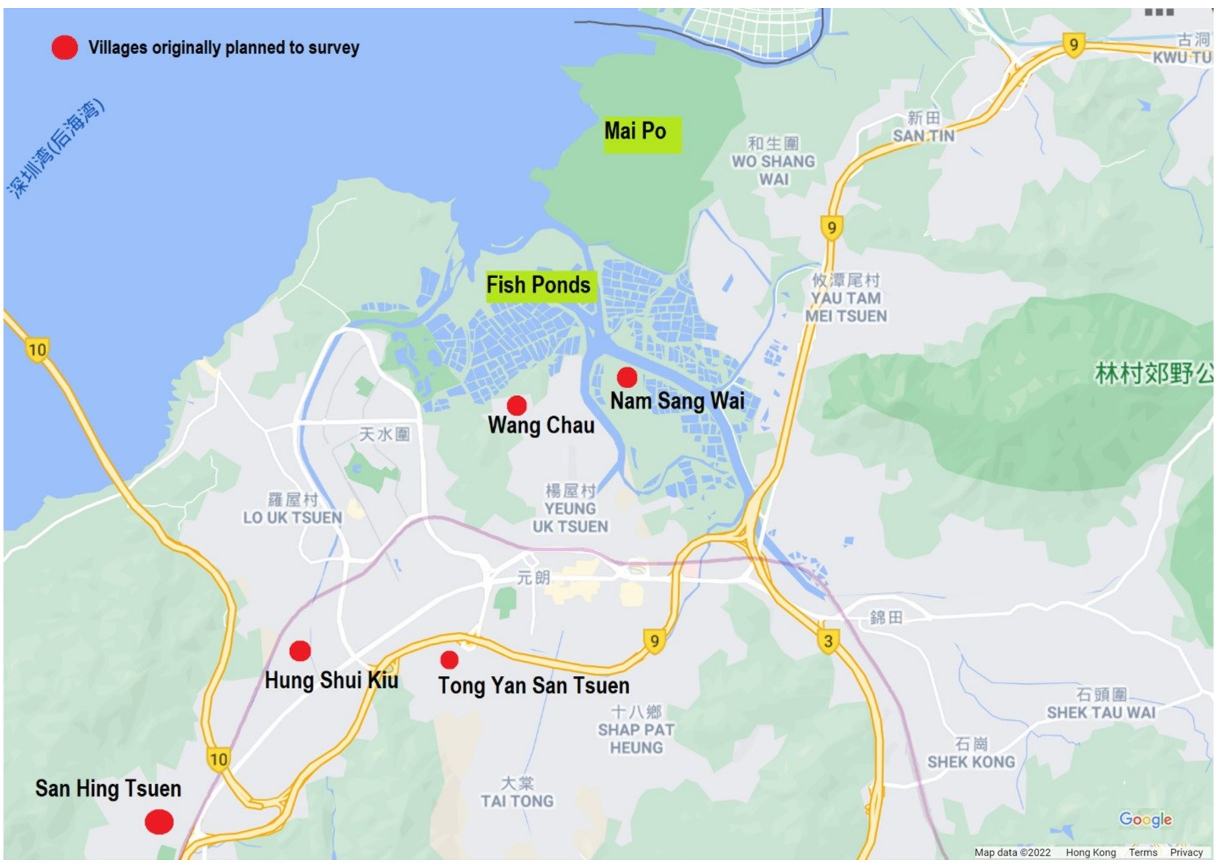


Figure 4.11: Locations of the 5 "Villages" Intended to Survey in Yuen Long District

Wang Chau	Nam Sang Wai	San Hing Tsuen
https://en.wikipedia.org/wiki/Wang_Chau_(Yuen_Long)	https://petespurrier.com/2016/02/19/hong-kong-hiking-nam-sang-wai/	https://www.mydreamhse.com/Uploads/Building/ac468c767434ea32c4594cb57a99b97c.jpg

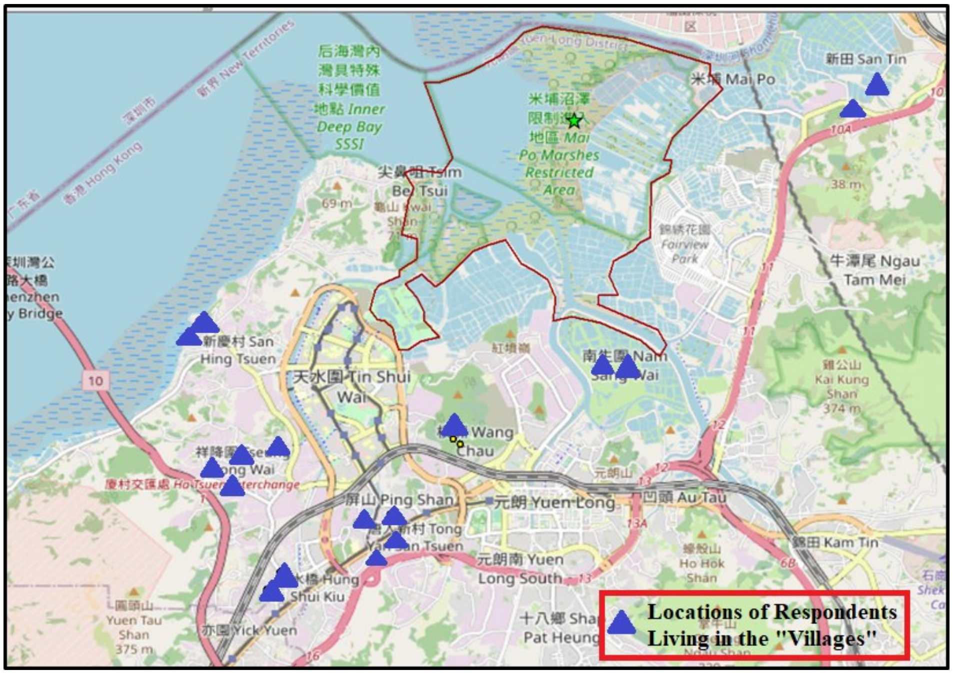


Figure 4.12: Locations of Respondents Living in the 'Villages'

Table 4.6 shows a comparison between the mean values of the experience/concern judgements of the people living in the villages and people from other areas in Yuen Long District. As indicated in Table 4.6, respondents living in the villages generally had more experience with flooding (item (3) in Table 4.6). These people also showed higher mean values for (1) level of concern for flooding, and (2) level of concern for sea-level-rise. It was interested to note that the villagers felt less vulnerable in flooding. This was logical as the villagers lived in low-rise small house. According to the Building Regulation (Application to New Territories) Regulations of Hong Kong (https://www.elegislation.gov.hk/hk/cap121!en?INDEX_CS=N), the village-type houses can only be erected up to 7.62m. This indicates that the village-type houses are limited to three storeys and shallow foundation. It was not surprising that the villagers felt less vulnerable.

Table 4.6: Comparison of the Level of Experience/Concern

	Opinion of all the respondents (473)	Opinion of the respondents living in the villages (38)*
(1) Level of Concern for Flooding (mean value)	2.89	3.11
(2) Level of Concern for Sea-Level-Rise (mean value)	3.19	3.45
(3) Flooding Experience (mean value)	2.05	2.39
(4) Vulnerability in Flooding (mean value)	2.64	2.34

*Opinion of the respondents from the villages determined from a sample size of 38; as the sample size is limited, simple mean values for items (1) to (4) above are calculated for comparison purpose.

4.2 Latent Class Modelling Analyses

In this study, I explore the preferences of survey respondents with respect to flood risk management in Hong Kong using a set of four attributes to describe the flood management system: (i) Mangroves for flood risk management, in the form of increasing mangrove areas in Mai Po; (ii) Green infrastructure for flood risk management, in the form of increasing the number of green infrastructure projects in the Yuen Long District; (iii) Adaptation strategies for flood risk management, including actions and programs to help mitigate potential flooding and storm damage, such as early warning systems and evacuation drills,[6] and (iv) One-time payment for different programs. A choice option "existing situation" which served as an opt-out option was also included. Covariates, including the demographic and basic information about the respondents such as their flooding experience, flooding concern, etc., were used in the estimation. As geographic location and the corresponding elevation may also affect their views, the distance of respondents from the Mai Po wetland, along with their elevations, were also added as covariates for the estimation.

Latent class modelling analysis was adopted to recognize the relationships among the attributes and to group together the respondents for exploratory investigations. It is a person-centred approach that defines mutually exclusive subgroups of respondents (classes) within a population based on common characteristics. The judgement of categorical attributes for every respondent is used to define class constructs. The number of classes is not known at the beginning, and is established by iteratively adding potential classes to determine which model (number of classes) is best fit to the data. To judge the "optimal model" requires consideration of several criteria, including information criteria (e.g., Akaike (AIC)/ Bayesian information criterion (BIC)) and model interpretability[7]. Information criteria (with lower numerical number indicating better model fit) indicate how well the model predicts the data (Law and Harrington, 2016). Both the BIC and the AIC are computed on the basis of log-likelihood, number of elements in the utility function and number of parameters (Louviere et al., 2000; Ruto et al., 2008; Shen, 2009; Kim et al., 2020).

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[6] Three types of situation for adaptation strategies were considered: (a) Adaptation strategies only applying to areas that were seriously affected by flooding; (b) Adaptation strategies applying to the areas that were affected (not just seriously affected areas, but also included those minor affected areas; (c) Adaptation strategies applying to the all the areas in Hong Kong that were considered potentially affected in the coming 10 years.

[7] Law EH, Harrington R (2016), "A Primer on Latent Class Analysis", Value & Outcomes Spotlight, pp18-19.

After comparing different information criteria, interpretability should be considered when making the final selection.

4.2.1 Establishment of the Latent Class Model

Figure 4.13 shows the procedures used to obtain the optimal model. The computation was implemented using Latent GOLD 5.1 and the procedures, along with 'screen shots' for obtaining the results and the additional information about the implementation procedures of Latent GOLD 5.1 are provided in Appendix IV.

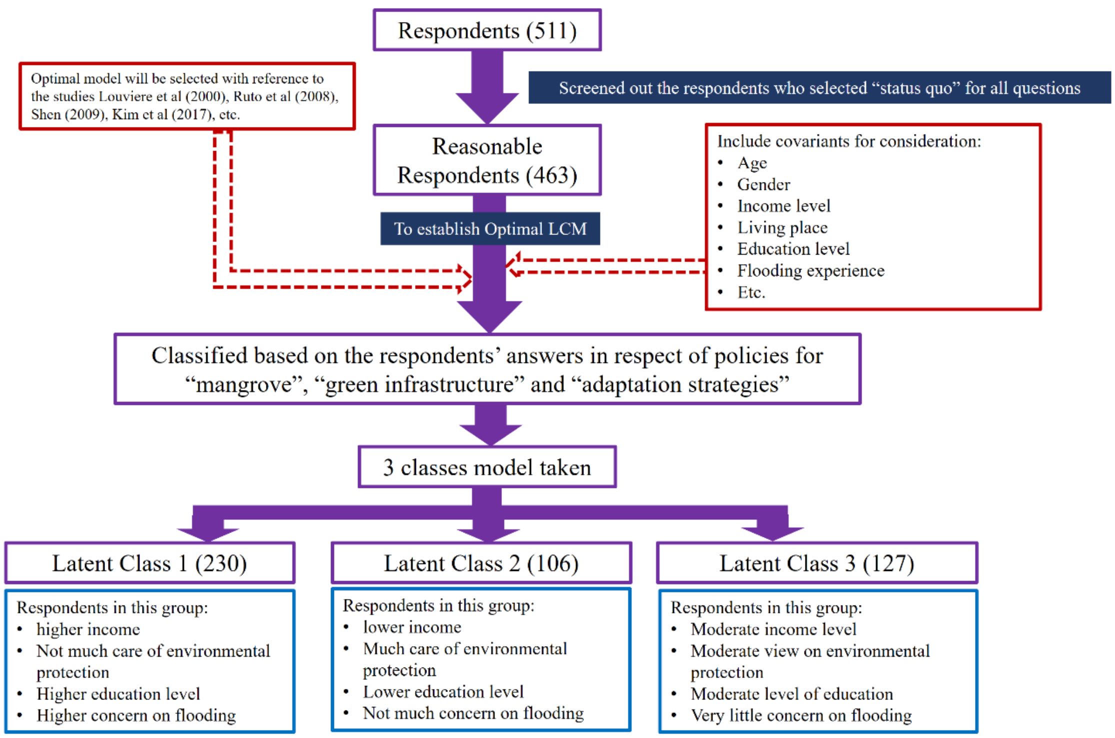

Figure 4.13: Flow Chart Showing the Establishment of Optimal LCM

Table 4.7 summarises the results of the above-mentioned assessment criteria given by Latent GOLD 5.1 for one to three classes models. Reviewing the results in Table 4.7 indicates that the 3 class model is preferred as the optimal model for further analyses as the BIC and AIC values for 3 class model are the lowest and R^2 is the highest. Having considered model simplicity and interpretability of the results, the 3 class model with the socio-demographic covariates from the questionnaire was selected.

Table 4.7: Summary of 1-3 classes models assessment criteria given by Latent Gold

	Number of parameters	Bayesian information criterion (BIC)	Akaike information criterion (AIC)	Goodness of fit (R^2)
1 class choice model	7	2893.0833	2864.1192	0.4644
2-classes choice model	21	2701.5691	2614.6769	0.5268
3-classes choice model	35	2637.3583	2492.5379	0.5910

4.2.2 The Optimal LCM

The class probabilities for the 3 class model indicated that 224 of the respondents were assigned to class 1, 120 to class 2, and 119 to class 3. The settings for the LCM implementation are shown in Figure 4.14 below:

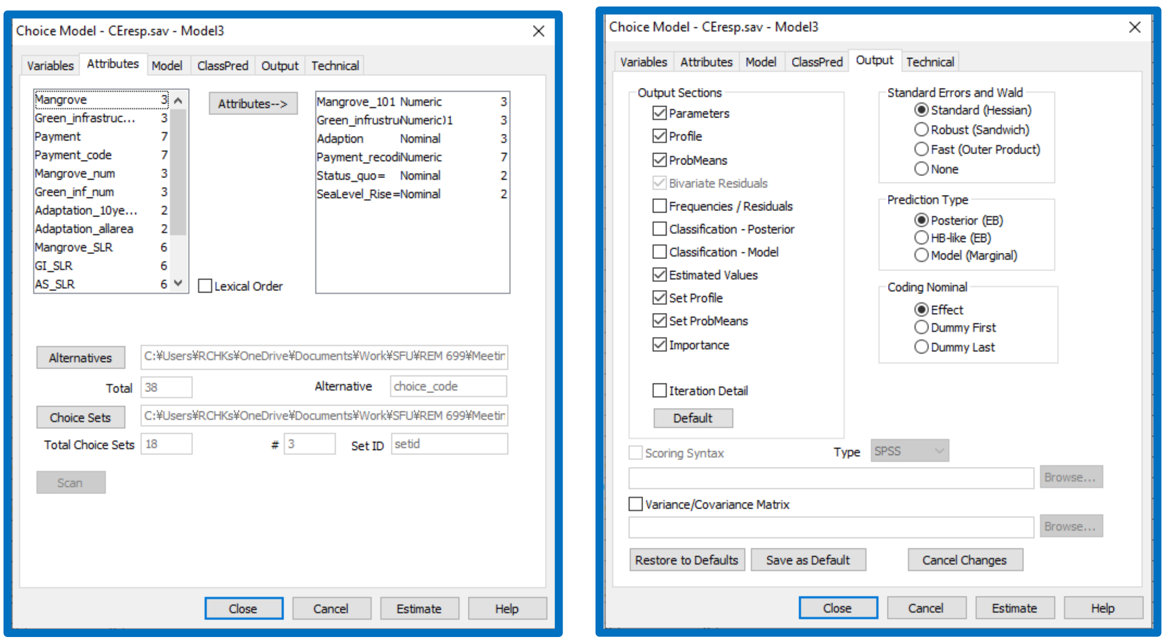

Figure 4.14 Screen Shot from Latent GOLD Showing the Settings

4.2.3 Statistical Significance

The estimation given by the 3-class optimal model was extracted from the Latent Gold model and shown in Table 4.8. The estimated coefficient on the variable "mangrove management" was significant for all three classes at the 1% level (all z-values are > 2.58). The views for class 1 and 2 respondents are consistent. However, for class 3, the utility value is negative indicating that they have an opposite view.

For the variable "provision of green infrastructure to manage flooding," both class 1 and 2 respondents showed consistent views and the estimated coefficients of their responses, were significant at 5% level (z-values > 1.96). Class 2 respondents showed a higher utility value indicating that they were more in favour of providing green infrastructure for managing flooding. Class 3 showed a diverse view and the significance of the estimated coefficient could not be established.

For the variable "adaptation strategies", all 3-classes showed consistent negative views for maintaining the current situation (no action). The estimated coefficients of the variable were significant for all 3 classes at 1% level (z-value > 2.58). Class 1 respondents showed a very large negative utility value implying that they did not want the situation to maintain. Class 2 and 3 respondents had similar views but their views were not as strong as class 1 respondents.

When the "adaptation strategies" were extended to all affected areas, class 1 and 2 respondents showed positive supportive views with positive utility values and the estimated coefficients for the two classes were significant at 1% level (z-value > 2.58). However, for class 3 respondents, their views were diverse and the significance of the estimated coefficient for this class could not be established at 5% level.

For "adaptation strategies" to apply to all potentially affected areas in Hong Kong in 10 years, only class 2 respondents showed supportive views (the estimated coefficient was significant at 1% level, z-value > 2.58) and the other two classes of respondents showed diverse views and the significance of the estimated coefficients could not be established at 5% level (z-value < 1.96).

The estimated coefficients of the variable "sea-level-rise" for all three classes were also significant at 1% level (z-value > 2.58). This showed the concerns of all the three classes of respondents. Further discussion on the findings will be given in section 4.2.4 below.

Table 4.8: LCM Estimation Showing the Estimated Model Coefficients and Z-values for the Attributes by Latent Class

	Class1		**Class2**		**Class3**		**Overall**					
R2	0.7963		0.3369		0.3899		0.5910					
R2(0)	0.8526		0.5004		0.4638		0.6817					
Attributes	Class1	z-value	Class2	z-value	Class3	z-value	Wald	p-value	Wald(=)	p-value	Mean	Std.Dev.
Mangrove Management												
	3.8449	4.9053	1.1578	5.7030	-0.6280	-4.5728	100.9045	9.9e-22	100.2169	1.7e-22	2.0006	1.8988
Green infrastructure												
	0.2396	2.1398	0.8327	5.4693	-0.0011	-0.0111	35.9963	7.5e-8	21.8921	1.8e-5	0.3314	0.3123
Adaption Strategies												
Current situation (no action)	-9.6283	-2.9583	-1.9812	-8.2183	-0.4667	-3.1968	117.0611	6.7e-23	69.8386	2.5e-14	-5.2958	4.2336
increase to all area	7.1871	3.8830	0.8191	4.6344	0.2598	1.9332					3.7595	3.3277
10 years effect	2.4412	1.5876	1.1620	8.5507	0.2069	1.5856					1.5363	0.9416
One-time Payment												
	-5.4510	-6.7513	-0.8471	-10.2295	-0.9859	-12.2590	326.6224	1.7e-70	32.1864	1.0e-7	-3.1124	2.2668
Status quo												
0	0.1436	1.0977	0.1436	1.0977	0.1436	1.0977	1.2049	0.27	0.0000	.	0.1436	.
1	-0.1436	-1.0977	-0.1436	-1.0977	-0.1436	-1.0977					-0.1436	.
Sea-Level-Rise												
no rise	-0.9715	-6.5408	-0.9715	-6.5408	-0.9715	-6.5408	42.7823	6.1e-11	0.0000	.	-0.9715	.
rise	0.9715	6.5408	0.9715	6.5408	0.9715	6.5408					0.9715	.

z-value (absolute values)	**p-value**	
>=2.58	<=0.01	99% confidence level
>=1.96	<=0.05	95% confidence level

Absolute value for z-value < 1.96 (not significant)

Remarks:

The “sea-level-rise” variable was set as “class independent” and the two scenarios, “no rise” and “rise”, shared the same values. This is the same for the “status quo” variable.

The covariates and the corresponding profile of the 3 classes were extracted from the Latent GOLD model (Tables 4.9). The p-values for all the covariates are < 0.01 except years of residence. This indicates that all of the estimated coefficients for the covariates are statistically significant at the 99% level. The estimated coefficient for the covariates “years of residence” is < 0.05 and is statistically significant at the 95% level. Accordingly, the covariates can be used to explain the membership in the 3 classes.

4.2.4 Distance and Elevation

In section 4.1 above, I adopted a simple Pearson Correlation test to examine if the distance and elevation have statistical correlation with the views of respondents, as a whole, on flooding. It is also important to examine if the estimated coefficients for distance and elevation as covariates, show statistical significance with the attributes for the 3 classes. The results of including elevation and distance as covariates in the optimal model show that there was no statistical significance (p-value for elevation and distance are 0.54 and 0.14, respectively) for these two covariates. Figure 4.15 shows the estimation results for this procedure in Latent GOLD. The results further support the findings in section 4.1.

Intercept	Class1	Class2	Class3	Wald	p-value
	-5.2125	2.7582	2.4543	19.4206	6.1e-5
Covariates	**Class1**	**Class2**	**Class3**	**Wald**	**p-value**
G7Income					
	0.2717	-0.2150	-0.0566	16.5615	0.00025
NEP_combine					
	-1.2278	0.3064	0.9214	40.9252	1.3e-9
Flood_concern					
	0.7467	-0.4143	-0.3324	19.6191	5.5e-5
G3Education					
	0.3950	-0.1258	-0.2693	15.6275	0.00040
B4Flood.Exp					
	0.3939	-0.3272	-0.0668	10.6292	0.0049
B2SLRHK					
	0.5357	-0.0256	-0.5101	17.0331	0.00020
C3Mangrove					
	0.3345	-0.3265	-0.0080	10.1081	0.0064
A1Res.Yrs					
	-0.0173	0.0133	0.0041	4.9496	0.084
Elevation_discretization1					
	-0.2030	-0.0604	0.2634	1.2281	0.54
Distance_discretization1					
	-0.3523	0.1804	0.1720	3.9965	0.14

p-value > 0.05 (no statistical significance at a 95% confidence level)

Remarks:
All the covariates shown above have p-value < 0.05 (i.e. significant at 5% level) except "years of residence", "elevation" and distance"; further examination of these covariates with respect to the attributes in this study was not presented.

Figure 4.15: Screenshot - Estimation of the Covariates Implemented by Latent GOLD

Table 4.9: Utility, z-score and p-value for different covariates

	Class1	s.e.	z-value	**Class2**	s.e.	z-value	**Class3**	s.e.	z-value	Wald	**p-value**
Covariates											
Income											
	0.2591	0.0668	3.8773	-0.0434	0.0631	-0.6885	-0.2157	0.0708	-3.0482	15.9909	**0.00034**
New Environmental Paradigm											
	-1.1678	0.1928	-6.0583	0.8491	0.1814	4.6804	0.3187	0.1764	1.8065	39.1759	**3.1e-9**
Flooding concern in HK and Yuen Long District											
	0.7218	0.1641	4.3978	-0.3137	0.1494	-2.0996	-0.4082	0.1461	-2.7937	19.5811	**5.6e-5**
Education											
	0.3519	0.0960	3.6648	-0.2516	0.0867	-2.9022	-0.1003	0.0904	-1.1099	14.8361	**0.00060**
Flooding Experience											
	0.3379	0.1164	2.9021	-0.0372	0.1031	-0.3606	-0.3007	0.1218	-2.4687	9.1191	**0.010**
Concern of SLR in HK											
	0.5026	0.1469	3.4215	-0.4940	0.1332	-3.7076	-0.0086	0.1333	-0.0646	16.4772	**0.00026**
Importance of Mangroves as a flood control strategy											
	0.3454	0.1257	2.7479	-0.0138	0.1088	-0.1267	-0.3316	0.1081	-3.0680	10.8559	**0.0044**
Resident Years											
	-0.0185	0.0079	-2.3427	0.0036	0.0070	0.5063	0.0150	0.0074	2.0364	6.1824	**0.045**

Remarks: s.e. – Standard Deviation;

Table 4.10 shows that Class 1 comprises members from the higher income and higher education groups. They are much more concerned about flooding and sea-level-rise, yet do not have much concern about environmental protection. Class 2 comprises members from the lower income and lower education groups. They do not have great concern about flooding and sea-level-rise. Class 3 respondents are a mix of members from different income and education levels. As this group is a mix of members of different background, it is logical that their views are diverse. They showed moderate view on environmental protection and flooding concern. This was due to the fact that the offsetting of positive and negative views.

Table 4.10: Profile of the members in each class and the corresponding p-values

Ordinal Values	Class 1	Class 2	Class 3	p-value
Income				**0.00034**
0 – 2 (0-9,999)	0.1080	0.2442	0.2074	
3 – 3 (10,000-19,999)	0.1590	0.2227	0.2095	
4 – 4 (20,000-29,999)	0.1494	0.1873	0.1598	
5 – 6 (30,000-49,999)	0.3420	0.2342	0.2656	
7 – 10 (50,000-100,000~)	0.2417	0.1117	0.1576	
Mean	4.9641	3.9824	4.2695	
	Relatively higher income	**Relatively lower income**	**Moderate income level**	
Attitude towards Environment (ATE)				**3.1e-9**
-1.874 - -1.045	0.3368	0.0137	0.1986	
-1.038 - -0.398	0.2735	0.0588	0.2008	
-0.384 - 0.432	0.0978	0.2730	0.2009	
0.432 - 0.956	0.1056	0.3396	0.2009	
0.960 - 3.941	0.1862	0.3149	0.1987	
Mean	-0.3574	0.6422	-0.0003	
	Not much care about environmental protection	**Positive value on environmental protection**	**Moderate value on environmental protection**	
Flood Concern				**5.6e-5**
-2.088 - -0.927	0.1123	0.2665	0.2269	
-0.914 - -0.340	0.1826	0.2341	0.2268	
-0.327 - 0.233	0.2382	0.1981	0.2160	
0.247 - 0.807	0.1417	0.1015	0.1058	
0.820 - 2.555	0.3253	0.1998	0.2246	
Mean	0.3445	-0.0387	0.0018	
	Relatively higher concern on flooding	**Basically not much concern on flooding**	**Very little concern on flooding**	
Education				**0.00060**
1 – 2 (Primary)	0.0604	0.1240	0.1145	
3 – 3 (Secondary)	0.2673	0.4790	0.3521	
4 – 4 (Diploma/ Certificate)	0.2221	0.1370	0.1706	
5 – 5 (Sub-degree)	0.0992	0.0485	0.0864	
6 – 6 (Degree or above)	0.3510	0.2115	0.2764	
Mean	4.4132	3.7348	4.0451	
	Relatively higher education level	**Relatively lower education level**	**Moderate level of education**	
Flood Experience				**0.010**
not at all affected	0.4381	0.4486	0.4990	
2	0.1411	0.1468	0.1490	
somewhat affected	0.2111	0.2188	0.1879	
4	0.1480	0.1207	0.1123	
very affected	0.0617	0.0650	0.0518	
Mean	2.2541	2.2068	2.0690	
	Slightly more experience and considered ‘somewhat affected’	**Slightly more experience and considered ‘somewhat affected’ (slightly lower than Class 1)**	**Not much experience and relatively not affected by flooding**	
SLR Hong Kong				**0.00026**
not concerned	0.0279	0.1389	0.0605	
2	0.1257	0.3237	0.1815	
somewhat concerned	0.3553	0.3749	0.3737	
4	0.3652	0.1091	0.2548	
very concerned	0.1259	0.0534	0.1296	
Mean	3.4354	2.6144	3.2115	
	Slightly more concern on SLR	**Relatively not concern on SLR**	**Moderate level of concern on SLR**	
Importance of Mangroves as a flood control strategy				**0.0044**
Resident Years				**0.045**

4.2.5 Attributes

Analysis of the estimation results with respect to the attributes is presented below.

(1) ***Mangrove*** forests can reduce storm damage by lowering flood energy and dissipating waves. Accordingly, this attribute was included to examine: How important did respondents consider mangroves to be for flood risk management?

The estimated coefficients on the attribute "mangrove management" for all 3 classes demonstrated statistical significance (absolute value of z-score > 1.96, 95% confidence level). The utility values (estimated coefficients) for classes 1 to 3 members were 3.85, 1.16 and – 0.63, respectively. This implied that people in class 1, who had higher income, higher education and more concern about flooding, considered that mangroves could offer good flood risk management. The utility value for class 1 was much higher than class 2. This implied that class 1 had a more positive view of the use of mangroves for flood management. However, this group (class 1) had a negative mean value for environmental protection (mean score for the new environmental paradigm covariate was -0.36). People in class 2 showed some positive consideration (mean score was 0.64) toward the new environmental paradigm. This implied that people of higher education background and in a higher income group did not necessarily have more concern for the environment. This is an issue worth further investigation in the future. Class 3 respondents showed negative utility for mangrove management and had a negative and statistically significant z-value. Class 3 members were a mix with different income and education backgrounds. As a result, the views of this class were diverse and conclusive findings could not be established for this attribute.

(2) ***Green infrastructure*** refers to the combination of natural and engineered structures that can divert or retain storm waters. Examples in Hong Kong include flood retention ponds, green river channels with constructed wetlands, green roofs and permeable pavements. Accordingly, this attribute was included to examine: How important did respondents consider green infrastructure to be for flood risk management?

The estimated coefficients for only class 1 and 2 were of statistical significance at 95% level (absolute value of z-score > 1.96). The utility values for class 1 and 2 members were 0.24 and 0.83, respectively. The results showed that class 2 members did have a higher degree of satisfaction for this attribute. They did think that provision of green infrastructure should have a higher utility value. The class 3 members did not show any statistical significance on the provision of green infrastructure. The characteristics of class 3 members showed moderate mean values in many covariates. This implied that members in this class held diverse views and therefore, statistical significance could not be established for this attribute.

(3) ***Adaptation Strategy*** refers to actions to reduce potential flood and storm damage. Examples in Hong Kong include awareness campaigns, early warning systems, evacuation plans and development restrictions in low-lying areas.

The respondents were asked to give views on **3 adaptation strategies**:

(i) **Maintaining the use of the strategies, such as early warning system, evacuation plans, etc. for those seriously affected areas** –

The estimation coefficients on this attribute for all 3 classes were significant at 1% level (z-value > 2.58) and the corresponding utility values were: - 9.63, - 1.98 and - 0.47. A higher negative utility value for class 1 implied that they had a strong negative preference for maintaining the current situation for those serious affected areas. Class 2 and 3 also had similar negative preferences, but the views were not as strong as class 1. Nevertheless, all three classes showed a negative preference for maintaining the current situation. It was logical to expect that they preferred more works should be done.

(ii) **Extending the strategies to apply for all areas in Hong Kong that are currently affected by flooding, i.e. including minor affected areas** –

The positive and statistically significant (z-value > 2.58) utility values for class 1 and 2 respondents showed that they had supportive views of extending the adaptation strategy to all other affected areas. Class 1 members showed a higher utility value, which implied they had a stronger view than class 2 on this aspect. For class 3, the utility estimate was shown to have less statistically significant (z-value < 1.96), which suggested the members could have more diverse views on this issue.

(iii) **Extending the strategies to apply for to all possibly affected areas in Hong Kong in the coming 10 years** –

The estimation coefficient on this attribute for both class 1 and 3 could not show statistical significance at 5% level (z-value < 1.96). This result implied that there could have very diverse views in these two classes. Class 3 consisted of members from a mixed background and this could lead to diverse views. Class 1 comprised members of higher income and education and results showed a diverse view on whether adaptation strategy should be applied to all areas in Hong Kong. Class 2 comprised members from lower income and lower education groups. The estimation coefficient for this class showed a statistically significant supportive view (z-value > 2.58). Perhaps people in this group simply considered that this action was good.

(4) ***Payment*** refers to the preferences of the respondents towards a one-time payment by each resident in Yuen Long District, i.e., it captured the views of respondents toward paying for flood risk management work as well as producing an estimate of respondent's marginal utility of income.

The estimation coefficients on this attribute for all 3 classes were of statistical significance at 95% confidence level (absolute value of z-score > 1.96). All utility values were negative: -5.45, -0.85 and -0.99 for class 1, class 2 and class 3, respectively. Negative utility can indicate that when individuals pay for additional environmental protection measures, consuming more is actually considered a disadvantage. It is clear that people in class 1 had a greater negative utility value for 'payment', i.e., additional 'consumption' actually produced disutility.

(5) Estimated coefficients on **sea level rise** (***SLR)*** showed statistical significance for all classes. This indicates that all classes were concerned about SLR. This will be discussed further in section 5.5.5.

4.3 Analysis of Willingness-To-Pay (WTP) for Flood Control Management

As one of the attributes of the choice sets, respondents were asked if their household would be willing to make a one-off payment of HK$50, 100, 250, 500, 750 or 1000 to a flood prevention fund established jointly by a non-government agent and the government. The respondents were told to make the payment to a fund in order to let the respondents think the funding was not levied by government. Serious social event[8] happened in the period which the survey was carried out. Many people had a very negative view on the government. In order to minimize the negative effect on government policies, the respondents were told to pay to a funding managed by a non-government agent. The WTP is the maximum a household would be willing to spend for one increment of the services for flood control management described in the CE[9]. This household WTP can be used to estimate the WTP for the flood control management programs that could be implemented in Yuen Long District (207,336 households in Yuen Long District in the year 2020) in the future. The hypothetical flood control initiatives presented to the respondents in the survey were constructed from the attributes described above, namely: (1) mangrove management, (2) green infrastructure provision, and (3) adaptation strategies.

[8] Shek DTL (2020), "Protests in Hong Kong (2019–2020): a Perspective Based on Quality of Life and Well-Being", Applied Research in Quality of Life, 15: 619–635.
[9] i.e., added satisfaction that one gets from having one more unit of a service

WTP per person for a flood control management scenario with arbitrary attribute levels can be estimated from the results of the LCM analysis. The marginal WTP in relation to a specific attribute is the **ratio of the marginal utility of the attribute to the marginal utility of money**, which in the case of linear utility is the ratio of the estimated coefficient on any attribute to the estimated coefficient on the payment attribute (Zito and Salvo, 2012). This approach to determine the WTP has been adopted in many other studies (Ardeshiri and Rashidi, 2020; Kawata and Watanabe, 2021; Khan, Maoh and Dimatulac, 2021). Using a simple ratio to determine the marginal WTP allows for a direct comparison of the average and aggregate WTP for each attribute and is useful for discussion purposes. However, it is also possible to construct more complex non-marginal valuation measures that allow for changes in multiple attributes simultaneously and that involve calculating welfare as compensating variation or surplus (reference may be made to Green et al, 1998, Ardeshiri and Rashidi, 2020). I leave that analysis to be completed as future research.

Taking the mangrove management attribute as an example, the estimated coefficient on this attribute indicates the utility of providing one additional unit and the estimated coefficient on the payment attribute indicates the utility of an additional dollar of income. This can be represented by Equation (4.1) below:

$$WTP_{mangrove\ management} = \frac{Coefficient\ of\ Mangrove\ Management}{Coefficient\ of\ Payment\ Attribute} \tag{4.1}$$

The payment recording information for the three classes is extracted from the Latent Gold model and shown in Table 4.13 below.

Table 4.11: Attributes (variables) for the 3-class Optimal Model

	Class1	**Class2**	**Class3**	**Overall**					
Attributes	Class1	Class2	Class3	Wald	p-value	Wald(=)	p-value	Mean	Std.Dev.
Mangrove									
	3.8449	1.1578	-0.6280	100.9045	9.9e-22	100.2169	1.7e-22	2.0006	1.8988
Green infrastructure									
	0.2396	0.8327	-0.0011	35.9963	7.5e-8	21.8921	1.8e-5	0.3314	0.3123
Adaption									
Current situation (no action)	-9.6283	-1.9812	-0.4667	117.0611	6.7e-23	69.8386	2.5e-14	-5.2958	4.2336
increase to all area	7.1871	0.8191	*0.2598***					3.7595	3.3277
10 years effect	*2.4412****	1.1620	*0.2069****					1.5363	0.9416
One-time Payment									
	-5.4510	-0.8471	-0.9859	326.6224	1.7e-70	32.1864	1.0e-7	-3.1124	2.2668

Remarks: ** 90% confidence level (z-score > 1.645); * 85% confidence level (z-score > 1.44)**

4.3.1 WTP for Mangrove Management

From Table 4.11, for Class 1 respondents:

Estimated coefficient for Mangrove Management attribute (Class 1) = 3.8449

The value for estimated Coefficient of Price (Payment) (Class 1) = - 5.451

By Equation (4.1), the average for Marginal WTP (in HK$; US$1 = HK$7.8) for Mangrove Management for one household for 1 Hectare of mangrove area is:

$$WTP_{managrove\ management} = \frac{-3.8449}{-5.451} = 0.7054\ (HK\$\ per\ hectare)$$

Taking a plan to increase 40 Hectare[10] of mangrove area through restoration, the average WTP for one household:

= 0.7054 x 40 = HK$28.216

The aggregate WTP for increasing 40 Hectare of mangrove area through restoration for Class 1:

= HK$28.216 x the number of households in Yuen Long District x percentage of class 1

= HK$28.216 x 207,336 x 48.43%

[10] 40 Hectare was arbitrarily taken as an example to illustrate the average and aggregate value. In the survey, two programs were presented to the respondents for selection and 40 Hectare was one of the programs presented to the respondents. As linear formulae were used for the calculations, adoption of 40 Hectare would not affect the discussion.

= **HK$2,833,071 (about USD363,214)**

Similarly, the 40 Hectare increase for Class 2, the average Marginal WTP = (1.1578/ 0.8471) x 40 = 1.3668 x 40 = HK$54.672

The aggregate WTP for class 2 = $54.672 x 207,336 x 25.89%

= **HK$2,934,713 (about USD376,245)**

For Class 3, the average WTP for increasing 40 Hectare mangrove area = (- 0.6280/ 0.9859) x 40 = - 0.6370 x 40 = - HK$25.480

The aggregate WTP for class 3 = - $25.48 x 207,336 x 25.68%

= **– HK$1,356,654 (about – USD173,930)**

The utility value for class 3 is negative and the negative utility means that the respondent needs to be compensated for accepting a marginal increase in mangroves.

A summary is given in Table 4.12 below:

Table 4.12: WTP for Mangrove Management

	Class1	**z-value**	**Class2**	**z-value**	**Class3**	**z-value**	**Total**
Percent of households	**48.43%**		**25.89%**		**25.68%**		**100%**
Mangrove							
	3.8449	4.9053	1.1578	5.703	-0.628	-4.5728	
Payment							
	-5.451	-6.7513	-0.8471	-10.2295	-0.9859	-12.259	
Marginal WTP	0.7054		1.3668		*-0.6370*		
Average HK$ (for 40 Hectare)	28.216		54.672		*-25.480*		
Aggregate HK$ (for household population 207,336)	2,833071		2,934713		*-1,356,654*		**5,767,784 - 1,356,654**
							Net value= 4,411,130
Comments	Willing to pay at a smaller amount		Willing to pay slightly more than Class 1 respondents		Need to be compensated for an increase in mangroves		Whole population by taking the compensation into consideration

Remarks:

- **Statistical significant at 99% confident level with z-value > 2.58**

- **40 Hectare is taken as an example for discussion**
- **Negative marginal utility noted for class 3; this implied that the respondent needs to be compensated for accepting a marginal increase in mangroves**

4.3.2 WTP for Green Infrastructure Provision

From Table 4.11, for Class 1 respondents:

Estimated Coefficient of Green Infrastructure Provision (Class 1) = 0.2396

The Coefficient of Payment Attribute (Class 1) = - 5.451

By Equation (4.1), the average WTP for Green Infrastructure provision for one household for 1 green infrastructure project is:

$$WTP_{green\ infrastructure} = \frac{-\ 0.2396}{-5.451} = 0.0440$$

Taking 20 additional green infrastructure projects, the average WTP of Green Infrastructure for class 1 = 0.0440 x 20 = HK$0.8791

Accordingly, the aggregate WTP of Green Infrastructure for Class 1

= HK$0.8791 x the number of households in Yuen Long District x percentage of class 1

= HK$0.8791 x 207,336 x 48.43% = **HK$275,033 (about USD35,261)**

The average WTP of Green Infrastructure for class 2 = 0.9830 x 20 = $19.66

The aggregate for Class 2 = HK$19.66 x 207,336 x 25.89%

= **HK$1,615,629 (about USD207,132)**

For Class 3, the average WTP = (- 0.0011/ 0.9859) x 20 = - 0.0011 x 20 = - HK$0.022

The aggregate WTP for class 3 = - HK$0.022 x 207,336 x 25.68%

= **- HK$1,171 (about - USD150)**

However, it is noted (Table 4.13) that the attribute for class 3 is insignificant at 5% level (z-value is -0.0111, which is < 1.96).

A summary is given in Table 4.13 below:

Table 4.13: WTP for Green Infrastructure (GI)

	Class1	z-value	Class2	z-value	Class3	z-value	Total
Percent of households	**48.43%**		**25.89%**		**25.68%**		**100%**
Green Infrastructure							
	0.2396	2.1398	0.8327	5.4693	-0.0011	-0.0111	
Payment							
	-5.451	-6.7513	-0.8471	-10.2295	-0.9859	-12.259	
WTP (for 20 additional GI projects)							
Average HK$	0.8791		19.66		0.022		
Aggregate HK$ (for household population 207,336)	275,033		1,615,629		- 1,171 insignificant		**1,890,662**
Comments	Willing to pay at a limited amount		Willing to pay more than Class 1 respondents		Almost not willing to pay; especially the z-score < 1.96 indicating no statistical significance can be established		Whole population (class 3 not included as z-score < 1.96)

Remarks: z-values for class 1 & 2 > 1.96 showing statistically significant at 95% confident level

4.3.3 Adaptation Strategies (AS)

Adaptation strategies (AS) include actions to reduce potential flood and storm damages. Examples in Hong Kong include awareness campaigns, early warning systems, evacuation plans and development restrictions in low-lying areas. There are 3 hypothetical strategies at 3 different levels, which shows an incremental change:

(i) Current situation (no action) Adaptation Strategies – Maintaining the use of current strategies, such as early warning system, evacuation plans, etc.

(ii) Expand strategies to all currently affected areas – Extending the current strategies to apply for all areas in Hong Kong that are currently affected by flooding

(iii) Expand strategies to areas possibly affected in 10 years – Extending the strategies to apply for to all possibly affected areas in Hong Kong in the coming 10 years

By adopting the same calculation approach and the information in Table 4.11, a summary of the findings for the three adaptation strategies is given in Table 4.14 below.

Table 4.14: Marginal WTP for Adaptation Strategies (AS)

	Class 1	z-value	Class 2	z-value	Class 3	z-value	Total
Percent of households	**48.43%**		**25.89%**		**25.68%**		**100%**
Adaption Strategies (estimated coefficient)							
Current strategies for seriously affected areas (Existing condition)	-9.6283 (set to 0)^	-2.9583	-1.9812 (set to 0)^	-8.2183	-0.4667 (set to 0)^	-3.1968	
Expand strategies to all currently affected areas (est. coeff. Marginal WTP)	7.1871 (16.8154)	3.883	0.8191 (2.8003)	4.6344	0.2598 *(0.7265**)*	1.9332**	
Expand strategies to areas possibly affected in 10 years (est. coeff. Marginal WTP)	2.4412 (*19.2566****)	1.5876***	1.162 (3.9623)	8.5507	0.2069 (*0.9334****)	1.5856***	
Payment							
	-5.451	-6.7513	-0.8471	-10.2295	-0.9859	-12.259	
Marginal WTP ($)							
Seriously affected	0		0		0		
Currently affected	3.0848		3.3057		*0.7369***		
Possibly affected in 10 years	*3.5327****		4.6775		*0.9467****		
Aggregate MWTP (for household population 207,336)							
Current strategies for seriously affected areas HK$	0	Existing Situation	0	Existing Situation	0	Existing Situation	**0**
Expand strategies to all currently affected areas HK$	639,590		685,391		*152,786***		**1,324,981 (US$169,869)**
							1,477,767** (US$189,457)
Expand strategies to areas possibly affected in 10 years HK$	*732,456****		969,814		*196,285****		**969,814 (US$124,335)**
							1,898,555 (USD 243,404)***
Marginal WTP for AS Improvement (HK$)	**639,590**		**1,655,205**				
	1,372,046***				***152,786*****		
					349,071***		

Remarks:

- *** 95% confidence level; ** 90% confidence level; *** 85% confidence level**
- **Statistical Significance: z-values > 2.58 (99% confidence level); > 1.96 (95% confidence level); > 1.645 (90% confidence level); > 1.44 (85% confidence level)**
- **"Seriously affected areas" is the Status Quo (SQ), i.e. the existing situation that is already taking place**
- **Estimated coefficients are mean-centered or center-coded, so the negative values plus the positive values for the AS attribute for the three levels will be added to zero**
- **The existing condition (SQ) coefficient estimate will be set at zero (the condition has already existed, and people are no need to pay)**
- **While sum of the estimated coefficients will be zero, the other level's coefficient estimates will be shifted upwards accordingly from zero to the first level and then to the second level to get correct estimates of Marginal WTP (MWTP) for an improvement**

The initial level of AS indicates an existing condition and the residents are not required to pay (except the general tax they needed to pay to the government) for the existing AS. In this study, only improvements were offered to the respondents for selection. The second level of AS (i.e. expand strategies to all currently affected areas) can be considered as improvement works and both class 1 and 2 show positive estimate coefficient for marginal WTP (at 95% confidence level). The results for class 3 does not show a statistical significance at 95% confidence level (z-score > 1.96) but it shows a statistical significance at 90% confidence level (z-score > 1.645). This indicated that the people in both class 1 and 2 were willing to pay for the improvement works at 95% confidence level, and all 3 classes people (100%) were willing to pay for the 2nd level improvement works at 90% confidence level.

The third level of AS (i.e. expand strategies to areas possibly affected in 10 years) can be considered as the highest improvement level. For this level, the results show that only class 2 respondents have positive MWTP with statistical significance at 95% confidence level. The results for the other two classes only show statistical significance at 85% confidence level, i.e. it is 95% confident that the people in class 2 are willing to pay for a higher improvement AS, and 85% confident that all people are willing to pay for higher improvement.

According to the findings, we may say that:

1) About 74.32% of the respondents (i.e. both class 1 and 2 people) are willing to pay for the expand strategies to all currently affected areas, i.e. first level improvement for AS); but if we accept a 90% confidence level, 100% (i.e. all three classes) are WTP.
2) Only 25.89% (i.e. class 2 people) are willing to pay for the expand strategies to areas possibly affected in 10 years, i.e. the highest level improvement for AS; but if we accept a 85% confidence level, 100% (i.e. all three classes) are WTP.

4.3.4 Comparison

A comparison of the aggregate WTP for the three attributes is given in Table 4.15 below:

Table 4.15: Comparison of Aggregate WTP for the three flood mitigation alternatives

Attributes	Yuen Long District (HKD) (USD 1 = HK$7.8)	Whole Hong Kong* (Million HKD) (USD 1 = HK$7.8)	Comments
Mangrove Management	4,411,130	**55.54 (USD 7.12M)**	Highest aggregate WTP
Green Infrastructure	1,890,662	23.80 (USD 3.05M)	
Adaptation Strategies			
Seriously affected	0	0	Existing Condition
Currently affected (1st level improvement)	1,324,981 (US$169,869)	16.68 (USD 2.14M)	
	*1,477,767** (US$189,457)*	*18.61** (USD 2.39M)*	@ 90% confidence level
Possibly affected (2nd level improvement)	969,814 (US$124,335)	12.21 (USD 1.57M)	
	*1,898,555*** (USD 243,404)*	*23.90*** (USD 3.06)*	@ 85% confidence level

Remarks:

(1) 95% confidence level is taken (except specified)

(2) The total number of household in Hong Kong is 2,610,000 for the year 2019, i.e. 12.59 times for Yuen Long District;

(3) The evaluation was extended for the whole Hong Kong situation as most of the people in Hong Kong were considered to live in high-rise buildings and in urban environment; their perception on flooding and flood prevention measure could be similar – in a well-developed urban environment and only very small number of people living in low-rise buildings

Residents of the Yuen Long District seem to prefer mangrove management as a flood mitigation alternative. Although they also show supportive view to provide green infrastructure to manage flood risk, the WTP level is about 2.33 times lower than mangrove management. The residents also showed positive WTP on the improvement of AS, in particular about 75% respondents (100% if 90% confidence level is accepted) supported the 1st level of improvement of AS, and their WTP on AS also exceeds green infrastructure when considering all levels of improvement works, albeit to a lesser extent than mangrove management.

4.4 Summary

There were 463 effective survey respondents. The sample size was reasonable and can be regarded as representative. The age and income distribution of the respondents matches the distribution pattern in the Yuen Long District reasonably well. The survey results show that the flooding experience of respondents has a positive but weak relationship with the distance from Mai Po. This indicates that the flooding experience may not be from Mai Po. The 'elevations' of the respondents' locations have no relationship to the flooding experience. This is reasonable, as most respondents live in high-rise residential buildings made of concrete, with deep foundations; these structures are not affected by flooding. However, if respondents believe flooding prevention strategies are necessary, green infrastructure may be considered. Further examination of the views of respondents living in the ‘villages’ (houses/low-rise buildings) indicates a greater concern about flooding and SLR. These respondents also believe their residences are more vulnerable.

When we adopted the LCM analysis, we note that Class 2 respondents are more willing to pay for various flood risk management strategies. Though the Class 2 respondents are from a lower income and education group, they are basically the people who have positive values for environmental protection. Class 1 people, who are from the higher income and education group, are also willing to pay for various flood risk management strategies.

For the three hypothetical flood control management approaches, in the aggregate the respondents are more willing to pay for the works to manage mangrove areas for flood risk control than they are willing to pay for the other management approaches presented. They also show support for providing green infrastructure to control flooding. However, the amount they are willing to spend is almost 2.33 times less than that for managing the mangrove areas. The views pertaining to the improvement of adaptation strategies for flood control are also positive. Especially, class 2 respondents (about 26% of the population) support both levels of improvement, while three quarters (100% support if 90% confidence level is taken) of population support at least one level of improvement on AS. Moreover, 100% support for two level of improvement if 85% confidence level is taken.

Chapter 5

Discussion

In this section, a brief discussion of the findings is presented. Insights, and possible future work derived from the findings, are also discussed.

5.1 Mangrove Management

In Hong Kong, wetlands and mangrove forests – freshwater and intertidal, natural and human-modified (such as fish ponds) – cover about 5% of the territory's area. Although wetlands cover a small portion of the land in Hong Kong, they support a wide array of wildlife (Environment Bureau, 2016). The Mai Po Wetlands support over 70% of bird species recorded in Hong Kong, and are important feeding and resting grounds for migratory birds. This study found that people living near the Mai Po wetland also view the area positively for flood risk management. People who have a higher income and higher level of education (class 1), comprising close to half the sample population, have a very positive view of the flood protection service of urban mangroves. These people also showed concern about the adverse effects of flooding and SLR (sea level rise) in Hong Kong (SLR in the Victoria Harbor in Hong Kong, based on the records of the tide gauges measurements has been rising at a rate of about 3 cm per decade since 1954 www.hko.hk). From this point of view, the government should consider investing more in wetland protection.

Chan et al. (2013) found that the government barely informed citizens of Hong Kong about climate change and coastal flooding. Interestingly, class 1 highlighted that people do not need to have a positive view of the environment (ATE score) in order to express high interest in pursuing mangrove flood protection services. This perhaps is due to the higher education level of class 1, which means they were either more informed about mangrove services or able to interpret the information presented in the survey better than others. On the other hand, people with a lower level of education were more likely to have lower concerns about flooding and SLR (class 2 and 3). These results could be used to argue that education and flood concern were major factors influencing people's higher level of support for flood protection from mangroves.

If the government provided better education for the citizens of Hong Kong about the effects of climate change, SLR and the functions of wetlands, people might be more inclined to support non-conventional flood mitigation measures, such as urban mangroves. This is also supported by the fact that members of class 1, who had more flooding experience, had a higher positive utility value for mangroves; class 2 people had a moderate level of flooding experience and tended to have a much lower positive utility toward mangroves; while class 3 people had no flooding experience and displayed negative utility toward mangroves. This is to say that, if people are aware of the effects of flooding, they will be more agreeable to flood protection from mangroves. If the government provides comprehensive education about the adverse effects of flooding, it may help people's understanding and lead them to accept mangroves as flood protection.

However, Chan et al. (2013) pointed out that the Hong Kong Government is managing coastal flood risk based on an ad hoc engineering approach. The government is aware[11] that the risk of coastal flooding is increasing under climate change. The Stormwater Drainage Manual (DSD, 2018), Hong Kong's official flood management document that provides guidance on inland and urban drainage infrastructures, does not include any detailed discussion of the use of mangrove wetlands for flood risk management, nor any detailed mention of the SLR phenomenon. Presently, the DSD is only authorised to deal with coastal flooding through conventional coastal drainage systems. On the other hand, the role of the Environmental Protection Department is primarily to formulate and provide guidance for government institutions in Hong Kong to initiate and adapt plans and policies. The department is not authorized to expand urban wetland areas to promote their use as flood mitigation alternatives. No current government body can utilise urban mangroves as a flood mitigation alternative. Hopefully, the findings of this study highlighting people's preferences for urban mangroves to function as a flood control measure will incentivise the government to focus more attention on this field. The government should dedicate more investment to improving mangrove wetlands for managing flood risk. In addition, the government should also establish a comprehensive flood risk management plan and coordinate various governmental departments to implement the plan.

[11] Lee BY, Wong WT, Woo WC (2010), "Sea-level Rise and Storm Surge – Impacts of Climate Change on Hong Kong", presentation at HKIE Civil Division Conference 2010, 12-14 April 2010, Hong Kong

5.2 Provision of Green Infrastructure (GI)

Thorne et al. (2018) found that urban planners and many policymakers have criticised the adoption of GI for flood risk management. However, a study in Hong Kong by Kim et al. (2020) has indicated that people there consider GI to be a viable alternative strategy for flood risk mitigation. By using housing prices as an indicator of flood risk, Kim et al. found that GI had a positive effect on the value of nearby housing, possibly due to the fact that people believed in GI's capacity to reduce flood risk. This finding matches the findings of the present study, in that people – irrespective of income level or education level – perceive GI as having a positive effect on controlling flood risk. Kim et al. (2020) found that housing near traditional flood control infrastructure showed no evidence of such price effects.

The findings of the present study indicate that the majority of respondents (~75%, class 1 and 2) would prefer an increase in the use of GI as flood risk control measures. Yet, the model shows that for people who desire more GI programs, they will tend to opt for mangroves, if they are given the opportunity. Alternatively, the remaining group of people who doesn't desire GI would opt for adaptation strategies instead. This means that no matter the class, there is always one mitigation measure that will be more appealing than GI

The findings of this study and Kim et al. (2020) show that the public's perception of flood risk may provide a basis for the government, particularly the Hong Kong Special Administrative Region Government, to better understand people's attitudes, and to dedicate more investment toward GI.

5.3 Adaptation Strategies (AS)

Hong Kong's ad hoc approach was further exposed in 2017, when Typhoon Hato (https://www.hko.gov.hk/en/informtc/hato17/hato.htm) caused flooding in the Hang Fa Chun District on Hong Kong Island. Currently, the DSD has adopted engineering approach for the rectification work in seriously affected areas. A flood warning system was established by the DSD for flood-prone villages[12]. In this sense, adaptation strategies (AS), such as early warning systems and evacuation plans, should help reduce the impact of flooding and storm damage in seriously affected areas.

This study found that most respondents supported the idea of improving AS. The marginal WTP shows that about 75% of people (100% if 90% confidence level is taken) support at least one level of improvement, i.e. most of the people prefer additional work over no action taken. For classes 2, with a lower education level and lower concerns about flooding and SLR, perceived that improvement of AS should be extended to the highest level. In other words, the lower education people appeared to be more supportive to extending the AS to the highest level. Perhaps, this group of people may have a simple and direct impression that more AS should be good for flood risk management. However, some of the high education people may question the necessity of extending the AS to the highest level. Accordingly, only 85% statistical significance can be established for all the three classes to support improvements to the highest level. An awareness campaign could be an effective way to expand support for AS. This means more awareness campaigns to educate and raise concerns surrounding coastal flooding and SLR, while also promoting the benefits and use of non-conventional flood protection measures, could lead the public to become more supportive and willing to pay for non-conventional mitigation alternatives against imminent SLR.

All in all, this study has revealed that the current practice of providing warning systems only to flood-prone villages may not match people's expectations. Most people do support improvement of AS.

5.4 Willingness to Pay for Flood Protection Measures

A study in Germany (Entorf and Jensen, 2020) has indicated that prior experience and knowledge of the threat from potential flood damage may lead people to be more aware of the risk they face, spurring the WTP for improvement work; in other words, better knowledge of climate risks strongly improves the WTP for flood risk control measures. In my study, similar effects of flooding experience on people's decisions was found. Those who had experienced more flooding (class 1)

[12] https://www.hkfsd.gov.hk/eng/cep_edu/cep/disaster_preparedness/natural_disasters_hk/flooding.html

were more inclined to choose one of the flood mitigation alternatives instead of status quo, and none of the three strategies had negative utility value for this group. Whereas people who had the least experience with flooding (class 3) were much less inclined to opt for any alternatives, even AS, which had a positive utility value – very close to zero – indicating this group likely thought existing flood mitigation measures were good enough. However, this study also revealed that flooding experience was one of the aspects affecting people's WTP. Class 2 demonstrated that even when flood experience was not a statistically significant factor, people still showed a positive WTP. Information has been summarized in Tables 4.17 to 4.19. When people had higher income, a higher education level and more previous flooding experience (class 1), they were much more WTP. People in class 2 had a much higher ATE value and had lived in the Yuen Long District longer than class 1, which could be two of the factors influencing why they had a lower WTP.

Class 1 people, who are from the higher income and education group, are also willing to pay for various flood risk management strategies. However, when compared with those of Class 2, they are less willing to pay. Normally, flooding in Hong Kong only affects people's activities for a short period of time, causing some inconvenience but nothing too concerning, i.e. the type of flooding they experienced did not seriously affect their lives. Therefore, even though class 1 was willing to pay for additional measures overall, they were only willing to do so to a certain extent, if the trade-offs were good. Additionally, people's education level in class 1 might also have affected their perception on who should pay for improvement work. People with a higher level of education might have a better understanding of their own costs and benefits when considering whether it is justified to pay for extra measures. Moreover, this may be due to the fact that they are the persons who will pay more attention to evaluate the value of government policies and the amount to pay is at a conservative level. On the other hand, this may also be related to their own self-protection since they can afford to locate in safer locations and perceive that flooding may not seriously affect their life. This could explain why this group tended to be reluctant to pay too much. For the class 2 respondents, they are from lower income and lower education group. They may not have good knowledge on flooding protection, i.e. least familiar with the hypothetical service, and they may tend to overstate their true willingness to pay (Aadland et al, 2012).

The Entorf and Jensen (2020) study detected a convex functional form that indicated relatively young and older residents were willing to pay more than middle-aged citizens. The results of my study did not indicate that the age covariate had statistical significance to support a relationship with the WTP (Table 5.1). However, some insight on this topic can still be inferred based on the profile of the LCM (Table 4.10). Younger and older people were likely to have lower incomes and lower levels of education (classes 2 and 3). These groups also had relatively higher utility value for payment and were not as sensitive to changes in payment. Perhaps this can be explained by these groups having a lower understanding of the trade-off scenario presented to them; therefore, they may have been more easily influenced by other factors, such as the SLR scenario. This appears to be somewhat in line with Entorf and Jensen (2020).

Table 5.1: Estimation for the covariate "Age" (extracted from Latent GOLD)

	Class1	z-value	Class2	z-value	Class3	z-value	p-value
Covariate							
Age							
	-0.0301	-0.2813	0.0400	0.2953	-0.0099	-0.0716	**0.94**

p-value > 0.05 showed insignificant at 5% level

5.5 Sea Level Rise

As many Asian coastal cities are predicted to be vulnerable to SLR due to climate change (Hanson et al., 2011), it is logical to hypothesise that if people clearly understood the effects of SLR, they would be more likely to support repair and improvement work on existing flood risk management infrastructure. The data from this study has demonstrated a statistical significance in the relationship between flood risk management and perceptions about SLR.

A 2006 World Bank report (Buys et al., 2006) indicated that SLR of 1.5 m could reduce China's GDP by 2.4-10.8%. A report by the Civic Exchange further suggested that the effect of SLR on the Pearl River Delta Region, where Hong Kong is located, could be even more serious (Tracy et al., 2006). A separate study by Chan et al. (2012) also recognised that many coastal cities in eastern China, such as Guangzhou, Shenzhen, and Hong Kong, are highly vulnerable to the impacts of coastal flooding due to large populations and economic assets. My paper addresses the social side of this discussion, in that people are clearly making different choices when presented with a SLR scenario. Even though no statistical significance for SLR between different classes was found, the overall trend shows that when a SLR condition is present, people tend to select one of the offered flood control programs, rather than the status quo. According to the model, people who had more previous flooding experience (class 1) also expressed more concern about SLR and flooding in general; as a result, they tended to opt for any additional mitigation program, rather than the status quo.

Although respondents in general expressed concern about SLR, there has not been much work by the Hong Kong Government on this issue. Reports[13] recently published by the Environmental Protection Department in Hong Kong did not address or mention coastal flooding issues. The major contents in the government reports focused on carbon emissions at the time (Chan et al., 2013). However, previous studies have pointed out that Hong Kong is a coastal city and, in the future, SLR can have a substantial effect on the economy and the living environment. To respond to people's concerns, the government needs to pay more attention to SLR, including commissioning more research and urban planning in response to the SLR scenarios.

As climate change continues and SLR becomes more imminent, breaches, such as the ones caused by Typhoon Hato in 2017 and Typhoon Mangkhut in 2018, will cause more and more Hong Kong residents to experience the effects of flooding, which might increase the public's overall concern about flooding and SLR. This study has also revealed that people are concerned about SLR (all three latent classes in my sample). Accordingly, the government should direct more attention toward preparing for SLR and coastal flooding, and this study could be used by policymakers to gain a better understanding of people's preferences regarding this issue, and hopefully incentivise them to take more action.

[13] Environment Performance Report 2016 and Environment Report 2016 (https://www.epd.gov.hk/epd/english/resources_pub/publications/pub_reports_ap_archives.html)

Chapter 6

Conclusion

In this section, I provide conclusions from the study beginning with a restatement of the problem addressed and then focussing on the key insights, limitations and future directions for the work. The study concentrates on the Mai Po area of Hong Kong, a wetland located along the northwest coast of Hong Kong. The area's sub-tropical climate causes heavy rainstorms and typhoons every year. Flooding is always a problem needing to be addressed by the Hong Kong Government. Traditionally, the government has adopted a hard engineering approach, constructing underground receptors and drainage to temporarily store water and divert flooding to suitable discharge points. However, wetlands are a type of ecosystem that can mitigate flood risk and regulate local climate (Ramsar, 2013). For example, the Mai Po natural area and adjacent fish farms comprise a wetland that could help mitigate flood risk.

This study aimed to investigate people's preferences in the Yuen Long District in the New Territories of Hong Kong for flood control and the protective role of wetland – the Mai Po Natural Reserve and the adjacent fish farms[14], which were considered as buffers for reducing storm damage in residential areas. The estimated value of the flood protection services provided by the wetland and fish farms was derived from the WTP of local residents for this ecosystem service.

In addition, these findings will increase understanding of the value of such services compared to conventional infrastructure. This study will also be useful for strengthening understanding of the flood protective function of wetland and the fish farms for the adjacent residential areas, which could highlight their importance at sites where there is a clear interplay between urban development and wetland including local aquaculture.

[14] The potentially negative impacts associated with living near fish farms have not been included in this study.

6.1 Key Insights

In reference to the research questions outlined in Chapter 1, the findings and discussion are summarised in Table 6.1. The findings of this study, described in Chapters 4 and 5, have revealed that all respondents have – to some extent – supported the adoption of GI and wetlands for flood risk management. Also, the SLR attribute showed statistical significance in the study. This implies that respondents are concerned about SLR.

Previous studies indicated that the government should be more concerned about the adverse effects of climate change, such as SLR and flooding. However, these studies have also pointed out that government departments do not have a holistic approach for tackling flood risk management. The Drainage Services Department of the Hong Kong Government normally adopts a hard engineering approach to deal with flooding problems. Even though there are studies indicating that mangrove wetlands and GI can have a positive effect on flood risk management, the responsible government department, the DSD which is empowered to deal with flooding issues in Hong Kong, do not pay much attention to consider utilizing mangrove and green infrastructures for flood control. This can be revealed by searching the flood management measures in the website of DSD (www.dsd.gov.hk). The DSD has clearly mentioned in the website that they concentrate on the provision of flood pathways, construction of large drains and underground reservoirs for flood prevention.

The survey in this study has revealed that respondents with lower income and lower education are willing to pay more for . . . . . than the respondents with higher education and higher income. This finding was not consistent with the belief that more wealthy people would have higher willingness to pay (Franzen and Vogl, 2012). However, Shao et al (2018) found in China that as residents' income rises, their marginal WTP for environmental protection declines, and a reversal occurred at the top income level. Moreover, Tsang et al (2009) has also studied trust in governance in Hong Kong and they argue that environmental policy is not widely agreed on by the people of Hong Kong. Accordingly, it is not surprising that higher income people show a lower willingness to pay for flood protection strategies. Further study of this specific issue may be necessary in future.

Table 6.1: Findings and Discussion for the Research Questions

Research Questions	Findings and Discussion
How do households located near coastal wetlands, such as those in Hong Kong, value the flood protection service of the wetlands?	The findings, described in Chapter 5, revealed that all respondents supported, to some extent, the adoption of mangrove wetlands and GI for flood risk management. People with higher income and a higher education level did have a greater utility for using mangrove wetlands for flood risk management. However, they showed a lower utility, compared to people with lower income and a lower education level, for the provision of GI for flood risk management. This indicates that most people in this area do support managing flood risk through a green approach. This presents an opportunity for the government to consider alternative approaches to flood risk management, in addition to the traditional hard engineering approach.
Does the prospect of sea level rise alter these ecosystem service values or affect preferences for flood management?	This study has revealed that the relationship between support for flood risk management and SLR has statistical significance. In other words, people were concerned about SLR. However, previous studies indicated that the Hong Kong Government did not seriously consider the effects of climate change on flooding. The construction of hard engineering facilities to prevent or mitigate flooding is based on the worst scenario in 100 years. To respond to the people's concerns, the government needs to pay more attention to SLR, and commission more research and urban planning efforts.
Are residents willing to pay for alternatives to supplement conventional flood mitigation measures, including improving wetlands to control flooding?	The findings in Chapter 5 show that people with flooding experience have diverse WTPs. This is not the same as the findings reported by Entorf and Jensen (2020) in Germany. On the other hand, two groups of people with similar flooding experience did show some difference in WTP. People with a low income and low education level showed a higher WTP, whereas people with a higher income and higher education level had a lower WTP. This indicated that flooding experience was only one aspect affecting people's WTP, and was not the only attribute dominating their decisions. People considered to have higher analytical skills (higher education level) may also take the responsibility aspect into account. They may believe it is the responsibility of the government to pay for the work, and that the payment not be restricted to local people. Aadland et al (2012) in their study indicated that if respondents had least familiarity on the hypothetical service, they would tend to overstate their true willingness to pay. This finding indeed is similar to the findings presented by Shao et al (2018) in that the WTP for environmental protection does

	not always rise with the increase in income. Moreover, the Hong Kong people in general are dissatisfied with the government performance on environmental issues (Tsang et al, 2009). Accordingly, it is logical to see that the higher education and higher income group people do not trust the government's environmental policy. The situation is further complicated by the current political situation in Hong Kong (Hartley and Jarvis, 2020).
Which alternative flood mitigation measures are most preferred by local residents?	This study found that people living near Mai Po did have a positive view of the wetland for flood risk management. People with higher income and higher education level (class 1), which consisted of close to half the sample population, did have a very positive view of the flood protection service of urban mangroves. The other two classes, although they showed a relatively lower utility, still agreed that flood protection by mangroves is desirable.

Respondents expressed a positive view about mangrove wetlands and GI, yet their WTP to adopt a green approach to tackling flooding is still not very high, particularly for those people with higher incomes and education levels. This is arguably to be expected in Hong Kong, as most people are living in high-rise residential buildings. These structures are considered 'strong', with deep foundations, and residents of these buildings feel they will be very safe in a flood situation. Although flooding may affect roads and some ground floor shops for a short period of time, most people's lives in high-rise buildings will not be affected, as the drainage system in Hong Kong is good. Water can be discharged quickly, and flooding in most situations only lasts for a few hours. The negative utility value for the higher income and higher education group indicated that their WTP could be conservative. This finding is similar to studies from other countries, in that middle-age people showed lower willingness to pay (Class 2 people have slightly higher age).

Furthermore, for the sampled population, the results showed that over 74% of Class 1 and Class 2 people would be willing to pay for flood risk management strategies, including mangrove management, green infrastructure provision and adaptation strategies. This is equivalent, from the study area, to over $140,000 HKD ($17,949 USD) of funding per hectare of mangroves, a point of interest that policy makers should consider when studying the flood mitigation alternatives outside of conventional infrastructure.

6.2 Limitations

The surveys were conducted in the Yuen Long District, and most respondents were residents of urban districts, living in high-rise residential buildings. There are still some people living in ‘villages’ near Mai Po; however, only limited surveying could be conducted there due to the social events in Hong Kong of late 2019. The uneven distribution of the locations of the respondents may, to some extent, have affected the results.

Another drawback of this study is the design of the survey. The survey was conducted in Hong Kong but the questionnaire and choice sets were designed in English, so there might have been some mistranslation and/or design flaws in the survey that failed to convey certain information to the respondents.

When the surveyors approached potential respondents, the project was introduced using familiar names like “project by World Wildlife Fund Hong Kong” instead of “project by Simon Fraser University from Canada”. The reason for this was to lower the guards of the potential respondents and make them more willing to cooperate for the survey. However, this approach could led to biases as respondents would realize that it was a survey relating to the environment or conservation, those that were uninterested might have refused to participate the survey already, while those that chose to partake the survey might wanted to “appeal” in front of the surveyor to “look better”.

When conveying information concerning the CE, the information might not have been conveyed properly and people might have conducted the CE without clear knowledge on what each attributes represented and the difference between each level. Particularly for the elders and lower educated groups. Adaptation Strategies, was potentially affected by this the most, given that it was the only nominal attribute in the CE without clear numerical definition to distinguish between the levels, which might have caused people not realizing that the 3 levels were designed to be in incremental changes.

The study sample size was also a limiting factor in the analysis. When finding the optimal LCM, it was not possible to test for models beyond three classes because anything beyond would have simply been too unstable. The most probable reason for this limitation was that the sample size was not large enough to support more detailed estimations. Therefore, it was not possible to further split classes with conflicting characteristics, which off-set each other and became insignificant.

A simplified measure of people's attitude towards environment (ATE) was performed in order to limit the interviewing time. The ATE concept was attributed to the well-known NEP concept which was widely used in environmental studies. The ATE could not totally reflect the NEP concept and this limited the measurement of people's attitude on pro-environmental issues. In next stage of study, a more complete measurement and calculation proposed by Dunlap (2008), should be performed.

In the study, Likert type questions were adopted and used in the regression analysis after coding. Likert scale questions were set to measure the attitude of respondents, however when coding the responses, it turned the attitudes of the respondents into coefficient and basically assumed that each change in the scale had equal interval, which might not necessarily be the case. Equidistance of the space between each choice cannot be assured and it is questionable whether this scale can truly measure the attitudes of respondents. It can hardly avoid the answer to concentrate on one response side (agree/disagree) and it is known that people tend to avoid choosing the "extremes" options on the scale even if an extreme choice is considered to be the most accurate. Hence lowering the accuracy on how much the data were actually able to reflect the respondents' attitude.

For examining the WTP in this study, the marginal values of the attributes were taken to be the degree of the respondents' preferences for each attribute in isolation. This approach was a simple approach in that a simple assumption was made. However, if the "attributes" were not isolated, a compensation surplus (CS) approach should be considered reflecting the non-marginal changes in households' welfare under differing resource and environmental governance scenarios. Consumer surplus is a measure for consumer benefits that the consumers pay for a product or service is less than the price they are willing to pay, i.e. the additional benefit that the consumers receive. In next stage of study, compensation surplus approach and similar method will be adopted in the WTP study to address non-marginal changes and more complex policy scenarios.

Lastly, several questions about mangroves for flood risk management were removed because: (i) the survey was considered to be too long during the test phase, and (ii) the limited knowledge of the respondents on mangroves.

6.3 Future Works

In view of the limitations described in 6.3, more surveys should be conducted in the future, especially collecting the opinion of residents in the ‘villages’ near Mai Po. Moreover, the survey could be extended to other parts of Hong Kong and, if possible, to residents in Shenzhen as well, where there is another mangrove wetland (Futian mangrove nature reserve). A comparative study between the opinions of the residents of Hong Kong and Shenzhen may yield interesting results, as well as provide some insights into the government policies of the two cities.

In the survey, more questions concerning mangroves and wetlands could be asked in order to carry out more in-depth analysis on people’s perception on wetlands and the ecosystem services they provide.

The WTP of an attribute in this study was determined by the ratio of the coefficient of marginal change of the attribute to the coefficient of price. It is enough to provide a simple comparison between the aggregated WTP of the attributes. The marginal value of the attributes reveals the degree of the respondents’ preferences for each attribute in isolation, but a compensation surplus (CS) approach should be used to reflect non-marginal changes in households’ welfare under differing resource and environmental governance scenarios (Cheng et al, 2021).[15] This has not been calculated in this study but in future, calculating the compensation surplus in respect of the provision of flood control alternatives can provide valuable information.

[15] $CS = -\frac{1}{marginal\ utility\ of\ the\ payments}(V_0 - V_1)$ where V_0 is the level of residents’ welfare in the initial state and V_1 is the level of residents’ welfare after strengthening the flood control alternative. The latter level of welfare may involve changes in multiple attributes that form a broad policy scenario (versus a simple marginal change in one attribute).

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Appendix I

Hong Kong Flooding Problems

(Information published by the Drainage Services Department, Hong Kong Government)
(extracted from: https://www.dsd.gov.hk/EN/Flood_Prevention/Our_Flooding_Situation/Flooding_Problems/index.html)

Hong Kong is on the common track of tropical cyclones and can experience very heavy rainstorms at times. The annual average rainfall is about 2400 millimeters, one of the highest among the cities in the Pacific Rim. During particularly heavy rainstorms, flooding in the rural low-lying areas and natural flood-plains in the northern part of the territory and in parts of the older urban areas may occur. Some rainfall records in Hong Kong are shown below:

Subject	Rainfall record	Date
Maximum hourly rainfall	145.5 mm	7 June 2008
Maximum daily rainfall	534.1 mm	19 July 1926
Maximum monthly rainfall	1346.1 mm	June 2008
Maximum annual rainfall	3343.0 mm	1997

Rapid urban development in the eighties resulted in intensive development in the rural areas including the flood-plains. This had turned large areas of natural ground into hard paved areas and as a result, rainwater which formerly was retained, now quickly becomes surface flow. The expansion of built-up areas in close proximity to the major watercourses had also reduced their flood carrying capacities and had further aggravated the flooding problems. In recent years, flooding threats in the New Territories have been significantly reduced subsequent to the completion of main drainage channels and village flood protection schemes under our flood prevention strategy.

The expansion of the built-up urban areas had also aggravated flooding risks in the old urban areas, where aged storm water drainage systems were built decades ago to the older protection standards. The flooding risks in the urban areas have been improved gradually over the years through implementation of various measures, such as interception, storm water storage and pumping, identified and adopted under the flood prevention strategy.

With our continuous efforts, flooding risks have been much reduced but cannot be entirely eliminated. For example, flooding may occur when there is an exceptional rainstorm whose intensity is more severe than that assumed in our design standards. Also the drainage system may not function as designed if some sections and in particular inlets such as catchpits are blocked by rubbish, fallen trees or landslide debris. Besides, flooding at low-lying coastal areas may occur when there is exceptionally high tide level caused by storm surge during the passage of a typhoon.

Appendix II

Survey of coastal wetlands and flood risk management in Yeung Long District

Date:	**Interviewer:**	**Survey No:**	**Version:**

Hello, my name is________. We are conducting a survey of residents of Yeung Long District. We are investigating strategies for flood risk management in the district.

Are you a resident of Yuen Long district?

- o Yes
- o No

[If "Yes", continue to the consent process and carry on the survey. If "No", apologize for taking up the potential respondent's time and find the next potential respondent.]

We would like to know your opinion about flood risks and coastal wetlands in Yeung Long District. This survey is a study research project and is a collaboration between World Wildlife Fund-Hong Kong, the Chinese Academy of Sciences and Simon Fraser University in Canada. The study results will be used to learn about public perspectives only and not to change anything or initiate any project.

Your participation is entirely voluntary, and you may choose not to participate at any time. You will not be required to provide your name or any other identifying information other than to identify the area where you live. Any information that is obtained during this study will be kept confidential and stored in a secure location. It will take 10 to 15 minutes of your time and we would really value your input. As a token of appreciation for your participation, you will receive supermarket coupons worth HKD $10.

Would you be willing to participate at this time? [If yes, continue survey]

A. Introduction

A1. For how long have you been living in Yuen Long District?__________ years

A2. What type of housing do you live in?

- ◯ High rise residential building
- ◯ Low rise residential building
- ◯ Village house
- ◯ Other ______________________________________

A3. Which floor do you live on?

◯ Underground or ground floor

◯ Above ground floor

A4. Do you rent or own your home?

◯ Underground or ground floor

◯ Above ground floor

B. Awareness of Local Flooding

Flooding has been an issue in Hong Kong, and especially Yuen Long District, for many decades. I would now like to ask you a few questions about your awareness and concerns about flooding.

B1. How concerned are you about flooding occurring in and around Hong Kong?

Not concerned		Somewhat concerned		Very concerned
1	2	3	4	5

B2. How concerned are you about a possible rise in sea level in your community?

Not concerned		Somewhat concerned		Very concerned
1	2	3	4	5

B3. Which of the following impacts of flooding in Hong Kong concern you the most? [choose up to three only]

☐ Disruption of transportation and other infrastructure

☐ Reduced industrial and commercial activities

☐ Damages to urban residential areas

☐ Damages to rural residential areas

☐ Destruction of the natural environment

☐ None of above

B4. As a resident of Yuen Long District, has your household or neighboring households ever experienced or been affected by flooding?

Not at all affected		Somewhat affected		Very affected
1	2	3	4	5

B5. Overall, how vulnerable do you and your household feel to flooding and storm damages?

Not vulnerable		Somewhat vulnerable		Very vulnerable
1	2	3	4	5

C. Flood Risk Management Alternatives

C

Most of the emphasis in flood and storm risk management in Hong Kong has been on engineering and drainage works. Various alternative protection measures are also in use but only in a limited way. Considering the possible increase in damages due to sea level rise in the future, more emphasis on these measures may be justified. Now I am going to provide you some information about these alternatives.

[Show the attribute page of the booklet to the respondent]

C1. Adaptation strategies include actions to reduce potential flood and storm damages. Examples in Hong Kong include awareness campaigns, early warning systems, evacuation plans and development restrictions in low-lying areas.

How important do you consider these adaptation strategies to be for flood risk management?

Not important		Somewhat important		Very important
1	2	3	4	5

C2. Green infrastructure combines natural and engineered structures that can divert or retain storm waters. Examples in Hong Kong include flood retention ponds, green river channels with constructed wetlands, green roofs and permeable pavements.

How important do you consider green infrastructure to be for flood risk management?

Not important		Somewhat important		Very important
1	2	3	4	5

C3. Mangrove forests can reduce storm damages by lowering flood energy and dissipating waves. Examples in Hong Kong include the Mai Po Nature Reserve in Yuen Long District and Ting Kok mangrove forest in Tolo Harbour.

How important do you consider mangroves to be for flood risk management?

Not important		Somewhat important		Very important
1	2	3	4	5

D. Choice Experiment

Now we would like to ask your opinion about possible flood risk management programs that could be implemented in Yuen Long District in the future. These hypothetical programs differ in their emphasis, but all consist of a mix of the following protective measures:

- adaptation strategies
- green infrastructure
- mangrove management

In the following section we will show you two different programs and ask you to pick the one you most prefer and a third alternative in case you prefer neither. Please consider the additional cost to your household to fund these programs. When making your choice imagine that these programs would actually be implemented, and you would have to contribute from your household budget to fund them. We will then repeat this exercise six times. Please consider each choice task independently.

Please feel free to take it slow and interpret the questions and choices offered to you before making your decision.

Here is an example for you to practice *[Surveyor should be ready to assist the respondent in understanding the questions]*

Record the respondent's selection from each choice set in the table below, checking only one box in each row. *[Be sure to use the correct set of choice cards for each choice task]*

Choice set	**Program A**	**Program B**	**Existing Situation**
Choice Set 1	☐	☐	☐
Choice Set 2	☐	☐	☐
Choice Set 3	☐	☐	☐
Choice Set 4	☐	☐	☐
Choice Set 5	☐	☐	☐
Choice Set 6	☐	☐	☐

E. Awareness of Coastal Wetlands

Yuen Long District contains extensive coastal wetlands made up of mostly mangrove forests. Mangrove forests consist of salt-tolerant trees that grow in swampy coastal areas. I would like to ask you a few questions about your familiarity with mangrove forests.

E1. How familiar are you with mangrove forests?

Not familiar		Somewhat familiar		Very familiar
1	2	3	4	5

E2. Have you visited any of the following mangrove areas? [Check all that applies]

- ☐ Mai Po nature reserve
- ☐ Hong Kong Wetland Park
- ☐ Other mangrove areas in Hong Kong
- ☐ Other mangrove areas outside of Hong Kong (e.g. Fu Tian nature reserve)
- ☐ None

F. Attitudes towards Conservation and the Environment

The following questions will consult your attitude towards conservation and the environment.

Please indicate how strongly you agree or disagree with the statements in each question.

	Strongly Disagree	Some-what Disagree	Neutral	Some-what Agree	Strongly Agree	Don't Know
1) When humans interfere with nature, it often produces disastrous consequences.						
2) The so-called “ecological crises” facing humankind has been greatly exaggerated.						
3) The balance of nature is very delicate and easily upset.						
4) Humans are severely abusing the environment.						
5) Humans have the right to modify the natural environment to suit their needs.						

6) If things continue on their present course, we will soon experience a major ecological catastrophe.						
7) Plants and animals have as much right as humans to exist.						
8) Humans were meant to rule over the rest of nature.						

G. Demographic and Basic Information

G1. What is your age?

◯ 15-34

◯ 35-64

◯ 65 and over

G2. What is your gender?

◯ Male

◯ Female

G3. What level of education have you completed?

◯ None

◯ Primary and below

◯ Secondary

◯ Diploma/Certificate Course

◯ Sub-Degree Course

◯ Degree Course

◯ Other Training (How many years ____________________)

G4. How many adults are in your household? ___________________ Person(s)

G5. How many are non-working dependents? (Children, senior or infirm)

___________________ Person(s)

G6. In which sector are you employed? (*Check only one*)

1. Manufacturing / Construction	☐	7. Finance and insurance	☐
2. Import / Export	☐	8. Public administration	☐
3. Wholesale trades	☐	9. Education	☐
4. Retail trades	☐	10. Health and social work	☐
5. Transportation / Postal	☐	11. Retired / Unemployed	☐
6. Accommodation and food	☐	12. Other, specify……..	☐
7. Information and communications	☐	13. Don't Know/Refused	☐

G7. Please indicate your **monthly** household income, in HKD$

◯ Under $4,000
◯ $4,000 - $9,999
◯ $10,000 - $19,999
◯ $20,000 - $29,999
◯ $30,000 - $39,999
◯ $40,000 - $49,999
◯ $50,000 - $59,999
◯ $60,000 - $79,999
◯ $80,000 - $99,999
◯ $100,000 and over

G8 Can you provide an address of where you live. (Exact address is not needed, only a rough location would be enough, nearby crossroads and buildings etc.)____________________

[Surveyor should take out their phone, open GOOGLE MAPS and let the respondent to point out the areas he/she lives in]

G9. Do you wish to make any final comments about flood risk management or mangrove forests?

Thank you for taking our survey!

Appendix III

Demographic distribution of Yuen Long District compared with the survey population

2019 Age distribution in Yuen Long District (extracted from Hong Kong Census)

	Population					
	Number of Persons					
Sex	**Male**	**Female**	**Sub-Total**	**Total (Yuen Long District)**	**% (Yuen Long District)**	**% (Data Collected)**
Age						
0 - 4	12 852	12 211	**25 063**	**Not count (Age range not in the survey)**		
5 - 9	13 690	12 454	**26 144**			
10 - 14	11 684	10 830	**22 514**			
15 - 19	15 875	14 394	**30 269**	**162,145**	**26%**	**30%**
20 - 24	20 728	19 419	**40 147**			
25 - 29	18 364	23 826	**42 190**			
30 - 34	19 989	29 550	**49 539**			
35 - 39	20 650	30 002	**50 652**	**285,578**	**47%**	**53%**
40 - 44	20 419	28 250	**48 669**			
45 - 49	19 364	25 823	**45 187**			
50 - 54	23 220	27 526	**50 746**			
55 - 59	24 292	24 775	**49 067**			
60 - 64	20 322	20 935	**41 257**			
65 - 69	16 374	16 997	**33 371**	**92734**	**15%**	**17%**
70 - 74	10 531	8 805	**19 336**			
75 - 79	8 473	8 268	**16 741**			
80 - 84	5 326	6 147	**11 473**			
85+	3 934	7 879	**11 813**			
Total	**286 087**	**328 091**	**614 178**	**540,457**		

2019 Income distribution in Yuen Long District (extracted from Hong Kong Census)

	Working Population (Excluding Unpaid Family Workers)				Respondents' Income Distribution
	Number of Population			Percentage of Population	Percentage of Respondents
	Sex		Total	Total Percentage (%)	Total Percentage (%)
	Male	Female			
Monthly Income from Main Employment (HK$)					
Less than 2,000	1,729	2,101	**3,830**	**3.34**	**5.17**
2,000 - 3,999	2,122	4,068	**6,190**		
4,000 - 5,999	3,274	25,603	**28,877**	**16.97**	**15.73**
6,000 - 7,999	4,024	5,892	**9,916**		
8,000 - 9,999	9,269	12,796	**22,065**		
10,000 - 14,999	42,657	38,252	**80,909**	**44.56**	**20.91**
15,000 - 19,999	34,119	18,758	**52,877**		
20,000 - 24,999	20,735	12,247	**32,982**	**16.36**	**15.95**
25,000 - 29,999	9,834	6,309	**16,143**		
30,000 - 39,999	14,279	6,800	**21,079**	**7.02**	**15.52**
40,000 - 59,999	9,717	6,120	**15,837**	**5.28**	**19.18**
60,000 and over	6,488	3,018	**9,506**	**3.17**	**15.73**
Total	**158,247**	**141,964**	**300,211**	**100**	**100**

Appendix IV

Implementation of Latent Gold 5.1 (as a demonstration)

(1) Data Preparation

The data collected from the field surveys were input to Excel files.

(2) Data Input

The software package, Latent GOLD 5.1, were used for the analysis. In general, Latent Gold 5.1 accepts data from an optional 1-file or its default 3-file structure from an SPSS.sav file, a Sawtooth.cho file, or ASCII rectangular file format. Therefore, in this study, we prepared he data for 3 SPSS .sav files.

(3) Choice Experiment

Choice Experiment approach was adopted in this study. The flood risk management programs included in this choice experiment corresponding to 5 attributes:

a) mangrove management (increase 80 Hectare, increase 40 Hectare, maintain the status quo);

b) green infrastructure management (20 additional, 40 additional, maintain the status quo);

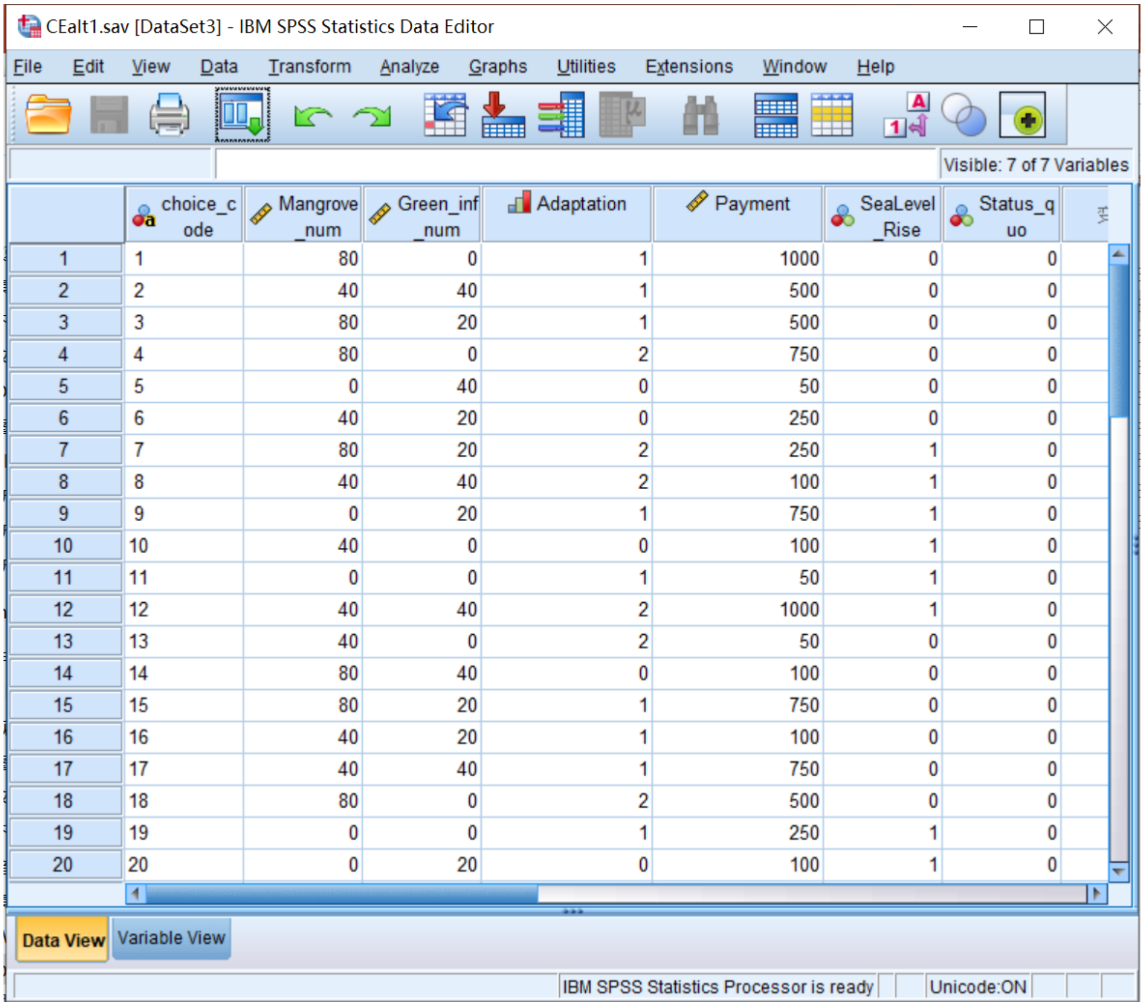
c) adaption strategies (implement in areas that might be affected in 10 years, implement in all years, maintain the current situation and take no action);

d) payment (0, 50, 100, 250, 500, 750, 1000); and

e) sea level rise (rise, no rise).

(4) Defining Alternatives

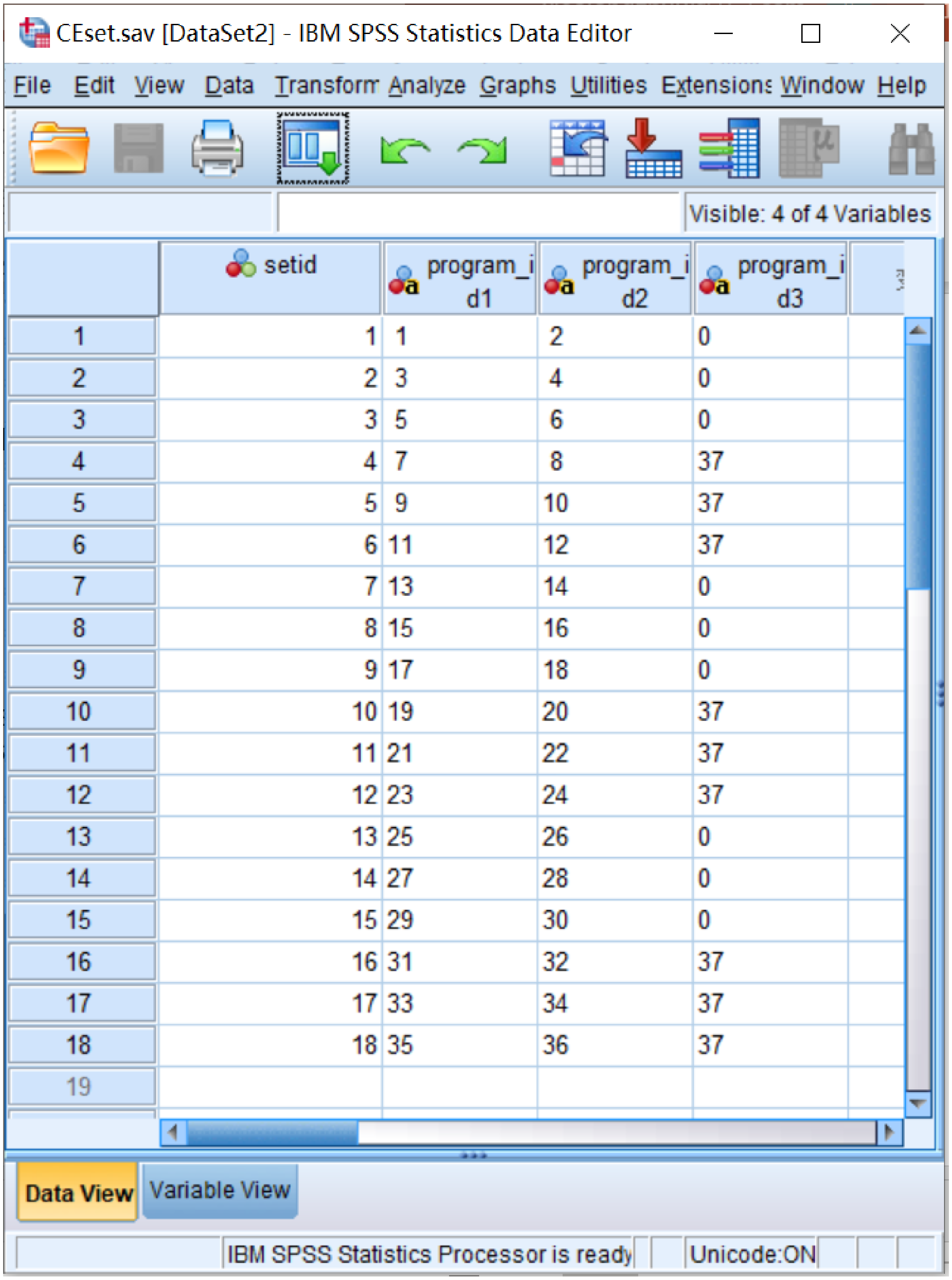
The 38 alternatives were defined in terms of the 4 attributes plus the dummy variable "status quo"; the arrangement is recorded in a SPSS file (the following 'screen shot' shows part of the SPSS file with the file name: 'CEalt.sav').



	choice_code	Mangrove_num	Green_inf_num	Adaptation	Payment	SeaLevel_Rise	Status_quo
1	1	80	0	1	1000	0	0
2	2	40	40	1	500	0	0
3	3	80	20	1	500	0	0
4	4	80	0	2	750	0	0
5	5	0	40	0	50	0	0
6	6	40	20	0	250	0	0
7	7	80	20	2	250	1	0
8	8	40	40	2	100	1	0
9	9	0	20	1	750	1	0
10	10	40	0	0	100	1	0
11	11	0	0	1	50	1	0
12	12	40	40	2	1000	1	0
13	13	40	0	2	50	0	0
14	14	80	40	0	100	0	0
15	15	80	20	1	750	0	0
16	16	40	20	1	100	0	0
17	17	40	40	1	750	0	0
18	18	80	0	2	500	0	0
19	19	0	0	1	250	1	0
20	20	0	20	0	100	1	0

(5) Choice Sets

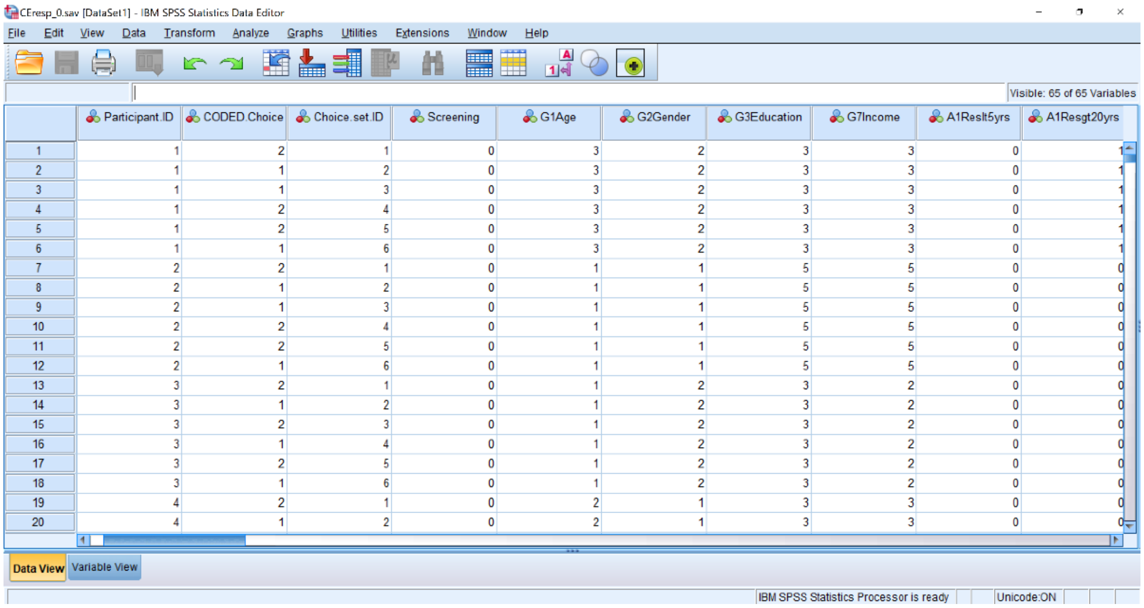
18 Choice sets were defined in that each of the 18 choice sets offered 3 of the 38 possible alternatives to 464 individuals (screened out the respondents with all "status quo" answers). We can consider that each set represents the actual options available for policy. the arrangement is recorded in a SPSS file (the following 'screen shot' shows part of the SPSS file with the file name: 'CEset.sav')



	setid	program_id1	program_id2	program_id3
1	1	1	2	0
2	2	3	4	0
3	3	5	6	0
4	4	7	8	37
5	5	9	10	37
6	6	11	12	37
7	7	13	14	0
8	8	15	16	0
9	9	17	18	0
10	10	19	20	37
11	11	21	22	37
12	12	23	24	37
13	13	25	26	0
14	14	27	28	0
15	15	29	30	0
16	16	31	32	37
17	17	33	34	37
18	18	35	36	37
19				

(6) Respondents' Records

The "answers" given by the respondents were recorded in a "response" file "CEresp_0.sav" (a SPSS file); the following 'screen shot' shows part of the SPSS file with the first 3 respondents:



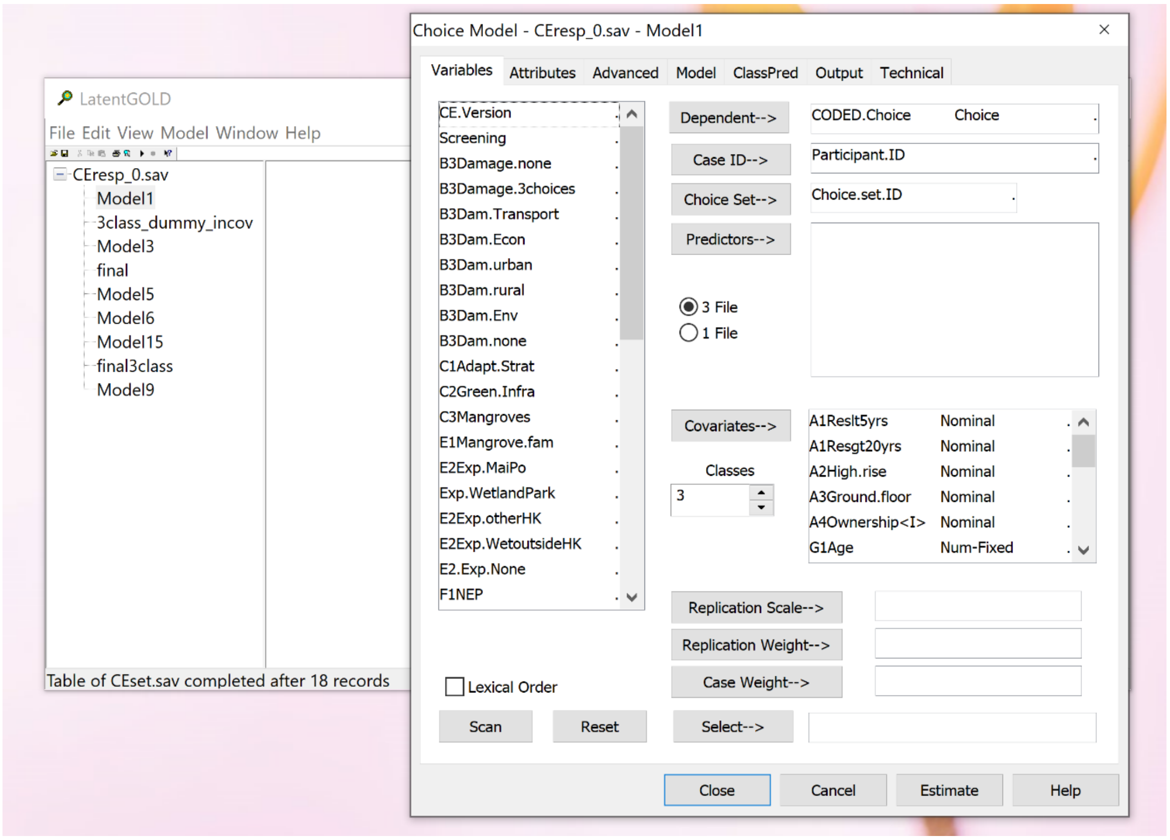
	Participant.ID	CODED.Choice	Choice.set.ID	Screening	G1Age	G2Gender	G3Education	G7Income	A1Reslt5yrs	A1Resgt20yrs
1	1	2	1	0	3	2	3	3	0	1
2	1	1	2	0	3	2	3	3	0	1
3	1	1	3	0	3	2	3	3	0	1
4	1	2	4	0	3	2	3	3	0	1
5	1	2	5	0	3	2	3	3	0	1
6	1	1	6	0	3	2	3	3	0	1
7	2	2	1	0	1	1	5	5	0	0
8	2	1	2	0	1	1	5	5	0	0
9	2	1	3	0	1	1	5	5	0	0
10	2	2	4	0	1	1	5	5	0	0
11	2	2	5	0	1	1	5	5	0	0
12	2	1	6	0	1	1	5	5	0	0
13	3	2	1	0	1	2	3	2	0	0
14	3	1	2	0	1	2	3	2	0	0
15	3	2	3	0	1	2	3	2	0	0
16	3	1	4	0	1	2	3	2	0	0
17	3	2	5	0	1	2	3	2	0	0
18	3	1	6	0	1	2	3	2	0	0
19	4	2	1	0	2	1	3	3	0	0
20	4	1	2	0	2	1	3	3	0	0

(7) Latent Gold Analysis

The steps are briefly outlined below:

- Initiate Latent Gold
- Select Open
- Select 'CEresp_0.sav' and click Open
- Right click on 'Model1' and select Choice

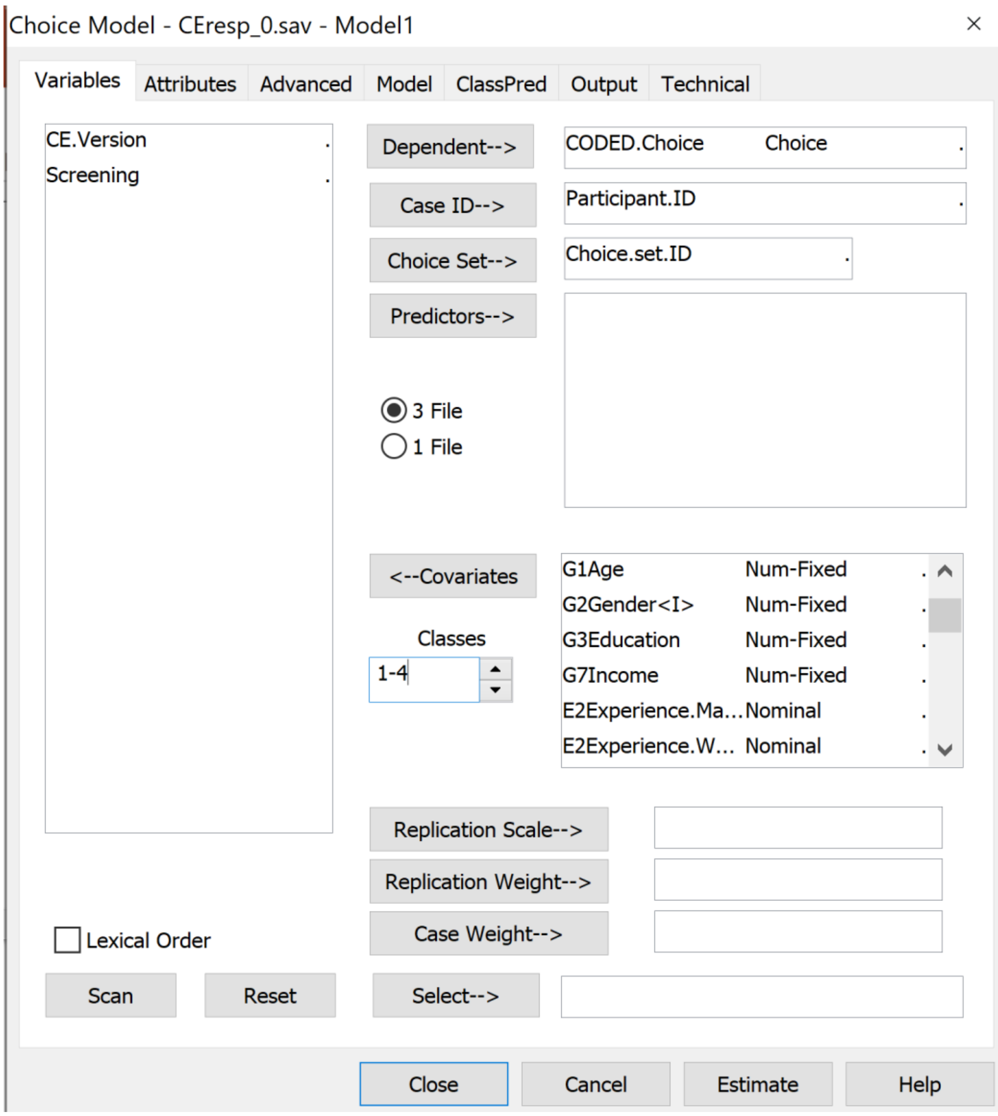
The following 'screen shot' shows part of the Latent Gold screen:



(8) Steps:

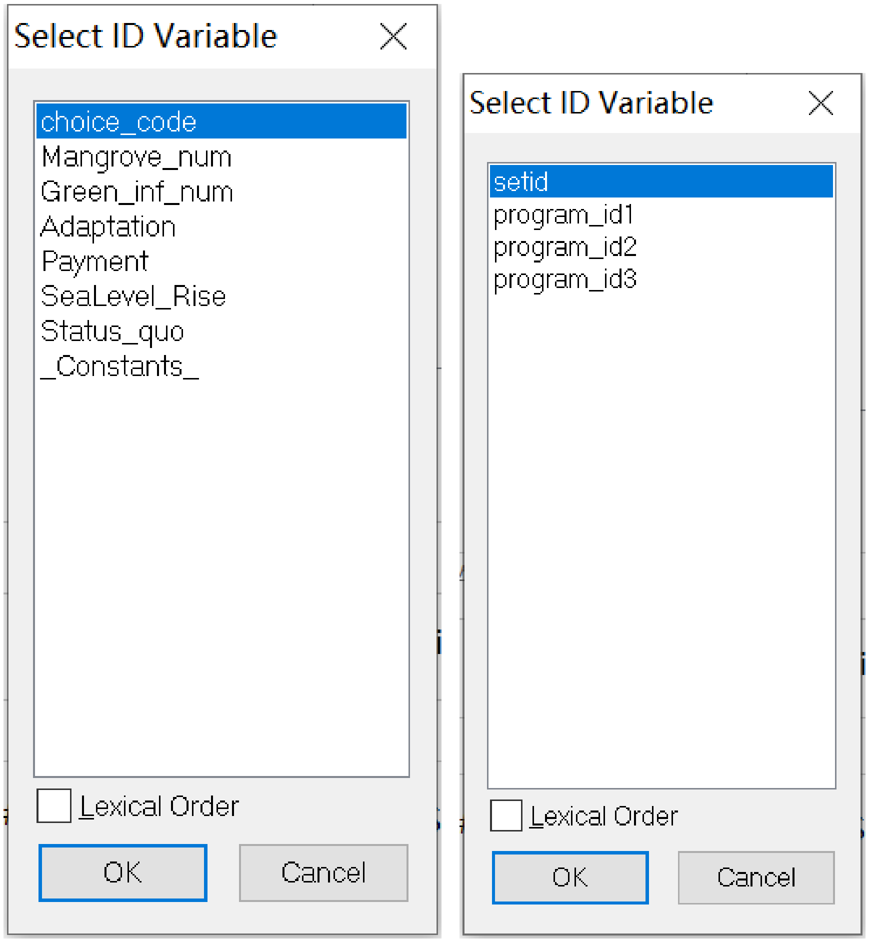
- Select each variable and move it to the appropriate box by clicking the buttons to the left of these boxes
- In the Classes box, type ‘1-4’ in place of 1 to request estimation of 4 models between 1 and 4 classes
- Right click on covariates and select ‘Nominal’ to change the scale type for these covariates
- Inactivate Gender, Ownership, E2Experience.Maipo and E2Experience.Wetland

The following ‘screen shot’ shows part of the Latent Gold screen:

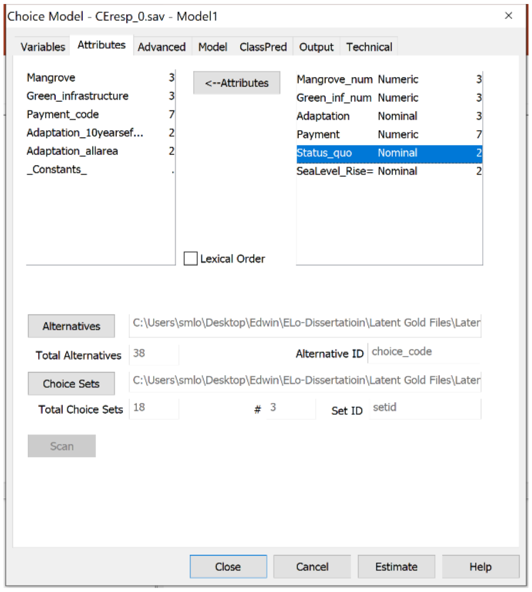


- Open the Attributes tab by clicking on ‘Attributes’ at the top of the setup screen
- Click the Alternatives button to display a list of files
- Select ‘CEalt.sav’ and click Open
- Select ‘choice_code’ and click OK
- Click the Choice Sets button to display a list of files
- Select ‘CEset.sav’ and click Open
- Select ‘setid’ and click OK

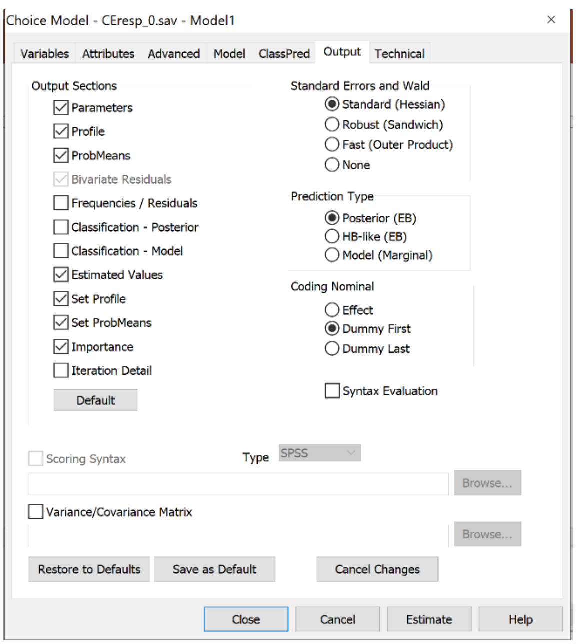
The following ‘screen shot’ shows part of the Latent Gold screen:



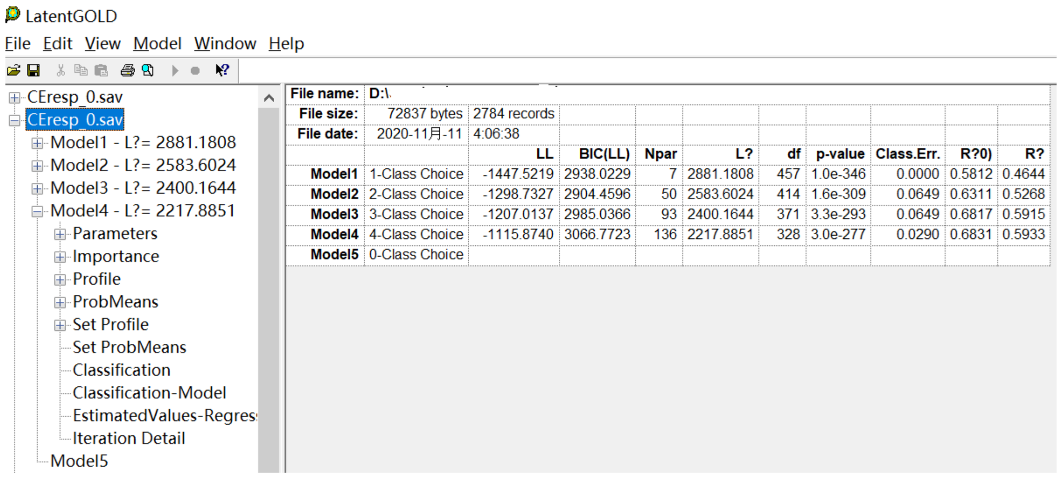
- Select all variables except for '_Constants_' and click Attributes to move them to the Attributes list box (or double click each variable that you want to move to the Attributes box and then click Attributes).
- Right click on Mangrove_num, Green_inf_num and payment, and select 'Numeric'.



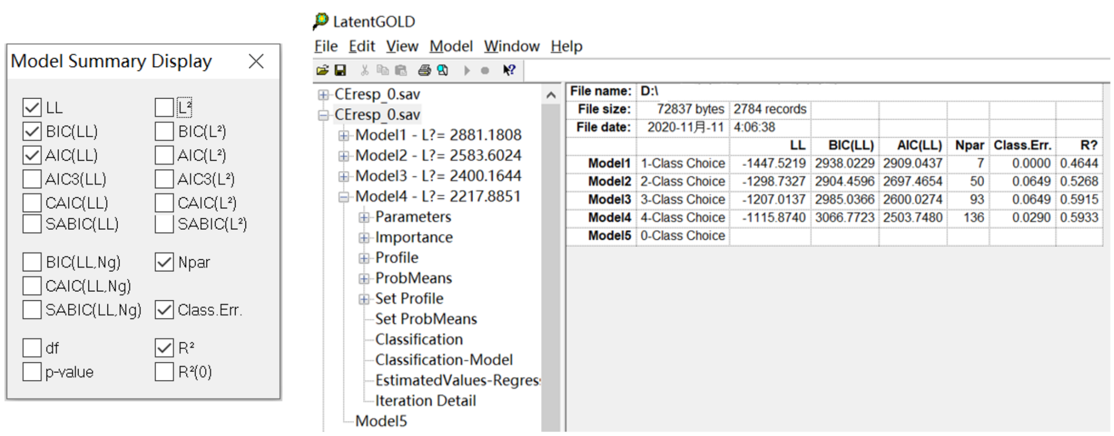
- Open the Output tab by clicking on ‘Output’ at the top of the setup screen
- Click Dummy First for Coding Nominal



(9) Estimating choice models that specify different numbers of classes (segments) and Explore which of these models provides the best fit to the data; highlight the data file name ‘Ceresp_0.sav’ and a summary of all the models estimated on this file appears in the Contents pane.



- Right click in the Contents Pane to retrieve the Model Summary Display
- Click in the boxes to the left of the L2, df and p-value to remove the checkmarks from these items
- Click in the boxes to the left of the AIC(LL)
- Close the Model Summary Display

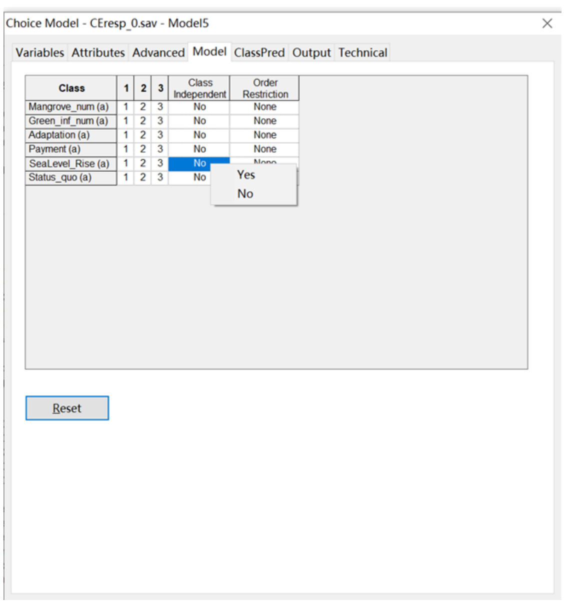


(10) Utilize restrictions to refine the best fitting model

Click on the expand icon (+) next to the 3-class model and select Parameters (Notice that the within-class estimates for Sea-Level-Rise are close to each other. The formal test of equality is given by the Wald (=) statistic, for which the p-value (0.96) is not significant. Thus, we will restrict the effect of Sea-Level-Rise to be equal across all 3 segments.)

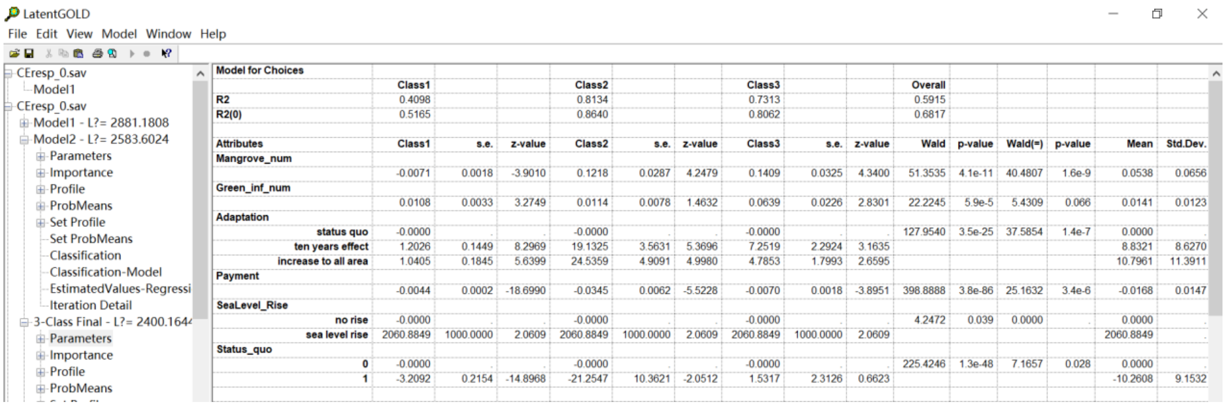
Model for Choices									
	Class1	Class2	Class3	Overall					
R2	0.4098	0.8134	0.7313	0.5915					
R2(0)	0.5165	0.8640	0.8062	0.6817					
Attributes	Class1	Class2	Class3	Wald	p-value	Wald(=)	p-value	Mean	Std.Dev.
Mangrove_num									
	-0.0071	0.1218	0.1409	51.3535	4.1e-11	40.4807	1.6e-9	0.0538	0.0656
Green_inf_num									
	0.0108	0.0114	0.0639	22.2245	5.9e-5	5.4309	0.066	0.0141	0.0123
Adaptation									
status quo	-0.0000	-0.0000	-0.0000	127.9540	3.5e-25	37.5854	1.4e-7	0.0000	.
ten years effect	1.2026	19.1325	7.2519					8.8321	8.6270
increase to all area	1.0405	24.5359	4.7853					10.7961	11.3911
Payment									
	-0.0044	-0.0345	-0.0070	398.8888	3.8e-86	25.1632	3.4e-6	-0.0168	0.0147
SeaLevel_Rise									
no rise	-0.0000	-0.0000	-0.0000	4.1647	0.24	0.0755	0.96	0.0000	.
sea level rise	1386.3458	1015.4686	1100.7300					1219.2354	180.6689
Status_quo									
0	-0.0000	-0.0000	-0.0000	225.4246	1.3e-48	7.1657	0.028	0.0000	.
1	-3.2092	-21.2547	1.5317					-10.2608	9.1532

- Double click on the 3-class model to re-open the model setup screen.
- Click on ‘Model’ to Open the Model tab.
- Right click under Class Independent column in the Sea-Level-Rise row and select ‘Yes’ to restrict the effect of Sea-Level-Rise to be class independent
- Click Estimate to re-estimate the model.
- Re-name this model ‘3-Class Final’



(11) Interpret results using our ‘final’ model

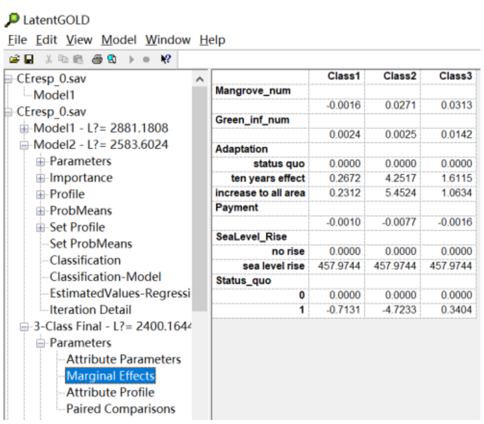
- Click on the expand icon (+) next to the 3-class model and select Parameters.
- Right click on the Contents Pane and select Standard Errors and Z Statistic from the Popup menu.



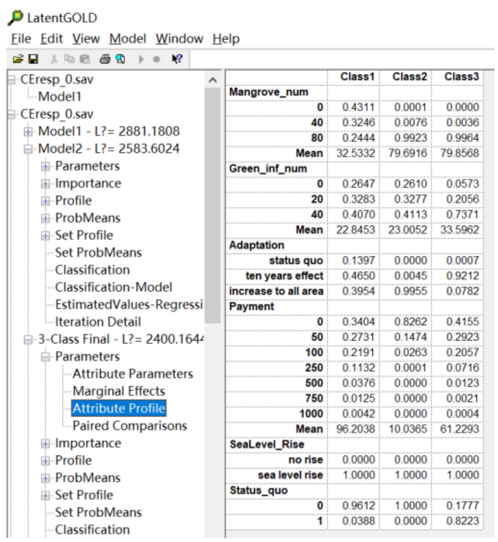
Model for Choices	Class1	s.e.	z-value	Class2	s.e.	z-value	Class3	s.e.	z-value	Wald	p-value	Wald(=)	p-value	Mean	Std.Dev.
R2	0.4098			0.8134			0.7313			Overall 0.5915					
R2(0)	0.5165			0.8640			0.8062			0.6817					
Attributes															
Mangrove_num	-0.0071	0.0018	-3.9010	0.1218	0.0287	4.2479	0.1409	0.0325	4.3400	51.3535	4.1e-11	40.4807	1.6e-9	0.0538	0.0656
Green_inf_num	0.0108	0.0033	3.2749	0.0114	0.0078	1.4632	0.0639	0.0226	2.8301	22.2245	5.9e-5	5.4309	0.066	0.0141	0.0123
Adaptation status quo	-0.0000	.	.	-0.0000	.	.	-0.0000	.	.	127.9540	3.5e-25	37.5854	1.4e-7	0.0000	
ten years effect	1.2026	0.1449	8.2969	19.1325	3.5631	5.3696	7.2519	2.2924	3.1635					8.8321	8.6270
increase to all area	1.0405	0.1845	5.6399	24.5359	4.9091	4.9980	4.7853	1.7993	2.6595					10.7961	11.3911
Payment	-0.0044	0.0002	-18.6990	-0.0345	0.0062	-5.5228	-0.0070	0.0018	-3.8951	398.8888	3.8e-86	25.1632	3.4e-6	-0.0168	0.0147
SeaLevel_Rise no rise	-0.0000	.	.	-0.0000	.	.	-0.0000	.	.	4.2472	0.039	0.0000	.	0.0000	
sea level rise	2060.8849	1000.0000	2.0609	2060.8849	1000.0000	2.0609	2060.8849	1000.0000	2.0609					2060.8849	.
Status_quo 0	-0.0000	.	.	-0.0000	.	.	-0.0000	.	.	225.4246	1.3e-48	7.1657	0.028	0.0000	
1	-3.2092	0.2154	-14.8968	-21.2547	10.3621	-2.0512	1.5317	2.3126	0.6623					-10.2608	9.1532

The information given by Latent Gold was summarized in Table 5.3

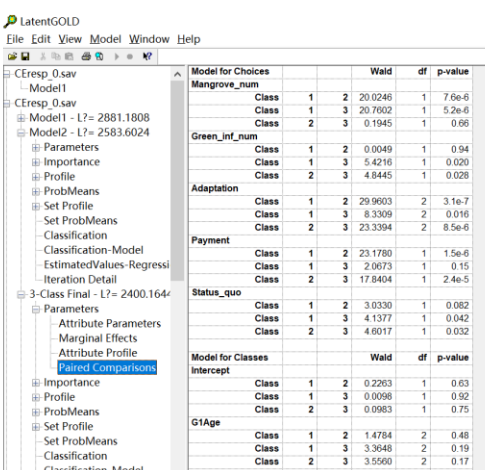
- Click on the expand icon (+) next to the Parameters and select Marginal Effects.



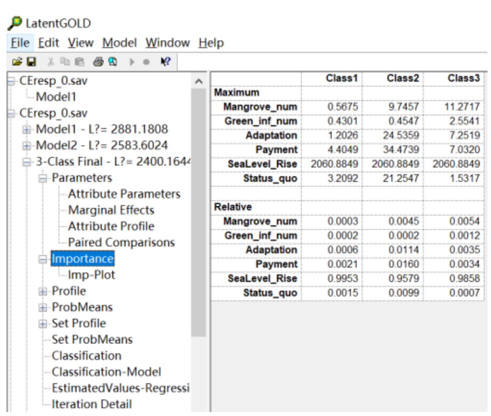
	Class1	Class2	Class3
Mangrove_num	-0.0016	0.0271	0.0313
Green_inf_num	0.0024	0.0025	0.0142
Adaptation status quo	0.0000	0.0000	0.0000
ten years effect	0.2672	4.2517	1.6115
increase to all area	0.2312	5.4524	1.0634
Payment	-0.0010	-0.0077	-0.0016
SeaLevel_Rise no rise	0.0000	0.0000	0.0000
sea level rise	457.9744	457.9744	457.9744
Status_quo 0	0.0000	0.0000	0.0000
1	-0.7131	-4.7233	0.3404



	Class1	Class2	Class3
Mangrove_num 0	0.4311	0.0001	0.0000
40	0.3246	0.0076	0.0036
80	0.2444	0.9923	0.9964
Mean	32.5332	79.6916	79.8568
Green_inf_num 0	0.2647	0.2610	0.0573
20	0.3283	0.3277	0.2056
40	0.4070	0.4113	0.7371
Mean	22.8453	23.0052	33.5962
Adaptation status quo	0.1397	0.0000	0.0007
ten years effect	0.4650	0.0045	0.9212
increase to all area	0.3954	0.9955	0.0782
Payment 0	0.3404	0.8262	0.4155
50	0.2731	0.1474	0.2923
100	0.2191	0.0263	0.2057
250	0.1132	0.0001	0.0716
500	0.0376	0.0000	0.0123
750	0.0125	0.0000	0.0021
1000	0.0042	0.0000	0.0004
Mean	96.2038	10.0365	61.2293
SeaLevel_Rise no rise	0.0000	0.0000	0.0000
sea level rise	1.0000	1.0000	1.0000
Status_quo 0	0.9612	1.0000	0.1777
1	0.0388	0.0000	0.8223

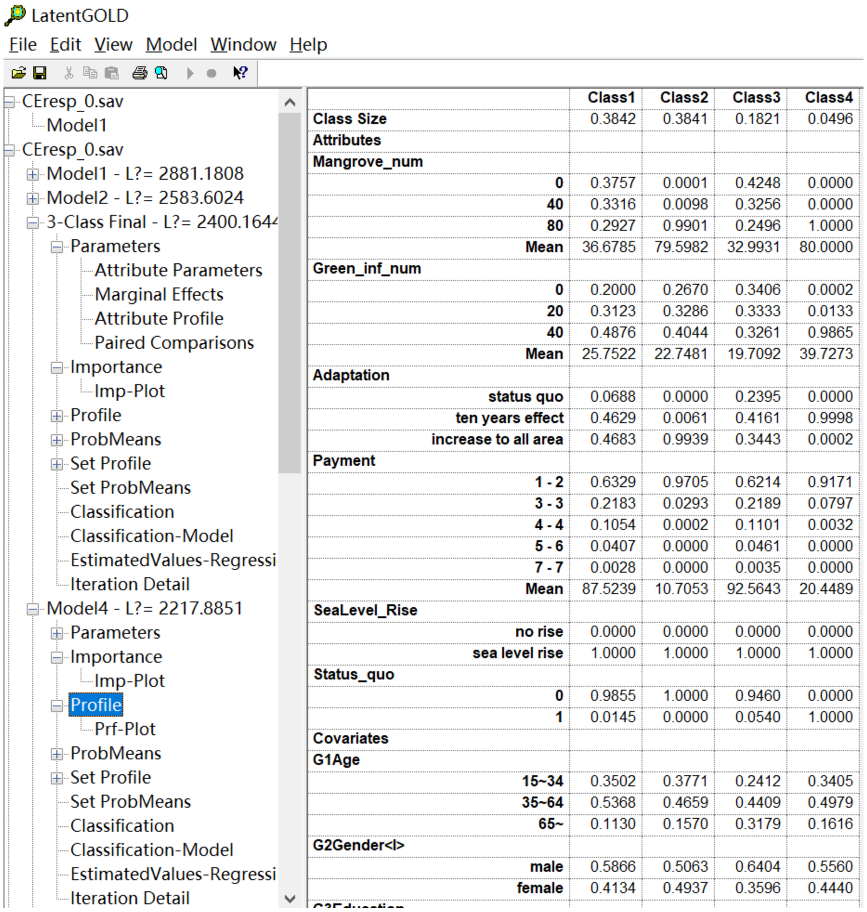


			Wald	df	p-value
Model for Choices					
Mangrove_num Class	1	2	20.0246	1	7.6e-6
Class	1	3	20.7602	1	5.2e-6
Class	2	3	0.1945	1	0.66
Green_inf_num Class	1	2	0.0049	1	0.94
Class	1	3	5.4216	1	0.020
Class	2	3	4.8445	1	0.028
Adaptation Class	1	2	29.9603	2	3.1e-7
Class	1	3	8.3309	2	0.016
Class	2	3	23.3394	2	8.5e-6
Payment Class	1	2	23.1780	1	1.5e-6
Class	1	3	2.0673	1	0.15
Class	2	3	17.8404	1	2.4e-5
Status_quo Class	1	2	3.0330	1	0.082
Class	1	3	4.1377	1	0.042
Class	2	3	4.6017	1	0.032
Model for Classes					
Intercept Class	1	2	0.2263	1	0.63
Class	1	3	0.0098	1	0.92
Class	2	3	0.0983	1	0.75
G1Age Class	1	2	1.4784	2	0.48
Class	1	3	3.3648	2	0.19
Class	2	3	3.5560	2	0.17

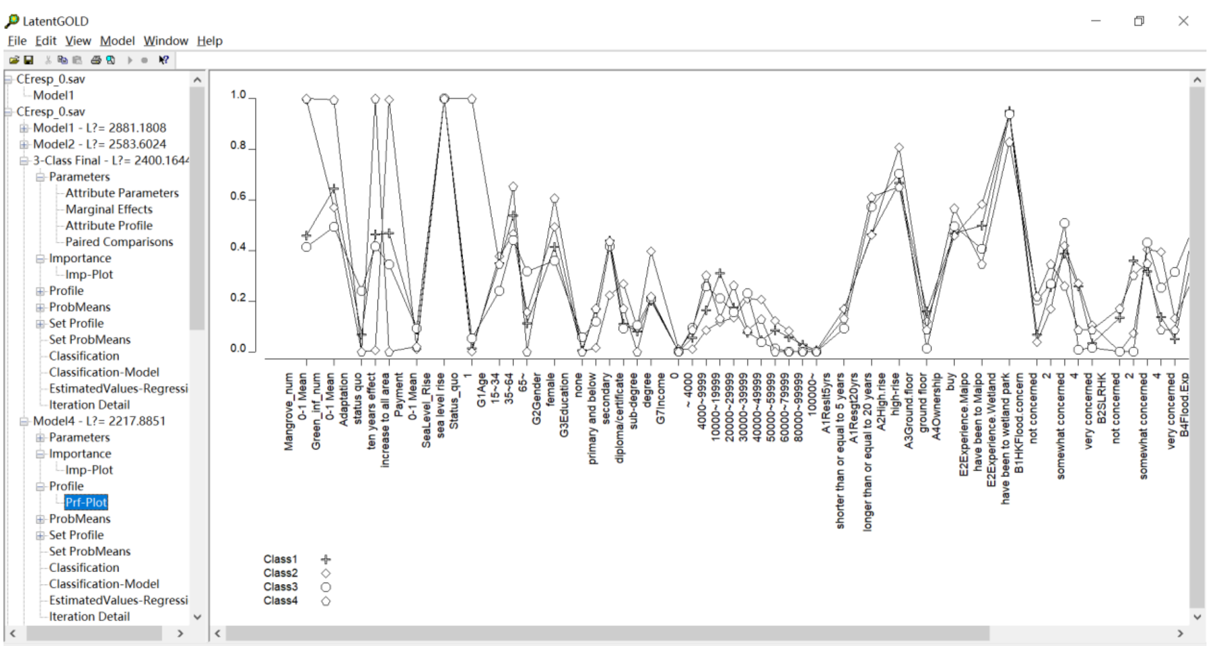


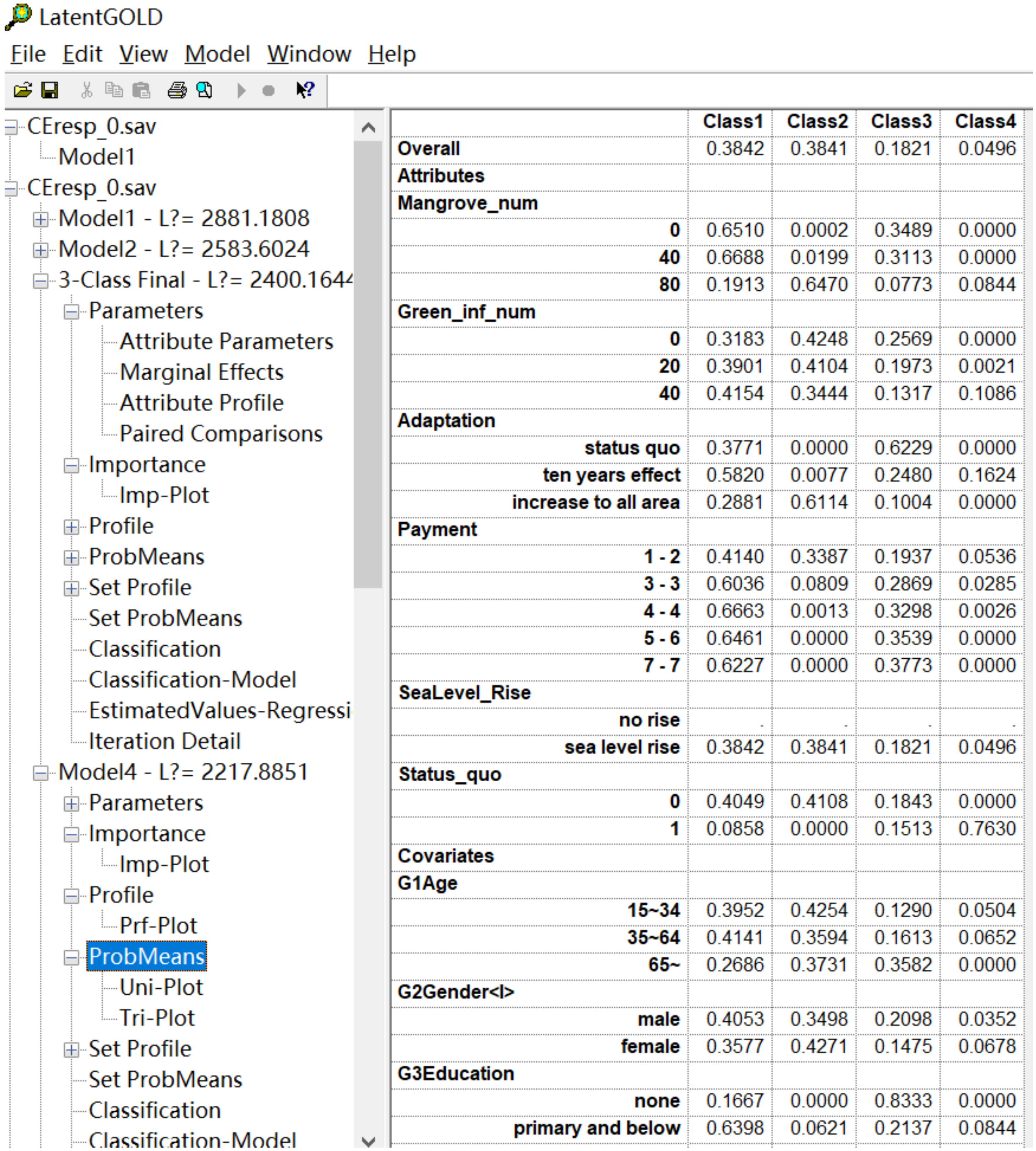
	Class1	Class2	Class3
Maximum			
Mangrove_num	0.5675	9.7457	11.2717
Green_inf_num	0.4301	0.4547	2.5541
Adaptation	1.2026	24.5359	7.2519
Payment	4.4049	34.4739	7.0320
SeaLevel_Rise	2060.8849	2060.8849	2060.8849
Status_quo	3.2092	21.2547	1.5317
Relative			
Mangrove_num	0.0003	0.0045	0.0054
Green_inf_num	0.0002	0.0002	0.0012
Adaptation	0.0006	0.0114	0.0035
Payment	0.0021	0.0160	0.0034
SeaLevel_Rise	0.9953	0.9579	0.9858
Status_quo	0.0015	0.0099	0.0007

- Click on Profile to display the Profile Output in the Contents Pane



	Class1	Class2	Class3	Class4
Class Size	0.3842	0.3841	0.1821	0.0496
Attributes				
Mangrove_num				
0	0.3757	0.0001	0.4248	0.0000
40	0.3316	0.0098	0.3256	0.0000
80	0.2927	0.9901	0.2496	1.0000
Mean	36.6785	79.5982	32.9931	80.0000
Green_inf_num				
0	0.2000	0.2670	0.3406	0.0002
20	0.3123	0.3286	0.3333	0.0133
40	0.4876	0.4044	0.3261	0.9865
Mean	25.7522	22.7481	19.7092	39.7273
Adaptation				
status quo	0.0688	0.0000	0.2395	0.0000
ten years effect	0.4629	0.0061	0.4161	0.9998
increase to all area	0.4683	0.9939	0.3443	0.0002
Payment				
1 - 2	0.6329	0.9705	0.6214	0.9171
3 - 3	0.2183	0.0293	0.2189	0.0797
4 - 4	0.1054	0.0002	0.1101	0.0032
5 - 6	0.0407	0.0000	0.0461	0.0000
7 - 7	0.0028	0.0000	0.0035	0.0000
Mean	87.5239	10.7053	92.5643	20.4489
SeaLevel_Rise				
no rise	0.0000	0.0000	0.0000	0.0000
sea level rise	1.0000	1.0000	1.0000	1.0000
Status_quo				
0	0.9855	1.0000	0.9460	0.0000
1	0.0145	0.0000	0.0540	1.0000
Covariates				
G1Age				
15~34	0.3502	0.3771	0.2412	0.3405
35~64	0.5368	0.4659	0.4409	0.4979
65~	0.1130	0.1570	0.3179	0.1616
G2Gender<l>				
male	0.5866	0.5063	0.6404	0.5560
female	0.4134	0.4937	0.3596	0.4440





	Class1	Class2	Class3	Class4
Overall	0.3842	0.3841	0.1821	0.0496
Attributes				
Mangrove_num				
0	0.6510	0.0002	0.3489	0.0000
40	0.6688	0.0199	0.3113	0.0000
80	0.1913	0.6470	0.0773	0.0844
Green_inf_num				
0	0.3183	0.4248	0.2569	0.0000
20	0.3901	0.4104	0.1973	0.0021
40	0.4154	0.3444	0.1317	0.1086
Adaptation				
status quo	0.3771	0.0000	0.6229	0.0000
ten years effect	0.5820	0.0077	0.2480	0.1624
increase to all area	0.2881	0.6114	0.1004	0.0000
Payment				
1 - 2	0.4140	0.3387	0.1937	0.0536
3 - 3	0.6036	0.0809	0.2869	0.0285
4 - 4	0.6663	0.0013	0.3298	0.0026
5 - 6	0.6461	0.0000	0.3539	0.0000
7 - 7	0.6227	0.0000	0.3773	0.0000
SeaLevel_Rise				
no rise	.	.	.	.
sea level rise	0.3842	0.3841	0.1821	0.0496
Status_quo				
0	0.4049	0.4108	0.1843	0.0000
1	0.0858	0.0000	0.1513	0.7630
Covariates				
G1Age				
15~34	0.3952	0.4254	0.1290	0.0504
35~64	0.4141	0.3594	0.1613	0.0652
65~	0.2686	0.3731	0.3582	0.0000
G2Gender<I>				
male	0.4053	0.3498	0.2098	0.0352
female	0.3577	0.4271	0.1475	0.0678
G3Education				
none	0.1667	0.0000	0.8333	0.0000
primary and below	0.6398	0.0621	0.2137	0.0844