DOCTORAL DISSERTATION

Pricing the Urban Heat Island Mitigation: An application of the Contingent Valuation Method and Theory of Planned Behavior

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ABSTRACT

The biophysical characteristics of the city are changing due to the rapid raise of urban population, which is combined with the degradation of urban vegetation. The additional heat is accumulating in the city, which results in a higher ambient temperatures compared to its surrounding area. This phenomenon is known as the urban heat island effect.

In order to counterbalance the effects of urban climate warming, some mitigation and adaptation techniques have been proposed and tested, while policy makers need more evidence with regard to the economic value of these techniques in mitigating the urban heat island effect. This research employed the contingent valuation method, a commonly used non-market value evaluation method, to assess Beijing residents' willingness to pay for the urban heat island mitigation strategies, which is the green roof, the cool roof, and the permeable pavement.

Before the onsite interview, this study discussed the theoretical background of the non-market value evaluation of UHI mitigation. Explaining the reason why the UHI effect mitigation has economic value through labor economic value theory and subjective economic value theory, proposing that its economic value is composed of use value and intrinsic value. A literature review with regard to the climate value of urban green space was conducted, pointing out that the impact of payment vehicles in CVM research has long been overlooked. Among the factors that determining WTP of residents, TPB theory can greatly explain the behavior of residents'' pro-environmental behavior.

During the main survey, the questionnaires were collected with face-to-face interview and online survey. For a considerable number of zero responses exists, the spike model was employed to process the data for it was proved to be effective in dealing with zero-response bias. As for the antecedents of willingness to pay, factors related with the theory of planned behavior were added other than conventional factors. In addition, the predictive model of residents' willingness to pay was explored based on the theory of planned behavior.

The results indicated that Beijing residents are willing to pay 799 million, 8.8232 billion, and 8.128 billion CHY respectively for the promotion of these three techniques. Compared with the cost of these projects, it can be confirmed that these projects are economically feasible. As for factors that affecting residents' willingness to pay, the factors of TPB, which is attitude, perceived behavior control, and social norm, can greatly explain respondents pro-environment actions. In addition, the predictive power of TPB prediction model can be strengthened by adding the variable of environmental concern. At last, most respondents' expressed the desire for environmental information disclosure and enhancing governance transparency, and education and publicity of knowledge with regard to urban heat island effect mitigation should be promoted.

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RESEARCH BACKGROUND AND PURPOSE

1.1 Research background

1.1.1 The urban heat island effect

Urban population is increasing rapidly because increasing birthrate and the migration of the rural population into the cities caused by the expectation for a better life, local conflicts and lack of resources in the country areas [1]. According to the United Nations report, about 4 billion people in the world live in urban areas in 2011, and by 2050, the urban dwellers are expected to exceed 60% [2]. At the same time, the biophysical characteristics of the city are also changing, which is defined as urban sprawl. This phenomenon is combined with changes in the urban land use [3]. Early studies have shown that the degradation of urban vegetation, the use of a large number of paving, and a large amount of anthropogenic heat, have affect the urban climate significantly, leading to the decline of urban environment quality and the increase in ecological footprint.

The heat balance in the city is affected by the increased absorption in solar radiation, the corresponding heat released by urban structures, higher anthropogenic heat, reduced urban vegetation, and higher infrared radiation. The additional heat is accumulating in the city, which results in a higher ambient temperatures compared to its surrounding area. This phenomenon is known as the urban heat island (UHI) effect [4]. The UHI effect characteristics are available for most large and medium-sized cities around the world and the reported UHI effect intensities (including urban canyon effects) have reached 8-12k [5].

There are several causes of an urban heat island (UHI); for example, dark surfaces absorb significantly more solar radiation, which causes urban concentrations of roads and buildings to heat more than suburban and rural areas during the day [6]; materials commonly used in urban areas for pavement and roofs, such as concrete and asphalt, have significantly different thermal bulk properties (including heat capacity and thermal conductivity) and surface radiative properties (albedo and emissivity) than the surrounding rural areas [4]. This causes a change in the energy budget of the urban area, often leading to higher temperatures than surrounding rural areas. Another major reason is the lack of evapotranspiration (for example, through lack of vegetation) in urban areas. The U.S. Forest Service found in 2018 that cities in the United States are losing 36 million trees each year. With a decreased amount of vegetation, cities also lose the shade and evaporative cooling effect of trees [7].

Other causes of a UHI are due to geometric effects. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. This is called the "urban canyon effect". Another effect of buildings is the blocking of wind, which also inhibits cooling by convection and prevents pollutants from dissipating. Waste heat from automobiles, air conditioning, industry, and other sources also

contributes to the UHI [8]. High levels of pollution in urban areas can also increase the UHI, as many forms of pollution change the radiative properties of the atmosphere. UHI not only raises urban temperatures but also increases ozone concentrations because ozone is a greenhouse gas whose formation will accelerate with the increase of temperature [9].

The UHI effect increases the cooling energy consumption in the city and the peak electricity consumption in the summer, which increases the concentration of harmful pollutants such as tropospheric ozone and volatile organic compounds, increases carbon dioxide emissions, deteriorates indoor and outdoor thermal comfort during warmer periods, and increases mortality, especially for the elderly [10].

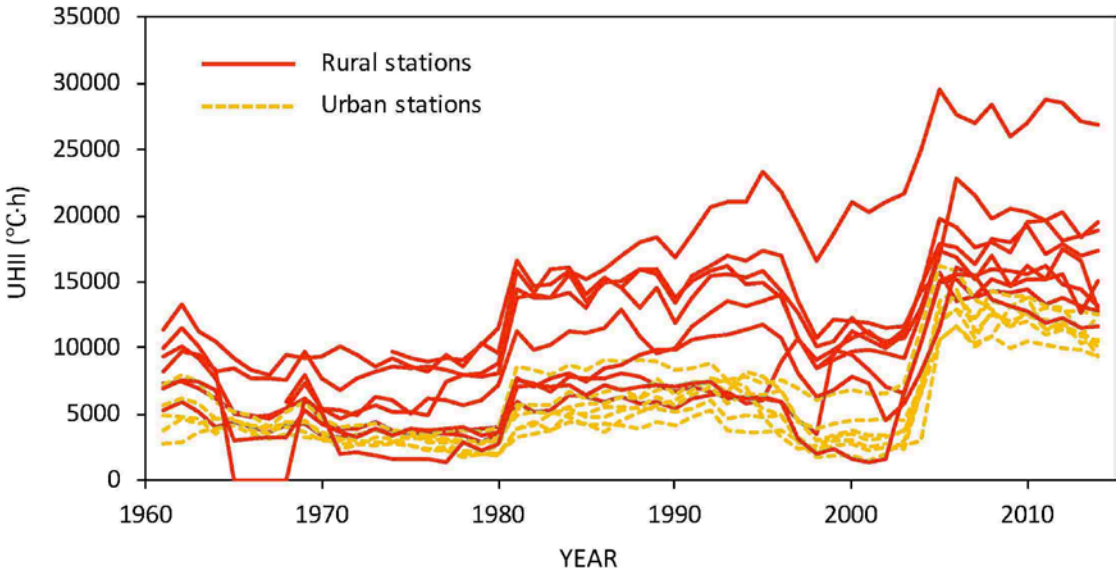

Figure 1-1. Yearly change in urban heat island intensity for urban and rural stations in Beijing from 1961 to 2014

(Source: Cui, Y., et al., 2017. Temporal and spatial characteristics of the urban heat island in Beijing and the impact on building design and energy performance. Energy 130, 286-297)

1.1.2 Strategies related to mitigating the urban heat island effect

In order to counterbalance the effects of urban climate warming, some mitigation and adaptation techniques have been proposed. These strategies to alleviate the UHI effect can be roughly divided into two types [11]:

One is to reduce the absorption of sunlight radiation. This strategy is mainly achieved through the use of highly reflective materials (and high thermal emissivity) to keep surfaces cool. These materials are called cool materials and they can be used as facades, roofs and paving of buildings.

The use of cool materials reduces the surface temperature of urban areas and minimizes the corresponding heat radiated into the atmosphere.

The other is to increase evaporation. This strategy is mainly achieved through increasing the transpiration and cooling effect in urban environments with greenery like parks, green roofs, and permeable pavements.

In the summer, unshaded urban horizontal surfaces absorb large amounts of solar radiation. On a dry surface, about 50% of the absorbed energy is transferred to the air, which rises the surrounding air temperature. High ambient temperature accelerates the photochemical reaction of pollutants in the air and cause pedestrian discomfort. Part of the solar radiation is absorbed by the roof, causing an increase in the indoor cooling load in air-conditioned building and reducing the comfort of the occupants. In the winter and in climate zones where there is a significant demand for heating, the solar radiation absorbed by the horizontal surface is only a small fraction of the summer absorption. Changing the horizontal surface material that absorb less sunlight (highly reflective material) and emit absorbed solar radiation freely (high emissivity material) keeps the surface temperature cool. A cooler surface releases less heat into the surrounding environment and delivers less heat to the building. Materials with high reflection characteristics and high heat radiation characteristics are called cold materials; for example, cool roof and cold pavement.

1.1.3 Economic evaluation of techniques in mitigating the urban heat island effect

The relationship between urban climatology and urban design and urban policy making has been mentioned in numbers of studies. Oke [12] Introduced eight modes of investigation of practice employed by urban climate, which is conceptualization, theorization, field observation, modelling (statistical, scale and numerical), validation of models, application in urban design and planning, impact assessment (post- implementation), policy development and modification. This study points out that although the first four items have made great progress during past decades, the transformation of research results into design and urban policy formulation has been stagnant. This barrier from knowledge to practice has become one of the important challenges in this field. This research points out accessible knowledge and appropriate tools are necessary to overcome this limitation, along with a more active environmental policy. Eliasson [13] indicated that although urban designers and urban development policy makers are interested in urban climate issues, the impact of urban climate researches on urban design and policy formulation is very limited. Five reasons may contribute to this phenomenon: conceptual and knowledge base (E.g. lack of relevant knowledge), technical reasons (E.g. lack of methods and techniques for collecting and analyzing climate data), Policy reasons (E.g. the need for economic priorities between different activities), organizational reasons (E.g. problems centered on the decision-making process), market reasons

(E.g. limitation of budget). Smith and Levermore [14] pointed out that although the technology to alleviate the UHI effect has been investigated and developed for decades, such as increasing urban vegetation, using high-reflective materials, designing urban wind channels. However, the improvement of relevant policy and norms still need to be strengthened, especially in constructed urban area.

Urban climate factors are often overlooked in urban construction and renewal. One of the important reasons is that policy makers and/or experts responsible for public resources (local municipalities) tend to be more concerned about the economic consequences of a certain urban transformation strategy. Since the total public resources for urban development are limited, if the value of urban heat climate improvement cannot be quantified, then urban development decision makers lack effective evidence for investment. There a missing link between fundamental urban heat climate studies and the economic consequences. Floater G [15] pointed out that pricing instruments is an important policy to balance the economic growth of the city while coping with the threat of urban climate deterioration. Its specific connotations include pricing for urban congestion, expansion, and pollution. Incentives that are not conductive to sustainable development can be reduced through reforming subsidy mechanisms and pricing negative externalities in urban expansion.

Some studies attempt to reveal the value of mitigating UHI effects from the aspects of energy efficiency, people's productivity improvement, and improvement of residents' thermal comfort. The study of Skelhorn, et al. [16], found that the summer UHI effect in Manchester, England, caused increase of the urban cooling load by 9% to 12%, while the UHI mitigation effect by increasing 5% of urban trees can reduce 4.8% of urban energy consumption during a three-day period of peak UHI condition. The study of Taleghani [17] compared the effect of commonly used UHI effect mitigation strategies in improving the outdoor thermal comfort, and it is concluded that our door greenery can better improve the resident's thermal comfort compared with reflective materials. In Cai, et al. [18], the effect of urban ambient temperature on the productivity of indoor manufacturing labor without air conditioning systems was studies. The results show that the rise of urban temperature cause a significant drop in worker's productivity, and the economic benefits brought by preventing extreme heat weather are very significant.

However, the value of UHI effect mitigation cannot be easily quantified through market-based means. The value of UHI effect mitigation should be defined as non-market value. Non-market value refers to those values that cannot be revealed by market prices. Most of the environmental services and environmental items, such as fresh air, clean drinking water, and biodiversity, are not traded on the market. In our research, it is the benefits of the UHI mitigation. Environmental goods and services are not traded on the market, and how much money people are willing to pay for these

items cannot be revealed through market prices. The only way to price these environmental items is the non-market value assessment.

Some studies have begun to explore the non-market value of urban thermal environment improvement. Zhang, et al. [19] used the contingent valuation method to find the WTP for the protective measures provided by the government or the market. The result indicated that the annual WTP accounts for 40 Chinese yuan (CHY), and is correlated with the factors of district, gender, income, air conditioner ownership, heat wave experience, and chronic non-communicable disease. Kim, et al. [20] assessed the WTP for mitigating UHI effect with urban forest. The research results showed that, in Korea, using the choice experiment, the WTP was $ 56.88-76.59 for every increase of the urban forest by $1m^2$. Ihara, et al. [21] evaluated the WTP to avoid heat disorders caused by UHI effect. Morawetz and Koemle [22] applied CVM method to estimate the WTP for trees and fountains as measures against UHI effect in Vienna, Austria, with limitation of the research method discussed. To the best of our knowledge, in this strand of research no studies have explored the social acceptance and WTP for the specific techniques for UHI effect mitigation.

1.2 Purpose of this study

1. This research discuss the theoretical basis of the economic assessment of UHI mitigation. Explaining why UHI mitigation has economic value, defining the connotation of its economic value, and discussing the theoretical connotation of its economic value assessment method.

2. This research conducted a literature review of relevant research on the use of contingent valuation method to assess the non-market value of urban environmental resources, sorting out the main trends of CVM research design with regard to the climate value of urban green space, summarizing the possible biases along with their remedies, and exploring the main determinants that influence residents' willingness to pay.

3. This research conducted an on-site questionnaire survey to analyze the Beijing residents' willingness to pay for the main techniques for mitigating the UHI effect, which is green roof, cool roof, and permeable pavement, and explore relevant determinants that affect residents' willingness to pay.

4. This research designed and tested a behavior prediction model on the basis of the theory of planned behavior to predict the incentives that promoting residents’ pro-environmental behavior such as paying for UHI effect mitigation.

1.3 Research structure

The research object of this study is UHI mitigation technical means，the research content is its economic value. Other than the introduction part of the first chapter and the conclusion part of the last chapter, the main part can be divided into three sections，which follows the research flow of theoretical study (Chapter 2), methodological study (Chapter 3), and experimental study (Chapter 4-7) .

The first part is the theoretical part, including the second chapter. This section mainly combed and reviewed the economic valuation of UHI mitigation, contingent valuation method, and the theory of planned behavior. For the aspect of economic valuation of UHI mitigation, this study mainly discussed the content of economic value of UHI mitigation, along with related economic principles including externalities, public goods, and willingness to pay. For the contingent valuation method, we mainly explained its economical basis, its developing history, and possible bias that may occur along with their remedies. For the theory of planned behavior, we explained its theoretical development process and connotation, then the application of this theory in related fields was discussed.

The second part is the methodological section. Based on the literature review of CVM research with regard to the climate value of urban green space, the research design of contingent valuation method is studied and discussed. Firstly, this research analyzes experimental subjects and experimental design of previous CVM researches. Secondly, this study analyzes the main academically controversy with regard to the CVM research, summarizing and discussing the possible errors along with their remedies. Thirdly, this study summarized the main influencing factors that affecting the respondents' willingness to pay. This section will provide evidence for experimental research design in section three.

The third part is the experimental part, including the chapter four to the chapter seven.

Chapter four explained the formulation of questionnaire, the details of on-site interview, and data processing method. The study applied face-to-face interview to collect data, double-bonded dichotomous choice format was chosen to elicit WTP, and the SPSS 24 and R language was used to process data. In order to deal with the large number of zero-response samples in the study, the spike model was used in the study. The study also explored determinants that affect residents' participation in supporting UHI effect mitigation.

Chapter five focus on eliciting Beijing residents' willingness to pay for promoting three strategies for mitigating the UHI effect, which is the construction of green roof, cool roof, and permeable pavement. In the seventh chapter, an extended TPB model was put forward to explain the incentive

that promoting residents' WTP for UHI mitigation. Amos 24 was used to conduct the structural equation model.

Based on the conclusion of previous research, the eighth chapter provides suggestions on how to extract the potential funds for UHI effect management reasonably and how to promote residents' pro-environment effectively.

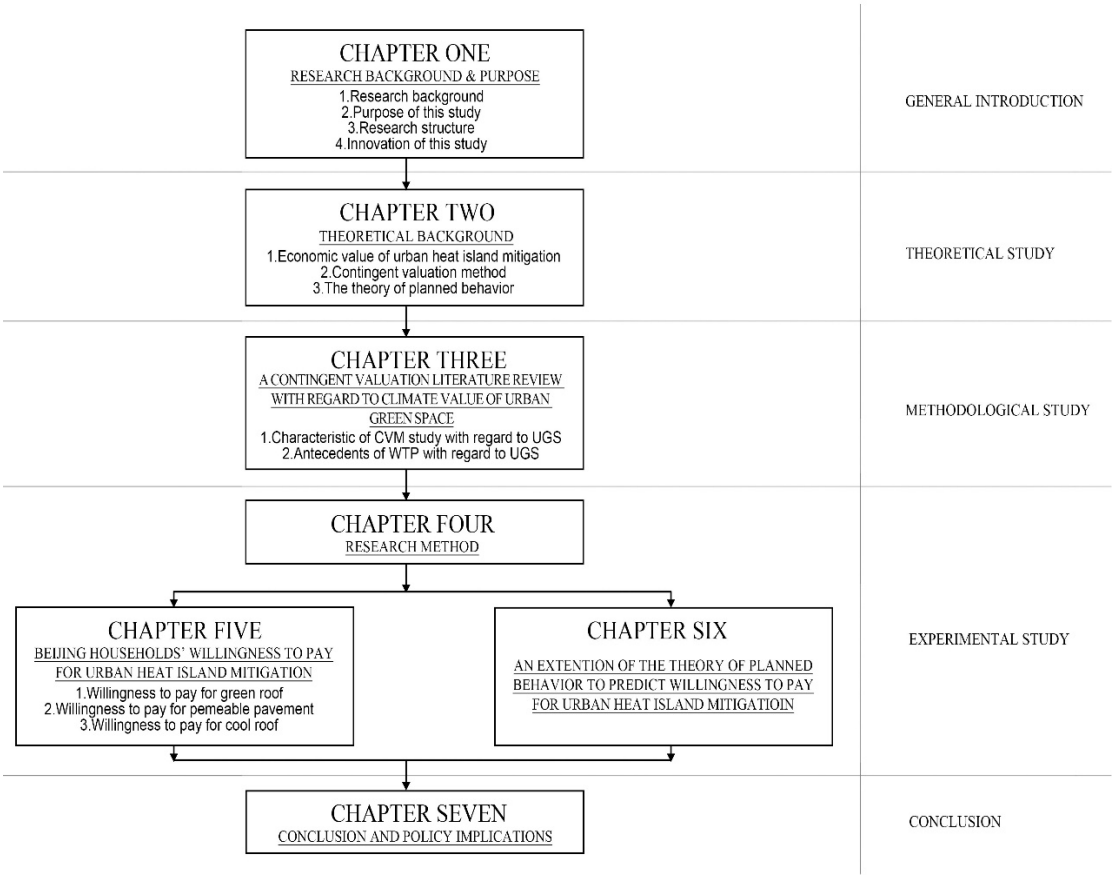

Figure 1-2. Research flow chart of the thesis

1.4 Innovation of this study

In terms of research object, this paper applied the contingent valuation method to evaluate the economic value of related technical approaches for UHI effect mitigation for the first time. In addition, it introduces the theory of planned behavior to explore the factors that affecting residents' willingness to pay.

From the theoretical perspective, this study explained the theoretical basis of economic evaluation of UHI mitigation and defined its content and connotation for the first time.

From methodological level, this study summarized the research design of related CVM research through literature review, along with the determinants that affecting respondents' WTP, and the possible bias along with their remedies. These information may provide new evidence for CVM research with regard to urban environment in the future.

From experimental level, compared with previous studies, this research introduced and tested DBDC plus spike model to deal with the zero responses that often appear in CVM studies. As for factors that affecting respondents' WTP, this research extended the conventional TPB by introducing the variable of environmental concern, which increases the predictive power of conventional TPB model.

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Chapter 2

THEORETICAL BACKGROUND

2.1 Economic value of urban heat island mitigation

2.1.1 The economic value of UHI effect mitigation

First, mitigating the urban heat island effect is economically valuable. The economic value theory is mainly composed of labor theory of value and marginal utility theory of value. This research will explain why the mitigation of UHI effect has economic value from these two aspects.

In the middle of the 17th century, with the rise of the classical school of political economy, the focus point of economic theoretical research and practice shifted from the circulation field to the production field, and the classical school put forward the labor theory of value. Three generations of the British Classical economists: William Petty, Adam Smith, briefly established the system of theory of labor theory of value. The basic proposition of labor theory of value was firstly put forward by William Petty, Adam Smith systematically discussed the theory, and David Ricardo complete of classical labor theory of value. In the 1860s, Karl Marx absorbed the idea of Hegel's philosophy, and analyzed the quality and quantity of value in a unified sense and formed the Marxist theory of labor value on the basis of the economic value theory of the classical school [1].

Marxist labor theory of value pointed out that labor is the only source of value. The essence of value is the abstract human labor in the state of condensation. The quantity of value is determined by the necessary labor time of the society.

This study first expounds the value of UHI effect mitigation from Marx's labor theory of value.

In modern commodity economy and society, population and the demand of human being is increasing rapidly, production scale is expanding rapidly and the science and technology is developing rapidly. The footprint of human activities has spread all over the globe, and the development and utilization of environmental resources has expanded to almost all areas, the impact of human activities on the environment is exceeding the environmental carrying capacity. As for the economic development, there has been a hollowing out of natural resources, and a deterioration of the natural environment. The stamina and foundation of economic development have been destroyed, the contradiction between resources and economic development has intensified, and the value of environmental resources has received more and more attention. In order to achieve sustainable development, a large amount of labor must be invested in the production and reproduction of natural resources, so that natural reproduction and social reproduction can be balanced. The modern natural resource reproduction process is the unification of the natural reproduction process and the social reproduction process. This makes the entire existing, useful and scarce natural resources manifest as direct production and reproduction of labor products [2]. In the

process of social reproduction, activities such as understanding, utilization, protection, renewal, development, and scientific research have already included “indiscriminate socially necessary labor which can be used for exchange and condensed in commodities.” According to labor theory of value, when general human labor condensed in the improvement of the urban thermal environment, the mitigation of the heat island effect has economic value, and the large amount of indiscriminate human labor condensed in the UHI effect governance constitutes the value basis of the UHI effect mitigation.

The utility value theory explains the formation process of value and value by the ability of the object in satisfying a person's desire or the subjective psychological evaluation of the person's utility.

In the early half of the 17th century, the early British economist Nicholas Baben believed that the value of all things came from utility; the utility of goods was to satisfy human desires and needs; all things could satisfy human beings' physical and spiritual desires are useful and valuable. The Italian economist Fernando Gariani believes that value is the ratio of the demand of goods to people, which depends on the estimation of the utility of the commodity by the exchange subject [3]. With the development commodity exchange relationship of commodity exchange relationship, the utility value theory has been clearly stated and fully developed in the bourgeois economics published in the first half of the 17th and 18th centuries [4].

From the second half of the 18th century to the early 19th century, the utility theory of value did not achieve any substantial progress. With the completion of the industrial revolution and the development of social productivity, classical political economy established the theory of labor value. In the process of expounding the labor theory of value, Adam Smith and David Ricardo strongly criticized the utility value theory. The French economist Jean Say insisted on the utility of the theory of value, but did not contribute to the further development of the theory [5].

After the 1930s, in the confrontation with the labor theory of value, the theory of marginal utility value appeared. The British economist William Lloyd is one of the pioneers of the marginal utility value theory. He believes that the value of goods only indicates the psychological feelings of people, while does not indicate the inherent nature of goods; the value depends on the desire of the person and the valuation of the person; the desire and valuation of the person will change with the number of items, and The margin between the satisfied and unsatisfied desires [6]. William Lloyd distinguishes the total utility and marginal utility, and implies that the value of the item depends on the marginal utility. The Irish economist Samuel Longfield also expressed a similar view: the market price of goods is always regulated by the minimum demand intensity that can cause actual purchases [7].

German economist Hermann Heinrich Gerson is the main pioneer of marginal utility theory. In his article "On the development of the law of human exchange and the resulting norms of human behavior," he reiterated the theory of utility value and proposed the famous Gerson theorem, which includes: the desire or utility diminishing theorem and the marginal utility equality theorem, which lays a theoretical foundation for the marginal utility value theory [8]. After H. Gerson, the Austrian economist Kal Mnger proposed the "Principles of National Economics", which indicated that the value of goods depends on the most unsatisfied desires of the various desires offered by the goods to satisfy the welfare of the people. The British economist William Jevons put forward the "last utility level" value theory in the "Political Economics Theory" published in the same year; in 1874, the French economics léon walras published "pure political economy" and puts forward the "sparse value theory". These three economists put forward the value of marginal utility to determine the value in almost the same time [9]. After the efforts of Kal Mnger, William Jevons, and léon walras, the theory of marginal utility has taken shape. After the development of Friedrich Wiesel and Eugen Boombavik, the marginal utility value theory has formed a complete theoretical system.

The theory of marginal utility has revived the theory of subjective utility, making subjective value theory a substitute for objective value theory as the mainstream of economic value theory. Utility value theory has been greatly promoted by studies with regard to the relationship between utility, total utility, and marginal utility. Marginal utility value theory holds the point that the value of an item depends on two factors: utility and scarcity. The so-called utility refers to the subjective enjoyment or usefulness obtained from the consumption of an item or service. There is no value without utility. Thus, utility is the source of the value of the item. UHI mitigation can improve people's comfort in urban life, reduce diseases caused by heat waves, and relieve air pollution caused by high temperature, and increase people's labor productivity, especially for outdoor workers. The utility of UHI effect mitigation has become the firm foundation for its economic value.

It is worth noting that utility can be divided into total utility and marginal utility. Total utility refers to the total satisfaction achieved by consuming a certain amount of items, and marginal utility refers to the added effect of each additional unit of consumption. The willingness to pay for the mitigation of urban heat island effects is determined by the marginal utility of urban thermal environment improvement.

2.1.2 Analysis of the economic value of UHI effect mitigation

In environmental economics, the value of environmental resources can be divided into use value and non-use value, and non-use value also called intrinsic value or preservation value. The use value indicates the function that satisfied the user's needs or preferences when the environmental resources are used, and can be further divided into direct use value and indirect use value. Non-use value is

the intrinsic value of environmental resources, including the choice value, existence value and heritage value of environmental resources, and has nothing to do with human use. The choice value is the willingness of consumers to protect unused resources in order to avoid the risk of future resource shortages. The value of existence gives the value of nature to humans without any motivation or intention to use it. Heritage values may include motivations or intentions for future use (Figure 2-1).

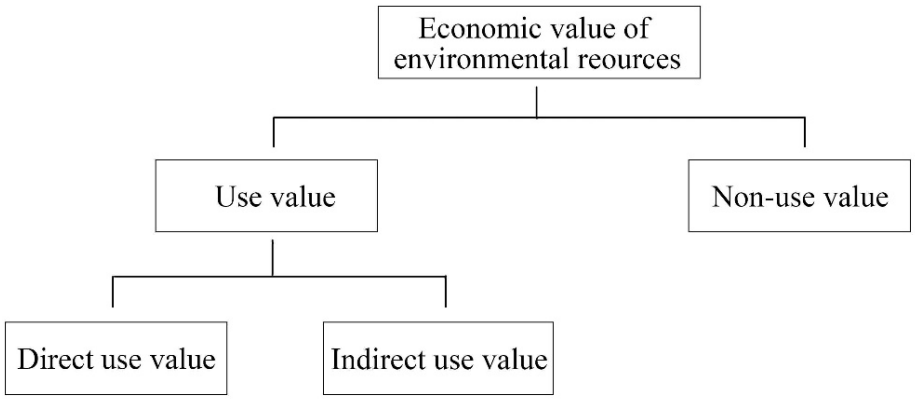

Figure 2-1. Economic value of environmental resources

Although the environmental economics field generally agrees on the classification framework for the value of environmental resources, there are subtle differences in specific views, as follows:

There is a crossover and overlap between choice value, heritage value and existential value, which are difficult to be defined, classified clearly. For the choice value, there exist divergence among scholars, and some scholars classify it as use value rather than non-use value.

Carson, et al. [10] argues that for the economic value of environmental resources, non-use value usually occupies a considerable proportion. Cost-benefit analysis that does not consider the non-use value of environmental resource is imperfect or even misleading. Non-use value, like use value, affects the level of human welfare. Zeng [11] explores the academic origin of non-use value, and believed that the non-use value of environmental resources is a vague and difficult to define deadline. As far as economic theory is concerned, it is inappropriate and infeasible to incorporate non-use values into the scope of economic valuation.

The urban thermal environment should be part of the urban ecosystem services, and a number of related studies are conducted within the framework of “use value – non-use value” of environmental values in environmental economics.

However, unlike conventional urban ecosystem services, the economic value of UHI effect mitigation is mainly reflected in the provision of non-physical direct use values (increasing thermal comfort, increasing productivity, reducing the hazards of related diseases), and indirect use value (maintaining Biodiversity of water bodies, preventing air pollution from deteriorating and mitigating global climate change). UHI effect mitigation is an integral part of urban ecosystem services, regardless of its non-use value (heritage value, choice value, and existence value).

Based on the value classification of UHI effect mitigation under the "use value and non-use value" framework, this study further distinguish its economic value from non-economic value.

In terms of the concept of value theory, economic value has a very clear definition. Pierce and Kerry Turner believe that value comes from human preferences and can be assessed through consumer surplus. Economic value can be understood as the sum of values motivated by all users and non-users [12].

Since the direct use value of the UHI effect mitigation can bring people direct effect, its economic value is not controversial.

The economic value of its non-use value deserves further exploration. Ecological value can be interpreted from different perspectives. One is the ecosystem with commodity value, that is, the value used as a resource entity for market exchange; the second is value of the existence of an object in the ecosystem for other valuable species or organisms; the third is the functional value of the ecosystem, which is the value for ecological research such as biodiversity research. If it is considered in the market perspective, the ecological value should be more reflected in the relevant knowledge of the resource value assessment subject and the ecological function of the resource utilization theme, reflecting the "expert value" of the ecosystem. From the perspective of welfare economics, expert judgment in related fields is only a specific information contained in evaluating UHI effect mitigation which is not a measure of welfare. It can be used in impact assessment and does not suitable for economic valuation.

The core ideas for constructing the UHI effect evaluation system are as follows: 1. the value of urban heat island effect mitigation is composed of direct use value and indirect use value. Direct use value is reflected in the environmental heat island effect mitigation can provide non-physical non-consumer value (heat comfort improvement, productivity increase, related disease attack rate reduction); indirect use value mainly includes ecological value (maintaining water body biodiversity, preventing air Pollution, regulating climate change). 2. The ecological value is an "expert value" which can explain the specific information contained in the UHI effect mitigation, however, is not

a measure of welfare and therefore is not a component of its economic value. Therefore, the focus point of this paper is on the direct use value brought about by the mitigation of UHI effect.

2.1.3 Introduction of related theory of economic value assessment for UHI effect mitigation

After clarifying the source of economic value of UHI effect mitigation and its composition, there is a theoretical basis for further discussion of economic value assessment methods. The theory of public goods is an important theoretical basis of the contingent valuation method. The externality theory expresses the necessity of evaluating the economic value of the UHI effect mitigation; the willingness to pay & the willingness to accept is a direct measurement of the mitigation of the UHI effect. Public goods theory, externalities theory, and willingness to pay & willingness to accept constitute the theoretical basis for the economical evaluation of UHI effect mitigation.

1. Public good

The concept of public goods was originally proposed by Eric Lindale and extended by Paul Samuelson later. Paul Samuelson believes that pure public goods or services mean that each consumption of such products or services does not lead to a reduction in the consumption of such products or services of other people. Public goods or services have three characteristics which are distinctly different from private goods or services: the indivisibility of utility, the non-competitiveness of consumption, and the non-exclusiveness of benefits. The definition proposed by Samuelson and developed by following economists is the most widely accepted one, which analyzes and defines public goods from two major characteristics. First, the non-exclusiveness of consumption is opposite to exclusiveness. Second, the non-competitiveness of consumption is relative to competitiveness.

The so-called non-exclusiveness means that the utility of a product cannot be divided among different consumers, which means any people can use it for free, or Individuals who does not pay for public goods cannot be excluded for technique reasons.

The so-called non-competitive means that once a public product is provided, any consumer's consumption of public goods will not affect the utility of other consumers, neither the utility of the whole society. The pure theory of public expenditures. The specific meaning consists of two aspects: First, the marginal production cost is zero, that is, increasing the marginal production cost of a consumer to the producer is zero. The increase in output leads to a difference in marginal cost. For public goods, the marginal production cost caused by the increase in output and the increase in consumers is inconsistent; but the marginal congestion cost is zero, that is, each consumer's consumption does not affect the quantity and quality of other consumption. This kind of product is not only consumed together, but also does not have crowding effect in consumption. The non-

competitiveness of consumption also comes from the indivisibility of products. When the product does not reach full consumption, the increase in consumers does not increase the variable cost of production and does not affect the consumption of others [13].

According to the non-competitive and non-exclusive characteristic of consumption, the discrimination of public products can be carried out according to the work flow shown in the figure. The first step in identifying public goods is to see whether there is non-competitiveness in the consumption of the product. A pure public goods should not have competitiveness. If the competitive product is exclusive at the same time, it is a purely private product; if the competitive product is also non-exclusive, it is a public resource that needs to be managed [14].

Second, if the environmental good is non-competitive, then we need to check its exclusiveness. If it is technically non-exclusive or the exclusive cost is high, then the product is a pure public product.

Third, if the product is non-competitive and the cost is not high, the product belongs to quasi-public product which is exclusive while non-competitive.

According to the discussion above, four different types of environmental goods can be derived: 1. pure public goods which is non-competitive and non-exclusive; 2. pure private products with competitive and exclusive; 3. non-competitive and exclusive Quasi-public goods; 4. Competitive and non-exclusive public resources [14].

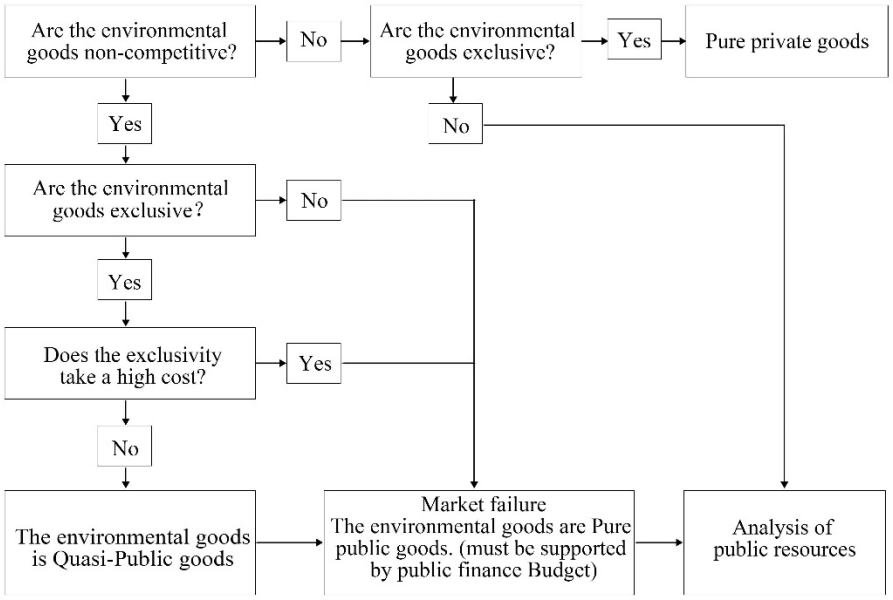

Figure 2-2. Identification of public goods

(Source: M, Hua. 2017. Public economic. Shanghai: Fudan University Press)

According to the definition of public goods and the identification flow, it can be considered that the UHI effect mitigation is a pure public good with non-competitive and non-exclusive characteristic. The non-competitive characteristic of UHI mitigation is that the utility of one resident does not reduce the utility of other residents. Even if an additional urban resident is added, the utility of residents who originally enjoyed the UHI effect mitigation will not be reduced, and the congestion cost of urban residents is approximately zero. The marginal cost of UHI effect management approach to zero. The exclusivity of UHI effect mitigation is also zero, which means that a resident cannot prevent the other residents from sharing the utility of UHI effect mitigation. Unlike quasi-public goods, which can be provided by private market mechanisms, pure public goods generally need to be provided entirely by the government.

2. Externalities

In economics, an externality is the cost or benefit that affects a party who did not choose to incur that cost or benefit [15]. Externalities often occur when a product or service's price equilibrium cannot reflect the true costs and benefits of that product or service. This causes the externality competitive equilibrium to not be a Pareto optimality. Externalities can be both positive and negative. Governments and institutions often take actions to internalize externalities, thus market-priced transactions can incorporate all the benefits and costs associated with transactions between economic agents [16]. The most common way this is done is by imposing taxes on the producers of this externality, in this case pollution. This is usually done similar to a quote where there is no tax imposed and then once the externality reaches a certain point there is a very high tax imposed.

The concept of externality was first proposed by Alfred Marshall and in 1890 in the book Principles of Economics [17]. He proposed the concept of "external economy" and "internal economy" when analyzing the economics of individual manufacturers and industries. In 1924, Marshall's student Arthur Pigou further studied and perfected the externality problem in his famous book "Welfare Economics." From the perspective of optimal allocation of social resources, Arthur Pigou applied the marginal analysis method and indicated that there is difference between the marginal social net output value and the marginal private net output value, supplementing the important idea that the externality can be positive or negative, and initially formed the theory of Static technical externalities [18]. The deterioration the UHI effect is related to the externalities of urban expansion. Samuelson believes that in the process of producing and consuming, one person may cause additional costs or additional benefits to others, while these costs or benefits imposed on others are not compensated in the form of money. In this circumstance, externality or spillover effects appears. We can define externality as "the impact of from an economic institution to the welfare of others, the value of which is not reflected in market transactions" [19].

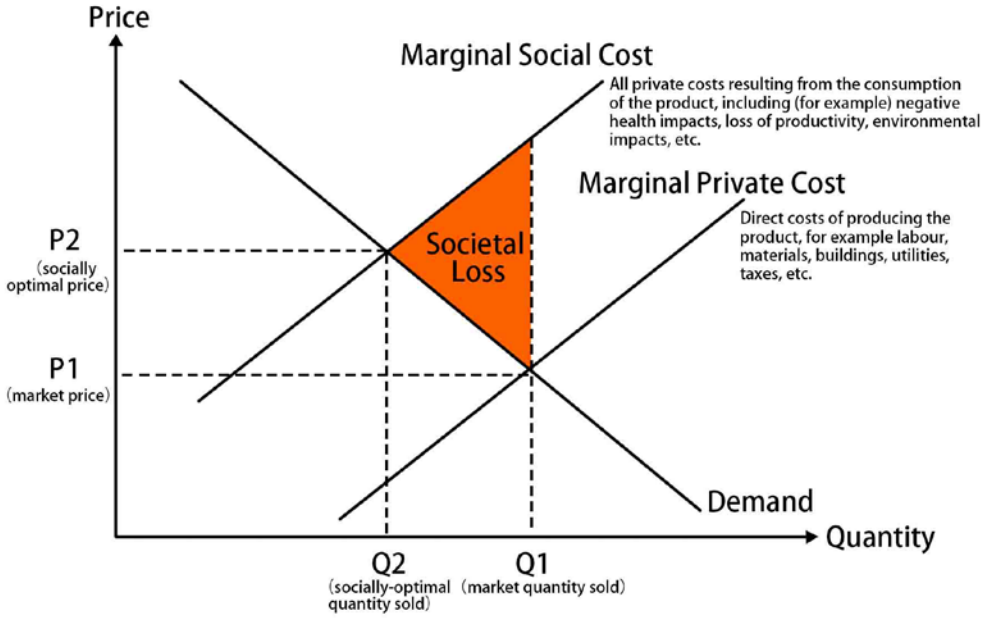

Figure 2-3. Externality and societal loss

(Source: https://en.wikipedia.org/wiki/Externality)

Positive or negative externality may also be caused by production behavior or consumer behavior [13]. Therefore, externalities can be divided into the following four specific forms: First, the external economy of production, that is, the producer adopts certain economic behaviors that benefits others or society; the second is the external diseconomy of production, that is, the producer adopts a certain economic behavior which damages others or society, while does not bear the corresponding costs for compensation; the third is the external economy of consumption, that is, consumers take certain economic behaviors to benefit others or society, but the beneficiaries do not have to pay. The fourth is the external diseconomy nature of consumption, consumers take certain economic actions to damage others or society, while they do not bear the corresponding costs for compensation.

The deterioration of UHI effect is one of the negative externalities in the process of urban expansion. This negative externality is simultaneously influenced by the external uneconomically of production in urban expansion and the external uneconomically of consumption. On the one hand, urban builders have changed the thermal properties of urban underlying surfaces, without considering the thermal environment of urban public space in the process of urban development. The heat capacity and thermal conductivity of these materials are much larger than the underlying layers of suburban nature, while their reflectivity and absorption rate of sunlight are large, which causes the temperature in the urban area to rise. On the other hand, energy-consuming devices such as boilers

and heaters, and various motor vehicles, which are widely used by urban residents in their lives, release a large amount of energy, most of which is released into the atmospheric space in the form of heat. In urban life, the roles of producers and consumers are often interchanged.

The pure public good nature of urban thermal environment has led to the inevitability of its externality. For urban developers, the superficial understanding of the economic value of UHI effects mitigation has made it unlikely for developers to invest for the analysis of cost-benefit. As for consumers of environmental goods. For public goods have externalities while there exist self-interested motivation, each urban resident only considers the marginal cost and marginal utility, and the social cost is unburdened, which has led to the emergence of the “tragedy of the commons". In our case, the deterioration of the urban thermal environment.

It is worth noting that in the process of urban development and expansion, external economy is more direct and is a dominant effect; while external diseconomy is accumulated in the process of urban development, which is an invisible effect. External diseconomy is often obscured by external economy for a long time [20]. Without the control of the external diseconomy such as deterioration of the urban thermal environment caused by urban expansion, the potential for sustainable urban development will continue lose.

3. Willingness to pay, willingness to accept

In welfare economics, an effective way to measure welfare levels in monetary terms is willingness to pay (WTP) and willingness to pay (WTA) [21]. WTP refers to the maximum amount of income a person is willing to pay for a change, or avoiding a change. WTA refers to the minimum income compensation that a person is willing to accept for an unfavorable change, or the minimum monetary compensation for giving up specific favorable condition.

Take the two choices faced by urban residents as an example to explain the difference between WTP and WTA. One case is that urban residents have monetary income M, and the other is the corresponding UHI effect intensity E, which should be non-exclusive and non-competitive, and the improvement of the urban thermal environment cannot be directly purchased through the market. The preference of rational consumers can be expressed by the indifference curve of utility. As shown in the figure, U1, U2, and U3 represent three utility levels respectively. The three indifference curves of U1, U2, and U3 are respectively derived from the combination of different monetary incomes and different UHI effect intensity. The utilities on the same indifference curve stay the same.

First, we analyze the willingness of urban residents to pay when the UHI effect is alleviated. Assume that the initial welfare level of the residents is at point A. At this time, while the tourists have the monetary income of M0, the UHI effect intensity is E0, and the utility level of the residents is U2.

Compared with A, B is in the same monetary income M0, while the urban thermal environmental quality is E1, E1 is better than E0, and B has a higher utility level U3 than point A. When the thermal environment quality is improved from E0 to E1, rational urban residents are willing to pay for the improvement of urban thermal quality from M0-M1. The urban residents' welfare level is at point C, while M1 represents the currency income, and the urban thermal environment quality level is E1. Point C has the same utility level U2 as point A. Urban residents are willing to pay M0-M1 for the improvement of urban thermal environment from E0 to E1. In this circumstance, the urban thermal environment has improved and the number of currencies has reduced, while the welfare level has remained unchanged. M0-M1 is the WTP of urban residents who improved the urban thermal environment from E0 to E1.

According to Figure 5, when the urban thermal environment deteriorates from E0 to E2, in order to maintain the tourist's welfare level, there should be monetary compensation of M2-M0. The tourist's welfare level is at point D which represents a combination of higher monetary income and a worsening urban thermal environment compared with point A. M2-M0 is the lowest WTA accepted by urban residents for the deterioration of urban thermal environment.

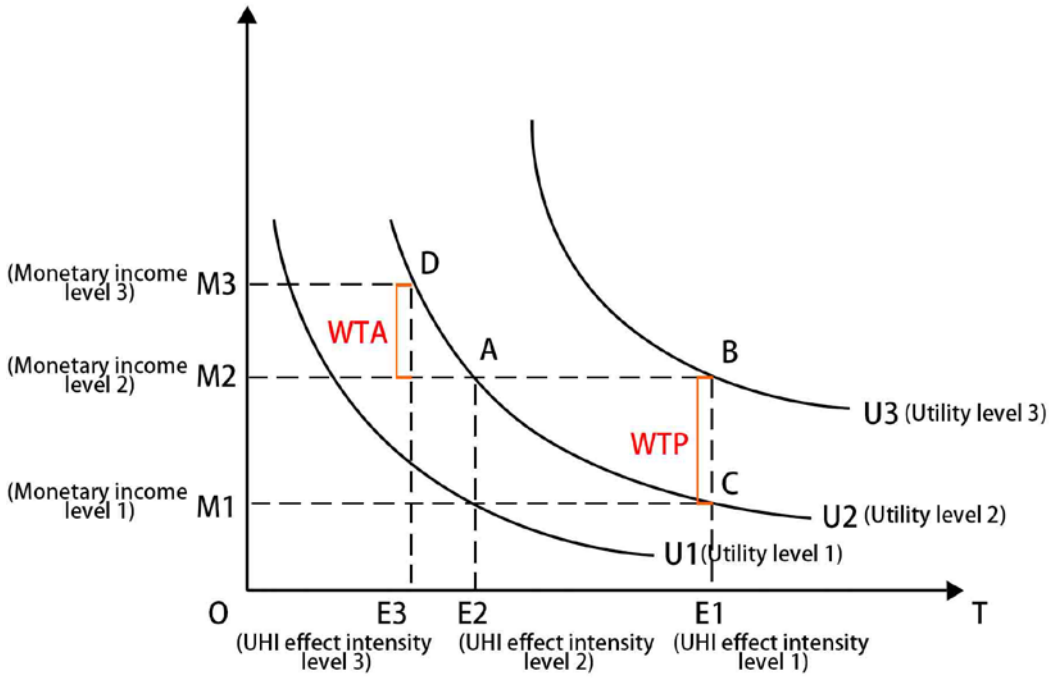

Figure 2-4. Comparison of WTP and WTA

(Source: T. Tunçel, J.K. Hammitt, A new meta-analysis on the WTP/WTA disparity, Journal of Environmental Economics and Management 68(1) (2014) 175-187.

2.2 Contingent valuation method

2.2.1 Contingent valuation method

As mentioned above, WTP and WTA are an effective way to measure welfare levels in monetary terms. The main techniques of measuring the economic value of environmental goods can be roughly divided into two categories: revealed preference method and stated preference method, as is shown in Fig 2-5 [22].

Revealed preference method revealed consumers' preference with regard to environmental good indirectly using market-related information, and estimating the economic value of environmental quality changes, which, however, can only assess the use value [23]. Revealed preference method includes travel expense method, hedonic price method, market cost method and benefit transfer method. Stated preference method refers to eliciting consumers' preference for specific environmental goods or services by direct asking. The most commonly use stated preference method is the contingent valuation method, which obtains people's willingness to pay for the benefit of environmental improvement or for environmental quality deterioration within a hypothetical market, thereby estimating the economic value of an specific environmental goods or service. Contingent valuation method can obtain both use value and non-use value [24].

Contingent valuation is a survey-based economic technique for the valuation of non-market resources, such as environmental preservation or the impact of contamination. While these resources do give people utility, certain aspects of them do not have a market price as they are not directly sold – for example, people receive benefit from a beautiful view of a mountain, but it would be tough to value using price-based models. Contingent valuation surveys are one technique which is used to measure these aspects. Contingent valuation is often referred to as a "stated preference" model, in contrast to a price-based revealed preference model. Both models are utility-based. Typically the survey asks how much money people would be willing to pay (or willing to accept) to maintain the existence of (or be compensated for the loss of) an environmental feature, such as biodiversity. At present, the contingent valuation method is one of the most widely used methods for assessing the value of environmental goods. Within a hypothetical market, respondents were described about the changes in the quantity or quality of an environmental goods or services in the form of a questionnaire, and were asked for their Willingness to pay (WTP) or the willingness to accept for the improvement or for the loss of environmental quality. Consumers' preferences for public goods and services along with it’s the economic value can be estimated in this way.

The measurement methods for WTP and WTA should be consistent theoretically, but empirical studies have shown that the measured value of WTA is usually higher than WTP, and the ratio of WTA\WTP is usually 2-10. At the same time, one of the principles proposed by NOAA indicates

"WTP should be used instead of WTA as a measure of value measurement," so researchers usually use WTP to assess the economic value of environmental public goods.

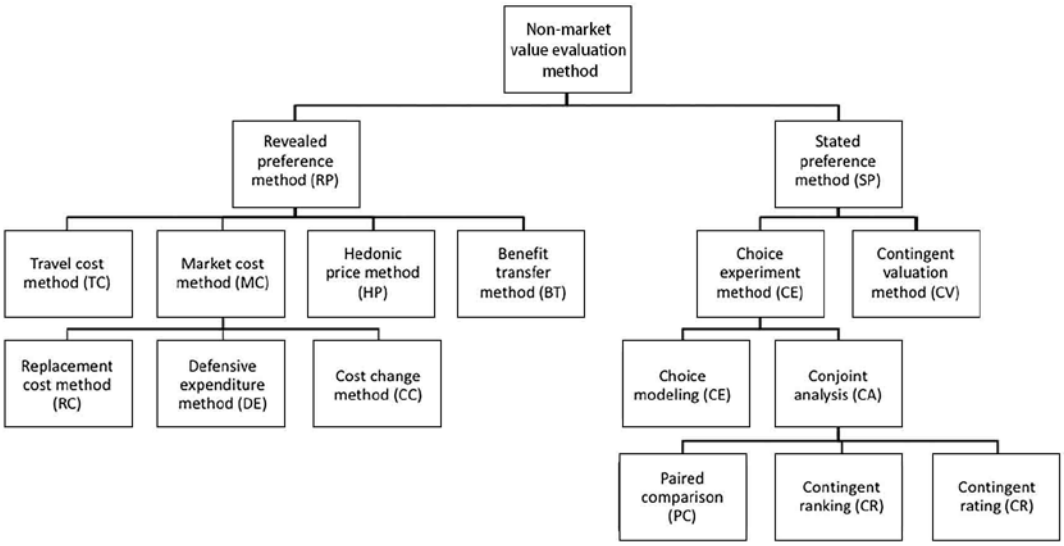

Figure 2-5. Classification of non-market valuation methods

(Source: Zhiqiang, Zhang. et al., The development and application of contingent valuation method [J]. Advance in earth science, 2003, (18): 454-463)

2.2.2 Development and application of contingent valuation method

The concept of contingent valuation method was first proposed by economist Ciriacy Wantrup in measuring the positive external effects of soil erosion, which is called direct access method [25].

In 1963, Dr. Davis of Harvard University in the United States applied CVM to the woodland of Maine for the first time for the evaluation of leisure and entertainment value, then it was gradually applied to the evaluation of and aesthetic value and leisure value of natural resources [26]. In 1979 and 1986, CVM was recognized by the US Water Resources Commission (WRC) and the Department of the Interior (DOI) as one of two recommended methods for evaluating the economic value of natural resources, and promote the application of CVM. It has become a commonly used approach for measuring the value of natural resources and the environment and the value of heritage [27]. In 1989, the assessment of environmental pollution losses in the oil spill in Alaska triggered a further discussion of CVM, including whether economic analysis should consider non-use value, the characteristic of hypothetical market, and the gap between willingness to pay and willingness to pay, and remedies for bias, etc. [28]. In 1992, the National Oceanic and Atmospheric Administration (NOAA) conducted a comprehensive and objective evaluation of CVM, and CVM was considered

to be an effective environmental valuation assessment method. NOAA also proposed guidelines to make its assessment results as reliable as possible [29]. Since then, CVM has been widely used in various countries and regions such as the United Kingdom, Norway, Sweden, France, etc., while the scope of research has been expanding continuously.

2.2.3 Possible bias and remedies

1. Information bias

Complete information is the basic premise of neoclassical economics. Only in the state of complete information, the respondents' willingness to pay can reflect its preference [30].

It can be seen that information plays an important role in CVM research. The validity of CVM largely depends on the quality of information provided to the respondent [31]. The main information that respondents need to get includes: the characteristics of environmental goods or services, the needs and budget constraints of the respondents, information about environmental resources or service substitutes or complements, and the WTP values of others. Among them, the characteristics of environmental goods or services, their own needs and budget constraints, complementary information and the WTP value of others will increase the WTP value of the respondent, and the information of the substitute will reduce the WTP value of the respondent.

In actual experimental studies, it is usually difficult to ensure complete information status due to limitations [32]. Some studies do not provide related professional information on the general situation of environmental goods or services, the respondents' own needs and budget constraints, and even the WTP of substitutes or complementary products and others. Referring to statistical results of the case study, the information bias with CVM research does exist, and the insufficient information with regard to the environmental goods directly leads to the low willingness to pay [33]. Therefore, in the hypothetical market, it is necessary to convey the characteristics of environmental goods or services and their background information clearly, accurately and thoroughly, to ensure that the respondents have a clear understanding of the relevant issues of environmental resources or services. At the same time, the questionnaire should not contain as much information as possible. In addition to the capacity limitation of the questionnaire, a long interview may lead to the tiredness of the respondents, which may contribute to interviewer bias.

In latest studies, the study of Bergstrom, et al. [34] suggests providing a combination of perspective, relative expenditure and provision cost information，and the combined effect of the three information types increases bids significantly. Blomquist and Whitehead [35] suggests providing information about the actual costs or quality of goods, which could reduce the number of zero bids, protest bids and "don't know" responses. The research of Akcura. [36]

indicates that questionnaire should avoid cognitively challenging information about the goods, which could prevents information being ignored due to it being too cognitively demanding.

2. Embedding bias

The embedding bias is also called part-whole bias, scope effect, etc., which means that there is a wide range of variation in WTP values for the same good is found, depending on whether it is valued separately or as a part of a more inclusive package [37]. The most famous case of embedding bias is the TRI (Research Triangle Institute, RTI), a CVM study on bird rescue. The study claims that the survey was the WTP for rescuing 2,000, 20,000 and 200,000 migratory water birds are same. This result led to the discussion of embedding bias [38].

Mitchell and Carson believe that the embedding bias only exists in the evaluation of intrinsic value [27], Daniel Kahneman and Jack Niki believe that in addition to intrinsic value, there will be an embedding bias in the assessment of the value of environmental public goods [37]. V. K. Smith and Laos-Osborne conducted a meta-analysis of five CVM studies on American national parks. These five studies include an assessment of both use value and the non-use value, and conducted both on-site and long-distance surveys. The meta-analysis found that the embedded bias was statistically valid and economically justified [39].

Meta-analysis and some studies have recognized the rationality of embedding bias. If the substitution and marginal utility decline can partially explain the existence of the embedding bias, and the limited budget of the respondent and the improper selection of statistical tools may also contribute to the occurrence of embedding bias [40]. In addition, in the case of embedding bias, there are often problems such as improper design of the questionnaire and misunderstanding of the questionnaire. Unreasonable questionnaire design, inappropriate survey methods, and irregular sampling are common source of embedding bias in some CVM cases. Considering embedding bias or scope effects, CVM is still an effective way to evaluate environmental values. Accurately defining the assessed environmental resources, providing different improvement status of environmental goods or services, providing comprehensive introduction or supplementary text descriptions and charts, and reminding the existence of substitutes, and allowing a second revision of the WTP will effectively reduce the occurrence of embedding bias.

In the latest research Cognitive ability and scale bias in the contingent valuation method. indicated that cognitive ability of respondents should be considered, for respondents with higher cognitive abilities have a smaller scope effect. Leiter and Pruckner [41] suggests controlling for perception and experience in the sample. Once controlled for attitude and experience, scope effects disappeared。

3. Sequencing effect

Another possible bias that may affect the WTP value is sequencing effect, which is also defined as order effect. That is, in the questionnaires for the evaluation of the economic value of multiple environmental resources or services, the WTP value will be different if the evaluated environmental resources are ranked differently. As with the embedded bias, this could happen in multiple environmental resource assessment studies.

A number of researchers have studied the sequencing effect and the results showed the respondent's familiarity with the evaluated environmental resources can reduce the sequencing effect. Carson, Flores and Meade [40] argue that sequencing bias may be related to alternatives and income effects. Inappropriate survey design is another important cause of sequencing bias. Offering information with regard to the questionnaire before the interview, or allowing bid editing after the interview will reduce the risk of sequencing effect. The proper response to the questions that raised by the respondents or proper treatment of the WTP data, such as reminding the respondents about the effect of sequence of items, or trying to make corrections could also partially reduce the impact of the sequencing effect.

As for the latest research with regard to this effect, the study of Carson, Flores and Meade [40] suggests using subsamples that do not offer the goods in a sequence, but as a package will reduce the risk of sequencing effect. Andersson and Svensson [42] use a design in which subgroups are presented in different sequences as a control. while Research found no differences among respondents. Gyrd-Hansen, et al. [43] indicate Avoid multiple valuations using a stepwise approach in one research for Simple valuations do not produce a sequencing effect.

In the latest research, the study of Carson, Flores and Meade [40] indicated that Use subsamples that do not offer the goods in a sequence, but as a package will reduce the sequencing effect. Andersson and Svensson [42] use a design in which subgroups are presented in different sequences as a control, while Research found no differences among respondents. Gyrd-Hansen, Kjæra and Nielsen [43] reported that avoiding multiple valuations using a stepwise approach in one research for simple valuations do not produce a sequencing effect.

4. Elicitation effect

The elicitation effect is related to the elicitation technique of WTP. The basic inquiry methods include sequential bids, payment card, open-ended and closed-ended methods [44].

When Davis first conducted a CVM study in 1963, the method of inquiry used was a sequential bids method. That is, a possible bid range is prepared in advance. The respondent was given a reasonable payment price as the starting point. If the respondent agrees to pay, the payment price is gradually increased by a fixed amount. Respondent is repeatedly asked until he/she is unwilling to pay, the

highest price is the maximum WTP. For developing countries that lack related experience, such approach is appropriate for a relatively large sample survey [45]. The disadvantage is that the cost is high and it is vulnerable to starting point bias [46].

The payment card method was first proposed by Mitchell and Carson for solving the starting point bias [47]. The payment card is prepared by the researchers, which displays the different maximum amount of bids. The amount of bids starts from zero, and respondents can choose their most favorable one. This method can avoid the starting point bias in the sequential bidding. The disadvantage is that it is easy to induce the respondent to choose the average value, and it can only provide the respondent within a range of price. The WTP is restricted and may not be able to get the real WTP of the respondent. In addition, in rural areas of developing countries, respondents have little experience with payment cards [48].

The open ended question format does not give any price range in advance, instead, it asks the respondent about the maximum willingness to pay for the use or change of environmental goods or services, to explore the respondents' preference for a specific environmental goods or services. This method is simple and feasible, but it may result in a large number of protest responses and zero responses due to the fact that the respondents have no actual experience or related knowledge with regard to the environmental knowledge or services, which leads to information bias and strategic bias [49].

Close ended format, which is also known as dichotomous choice question format, can be sorted into single bounded dichotomous choice format and multiple bounded dichotomous choice format. Because of the shortcomings of the WTP elicitation format mentioned above, Bishop and Thomas Hebrew applied the single-bounded dichotomous choice format for the first time in evaluating the economic value of the license for hunting goose for the first time. In the single-bounded dichotomous choice format, the respondent does not need to decide a price by himself, but decide to accept a given bid posed to them. This method is much easier to implement, and it is more similar to the barging action in the real market, consumers decide to "buy" or "not buy", and it is more suitable for telephone interviews or mailing surveys compared with other formats.

Although the single-boundary dichotomy method has its advantages mentioned before, M. W. Hanemann believes that this format is likely to overestimate respondents' WTP and is not statistically efficient [50]. R. T. Carson proposed a double-bounded dichotomous choice format which may overcome the shortcomings and possible biases of the single-bounded dichotomous choice format. If the respondent answers “yes” for the bid provided for the first time, then he/she will be asked with again with a higher bid; if the respondent answers “no" for the bid for the first time, then he/she will be presented with a lower bid [51]. This method is more likely to elicit the

true WTP of respondents, and it can reduce the risk of the starting point bias and strategical bias. In addition, the WTP result obtained with double-bounded dichotomous format is more accurate than that of the single-bounded dichotomous choice format. This method requires complex statistical model for data analysis, and can only elicit the lower limit of the WTA or WTP value, and it cannot avoid strategic bias completely [52].

In the comparison and discussion of the above WTP elicitation techniques. Rowe, et al. [53] Pointed out that payment card method are not sensitive to range effects as long as the card includes values that are large relative to the respondent's value, therefore, it can be used as a reasonable WTP elicitation method. Welsh and Poe [54] pointed out that the advantage of multiple-bounded discrete choice approach is that it allows the respondents to vote on a wide range of referendum thresholds and provides a higher level of precision.

5. Hypothetical bias

CVM provides the respondents a hypothetical market. The respondents will complete the transaction behavior in the hypothetical market situation, which is not necessarily the same as their decision in the real market situation, and this effect is difficult to be verified through real market behavior. This effect is defined as hypothetical bias. Although there are a few studies indicated that respondents' hypothetical WTP value is less than their actual WTP, most studies reported a higher WTP in hypothetical situation [48]. It is generally accepted that if the respondents are unfamiliar with the evaluation object, and the risk of hypothetical bias will be higher. Therefore, the method of repeated trials can make the respondents more familiar with CVM research along with evaluated objects, thus reduce hypothetical bias [55] [56] [57]. Adding a link of real payment in the questionnaire design can also effectively reduce the hypothetical bias. Marina-Rivina's study of nature reserves suggests that there are some differences in the characteristics of users and non-users, but they all have a desire to support protected areas. Those who have recently had a tour plan are more willing to pay a fee for the reserve, even if they have not had a tour before. Users are more cautious when considering income constraints than non-users, and are more familiar with related information with regard to the protected area. Even if there is a higher WTP among the user, the reason is that they may use this environmental resource later again, not for their special interest or their better understanding of the economic value of the environmental resources. Therefore, there is absolutely no need to limit the CVM survey to the group of users. Even if usage of environmental resources is very sensitive, non-users have the same motivation to evaluate these resources. Therefore, it is not reasonable to question about the existence of the non-use value [58]. Jordan-Lower Will, David Henscher, and Jofi-Sweet's meta-analysis of the relative studies also indicated that hypothetical behavior is often a reasonable indication of environmental consumer's actual behavior [59].

As for recent discussions, G. L. Poe [60] suggested using a consequential survey design in which respondents believe their responses will affect something that they care about for consequential surveys with well-defined incentives, stated values are closer to revealed WTP values. Loomis [61] reported that cheap talk reduces this type of bias. Jacquemet, et al. [62] suggested using oath design for oath-only design results in more sincere bidding behavior. Morrison and Brown [63] suggested using certainty scales for Well-designed certainty scales mitigate hypothetical bias, and applying dissonance minimization since The use of dissonance minimization is effective in mitigating hypothetical bias, but it cannot be used with open-ended responses.

6. Strategy bias

The strategic bias means that WTP values are biased because of strategic behavior on behalf of the respondent, (free-riding, excessive commitment, cautious bias, and flattery bias) among which, free rider and excessive commitment are the most common ones [30]. Respondents believe that other respondents will pay enough money for public goods, thus they do not have to pay themselves, which resulted in an underestimated WTP. This is defined as free-riding behavior. If respondents believe that a lower WTP may affect future pricing policies and products supplement, they may conduct excessive commitment action.

Mitchell and Carson believe that the following reasons lead to strategic bias in CVM research: limited amount of information (strategic behavior relies on a large amount of information support); a large number of CVM surveys use face-to-face interviews, so the respondents probably understand their WTP is only for research use without any actual impact; the payment medium in the questionnaire reminds the existence of budget constraints, which reduce the likelihood of over-exaggerate; a relative low WTP may lead to the evaluated environment goods or services no longer be provided, the feeling of which prevent the respondents from giving a unrealistic low WTP. Therefore, except for a few studies, most researchers do not believe that the strategic bias will have a great impact on the validity and reliability of CVM research [48]. In addition, some WTP elicitation technique, such as the double-bounded dichotomous choice elicitation format, can effectively reduce the strategic bias [40].

It should be noted that the above various bias are not limited to CVM research, and the existence of these bias does not invalidate the CVM method itself. In order to reduce these possible bias, some scholars and institutions have proposed a number of principles for the CVM questionnaire design and investigation, the most influential of which are the 15 guidelines proposed by NOAA for the assessment of resource and environment non-use value [29]. These principles have the same reference significance for the urban environment services such as UHI effect mitigation.

Among recent studies on reducing such deviations，Tuo, et al. [64] suggested using incentive-compatible elicitation technique for The use of reservation price and undisclosed price setting lowered this effect. The contingent valuation method: a review [48] suggested using and make known that the sample size is large since through a large sample size, the impact of the individual respondent is (perceived as) low, which reduces strategic bias. Prince [55] suggested designing the payment vehicle in such a way that it is clear that there is a budget constraint for the presence of a budget constraint lowers the probability of overstated WTP. Walton, et al. [65] suggested asking for a compulsory contribution (for example, tax percentage) for a scenario with a compulsory (tax) contribution lowers the probability of free-riding behavior. Lucas. [66] suggested using scenarios with background information describing the type of management strategy, its risks and benefits. In addition, ask behavioral or experience questions specific to each scenario before the WTP question is introduced which allows the researcher to capture strategic bias with a distinct variable and provide a better model for WTP estimation. Lucas. [66] suggested using in-person surveys for direct contact with the respondent for in-person surveys make the act of being dishonest a much harder task and are less prone to strategic bias.

Table1 provides an overview of remedies for possible errors in the contingent valuation. Table1 provides an overview of remedies for possible errors in the contingent valuation.

Table 2-1. Overview of possible errors in the contingent valuation method and their remedies.

Error type	Description of error	Proposed remedies
Information effect	The level and nature of the information provided to the individual influences WTP values.	1. Provide a combination of perspective, relative expenditure and provision cost information. 2. Provide information about the actual costs or quality of goods. 3. Avoid cognitively challenging information about the goods.
Embedding/ scope effect	A wide range of variation in WTP values for the same good is found, depending on whether it is valued separately or as a part of a more inclusive package.	1. Use labels under which a good is sold. 2. Take into account the cognitive ability of respondents. 3. Control for perception and experience in the sample. 4. Describing larger and smaller commodities and focus latter. 5. Using maps and pictures to describe scenarios. 6. Revision of bids.

Sequencing effect	This occurs if WTP values for a particular good differ, depending on the order of the good in a sequence.	1. Use subsamples that do not offer the goods in a sequence, but as a package. 2. Use a design in which subgroups are presented in different sequences as a control. 3. Avoid multiple valuation using a stepwise approach in one research design.
Hypothetical bias	WTP values are biased because potential divergence between real and hypothetical payments occurs.	1. Only use this for goods that have characteristics close to existing goods. 2. Use a consequential survey design in which respondents believe their response will affect something that they care about. 3. Use a "cheap talk" survey design. 4. Use oath design. 5. Use certainty scales. 6. Apply dissonance minimization.
Strategic bias	WTP values are biased because of strategic behavior on behalf of the respondent (free-riding and over-pledging).	1. Use incentive-compatible elicitation techniques. 2. Use and make known that the sample size is large. 3. Design the payment vehicle in such a way that it is clear that there is a budget constraint. 4. Ask for a compulsory contribution. 5. Use scenarios with background information describing the type of management strategy, its risks and benefits. In addition, ask behavioral or experience questions specific to each scenario before the WTP question is introduced. 6. Use in-person surveys for direct contact with the respondents.
Elicitation effect	This occurs if WTP value for a particular good differ, depending on the elicitation method used in a contingent valuation study.	1. Use payment card. 2. Use multiple-bounded discrete choice approach.

2.3 The Theory of Planned behavior

2.3.1 The connotation of the theory of planned behavior

The theory of planned behavior is a famous theory that links ones' behavior and attitude in social psychology. The theory is based on the theory of expected value, and explains the theory of the general individual decision-making process from the perspective of information processing. It includes five elements: Behavioral attitude, subjective norm, perceived behavioral control, behavioral intention and behavior. The TPB holds the following five main viewpoints: 1. Behavioral intention is the most direct and most important factor that affecting behavior. An individual's behavior is not completely controlled by personal will. It is also affected by behavioral intention, as well as other constraints of actual control conditions such as individual's ability, perceived resources and opportunities. 2. Accurate perceived behavior control can reflect the actual control conditions, so it can be used as a surrogate indicator of actual control conditions, and predict the possibility of specific behavior directly. The accuracy of prediction depends on the degree of cognition of perceived behavioral control. 3. Behavioral attitudes, subjective norms and perceived behavioral control are three important variables for predicting behavioral intentions [67]. A positive behavioral attitude, a positive social norm, and a strong perceived behavioral control, will contribute to a greater behavioral intention. 4. The individual can acquire certain behavioral beliefs in a specific time and environment. These beliefs are the cognitive and emotional basis of behavioral attitudes, subjective norms, and perceived behavioral control. 5. The individual's personal characteristics and social and cultural backgrounds further influence behavioral attitudes, subjective norms, and perceived behavioral control through influencing behavioral belief, which in turn affects behavioral intentions and behaviors. Structural model of the TPB was shown as follows:

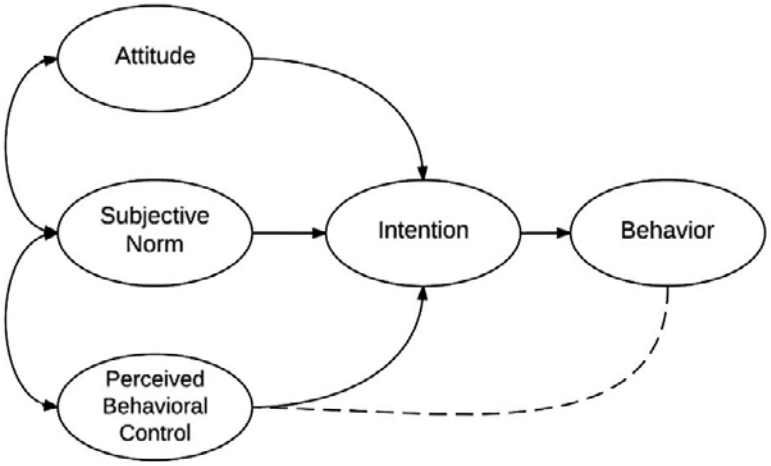

Figure 2-6. The theory of planned behavior

(Source: https://en.wikipedia.org/wiki/Theory_of_planned_behavior)

Behavioral intention is the motivation of an individual to perform a specific behavior, reflecting the degree to which an individual is willing to work hard and overcome obstacles, etc. It is considered to be able to affect individual's behavior through stimulating motivational factors. In the theory of planned behavior, people's behavioral intentions are affected by three internal factors. 1. Attitude towards the behavior: It refers to the stable position, inclination and opinion of an individual who performs a specific behavior, including instrumental components (useful-harmful, valuable-non valuable) and emotional components (like-dislike, happy-painful), which is determined by the strength of beliefs and the evaluation of behavioral option 2. Subjective norms: It refers to the social pressures that individuals perceive when deciding whether to perform a specific behavior, which reflects the influence of important groups or others on individual behavioral decisions. This is mainly determined by normative beliefs and motivation to comply. The former is the individual expectation of important groups, or the desire of others to perform a particular behavior, while the latter refers to the extent to which an individual follows the opinion of others when performing a particular behavior. 3. Perceived behavioral control refers to the perceived factors that may contribute or hinder the behavioral option, which reflects the individual's perceived ease or difficulty of performing a specific behavior, and is influenced by the control beliefs and the perceived power. The former one is the individual perceived factors that promoting or hindering the specific behavior option, and the latter is the degree to which the individual considers these factors may affect the conduction of the behavioral option.

I. Ajzen pointed out attitudes towards the behavior, subjective norms, and perceived behavioral control can be completely conceptually distinguished, but sometimes these three variables may share a common belief, so they are distinguished and related at the same time [67]: 1. Attitudes towards behavior and subjective norms are positively correlated. Individual with a positive attitude toward a particular behavioral option is likely to perceive greater social pressure, and in turn, a greater pro-environment behavior will stimulate a more positive attitude towards the behavior option. The subjective norms and perceived behavioral control are positively correlated, the stronger the subjective norms was perceived, the more likely they will prepare more resources for specific behaviors, in turn, the stronger an individual's perceived behavioral control, the more he/she is willing to have a positive social norm towards the behavioral option 3. Attitude towards the behavioral option and perceived behavioral control are positively correlated. The more positive the attitude towards the behavioral option, the more he/she is willing to prepare more related resources and overcome more challenges. In turn, the stronger the perceived behavioral control, and then the more positive attitude toward a particular behavior.

2.3.2 The development of TPB theory

The development of the theory of planned behavior has gone through three stages. TPB originated from the multi-attribute attitude theory (TMA) proposed by Peter C. Fishbern in 1963. TMA believes that behavioral intentions are determined by behavioral attitudes, while behavioral attitudes are influenced by expected behavioral outcomes and outcome assessments. In 1975, Peter C. Fishbern and I. Ajzen proposed the theory of rational behavior based on the theory of TMA. The behavioral intention is considered to be a direct factor in determining behavior, and it is pointed out that the behavioral intention is influenced by attitudes and subjective norms. The premise of this theory assumes that individual behavior is controlled by the will, while actually human behavior is often under control, which seriously restricts the practicality and application of the theory. Therefore, in 1985, I. Ajzen proposed the TPB theory. The variable of perceived behavioral control is added. In 1991, I. Ajzen published the article of "the theory of planned behavior", which is considered to be the maturity of TPB theory.

While the TPB theory has been affirmed and supported, it has also been criticized. Bagozzi, et al. [68] have pointed out that TPB theory only emphasizes the instrumental component of attitude while ignoring its emotional component, which is supported by numbers of researchers. Both types of attitudes have been examined in studies. The study of Chan and Fishbein [69] indicate that relationship of emotional attitude - intention is stronger than instrumental attitude - attention, while the study of Paisley indicate that both relationship are not significantly different [70].

For the variable of subjective norms, Sheeran and Orbell believe that the definition of the concept does not reflect the influence of society on individual behavior, which leads to a weak relationship between the variable and the intention in many behavioral analysis, and proposes that the definition of subjective norms should be improved. These questions have prompted the improvement of the development of TPB theory.

2.3.3 Application of TPB Theory

As a method to explain and predict people's behavior, the theory of planned behavior has been widely used in the study of customer's behavior intentions in the health industry, health care, leisure, management and other related fields.

Armitage found that behavioral attitudes, subjective norms, and perceived behavioral control have an explanatory power of 39%-50%, while the explanatory power of behavioral intention and the perceived behavioral control with regard to actual behavior is 20% to 40% [71]. Zhu Yuanfei’s research on the continued purchase intention of online shopping consumers shows that behavioral

attitudes, subjective norms and perceived behavioral control have an explanation of sustainable consuming intentions of 56% [72].

In the TPB model, attitudes, subjective norms, and perceived behavioral behaviors have different effects on different behaviors.

Although the TPB model has a good explanatory power for behavior, a large part of behavioral and behavioral intentions cannot be explained by the main variables. In this regard, many scholars have added variables that related to specific behaviors to the conventional TPB model to increase its predictive power. Pakpour, et al. [73] added variables such as ethical obligations, self-assessments, action plans, and past recycling experience to the TPB model to study household waste recycling behavior. 2,000 households samples were randomly selected from eight medical coverage areas in Kazvin, Iran. Through a questionnaire survey of the same subject at two time of one year, it is found that the past behavior experience has a significant impact on the recycling behavior of domestic garbage, and the final expanded TPB model explains 47% the variance of the recycling behavior of domestic garbage.

Table 2 provides a brief overview of TPB studies.

Table 2-2. Overview of application field of TPB.

Research literature	Research field	Research literature	Research field
Schifter, et al. (1985)	Intention of lossing weight	Burton N, et al. (1990)	Election intention
Doil, et al. (1990)	Intention of playing video game	Godin, et al. (1990)	Exercise intention
Parker, et al. (1990)	Traffic rules violation	Schlegel, et al. (1990)	Intention of drinking alcoholic
Ryn, et al. (1990)	Intention of work	Beck, et al. (1990)	Intention of fraudulent
Beale, et al. (1991)	Limit sugar intake	Beedell J D C, et al. (1990)	Intention of conserving soil and water

Hansen.(2004) (2008)	Intention of online shopping	Fielding K S (2008)	Environmental campaign
Zikic J, et al. (2009)	Intention of work	Zemore S E, et al. (2009)	Recreational activities
Ketal Y V, et al. (2009)	Food safety	Detal L G A, et al. (2010)	Intention of learning
Han H, et al. (2010)	Green hotel selection	Stone T H, et al. (2010)	Intention of academic immorality
Pakpour A H, et al. (2013)	Garbage collection behavior	Yeong Gug Kim (2014)	Intention of consuming genetically modified foods
Schifter, et al. (1985)	Intention of lossing weight	Burton N, et al. (1990)	Election intention
Doil, et al. (1990)	Intention of playing video game	Godin, et al. (1990)	Exercise intention
Parker, et al. (1990)	Traffic rules violation	Schlegel, et al. (1990)	Intention of drinking alcoholic

2.3.4 Research on the combination of the theory of planned behavior and contingent valuation method

The combined application for CVM and TPB has been launched in recent years. Spash, et al. [74] explored the factors behind people's willingness to pay for the diversity of life in aquatic ecosystems, the CVM model was used to estimate the economic value of environmental resource, and the TPB model was applied to reveal the motivation behind consumers'' economical behavior. This research indicates that the CVM model can be used as a standard economic model to exclude psychological and ethical factors. Therefore, the framework constructed by the TPB model can explore the impact mechanism under economic behavior. In addition, this research indicated that the willingness to pay is closely related to the behavioral attitude. In addition, subjective norms and perceived behavior control also play a non-negligible role in the willingness to pay.

A. M. Ryan [75] use TPB and CVM to examine the relationship between willingness to pay and attitude empirically. In the questionnaire survey, a case study scenario was presented, suggesting that the environmental proposal requires the investment, and people's willingness to protect the environment was drawled and TPB variable factors were added. It is assumed that people's environmental protection behavior is influenced by two attitudes, which is belief and political behavior, rather than economic interests. The relationship between willingness to pay and attitude was checked through data analysis, and thus discriminate whether the willingness to pay can be a reflection of individual attitude. In the first scenario, the TPB variable was not added. Therefore, after adding the non-attitude variable, the logistic regression model showed better results. The least squares model fitting showed that the attitude could not fully explain the residents' willingness to pay. The whole study shows that factors affecting willingness to pay are affected by subjective norms and perceived behavior control other than attitudes.

Lopez-Mosquera, et al. [76] studies the willingness of tourists to pay for urban parks, exploring the motivation of tourists to maintain public resources. The researchers selected the extended TPB model by adding the ethical factors. At the same time, the contingent valuation method was used to draw the willingness to pay when preparing the questionnaire. Before asking the valuation question, the hypothetical scenarios were carefully designed. Each respondent was explained about the public facilities provided as well as the diversity of plants and animals in details. Then respondents were asked about the maximum amount they are willingness to contribute to conserving the urban park. In data processing, CVM is used to estimate the average value of willingness to pay, and structural equation model is used to explore the direct or indirect impact of psychological factors on willingness to pay. The result showed that the determinants of attitude, subjective norms, personal norms and perceived behavioral control can explain 40% of the variances of WTP.

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Chapter 3

A CONTINGENT VALUATION LITERATURE REVIEW WITH REGARD TO CLIMATE VALUE OF URBAN GREEN SPACE

3.1 Introduction

The United Nations predicted that by 2050, up to 80% of the global population could be based in urban areas [1], while city life remains stressful for citizens due to hectic lifestyles. In this context, the demand for urban green spaces（UGS）in cities is increasing rapidly due to the benefits they provide, however, the demand is still subject to development pressures. One possible reason for this is that the planners and researchers have been unable to articulate their value in economic terms [2], If the benefits of UGS are not adequately assessed, then improper decision could be made such as the implementation of developments or other changes to public green spaces. Therefore, quantitative information about the value of UGS is needed for assessing urban land use.

Urban green space has the effect of cooling and humidifying the urban space, thus alleviating the UHI effect. A large number of studies have shown that the sunshade and transpiration of urban green space plants can effectively reduce the air temperature and ambient surface temperature, increase the air humidity, and reduce the UHI effect effectively [3-5].

The contingent valuation method is one of the most commonly used methods for environmental resource value assessment. In environmental economics, it is commonly used for evaluating the use value and non-use value of environmental goods or services, while the scope and number of CV studies of urban green space with regard to its climate effect has expanded in recent years, there is a lack of studies that summaries and examine the quality of these WTP studies. This paper conducts a state-of-the-art review of CV literature regarding UGS by sampling 48 studies and providing background information such as country, data collection method, WTP elicitation method, type of UGS, mean WTP, type of value and payment vehicle, which could become a reference for the future studies. We discuss the validity of different payment vehicles and data elicitation techniques and highlight the need for convergent validity testing in future studies. Moreover, we scan the primary antecedents that influence the WTP for UGS, which helps to explore to what extent a general theoretical framework can be traced in these studies. This chapter focuses on the evaluation of the contingent valuation research with regard to the climate value of urban green space. Focusing on the main characteristic of the current research design along with the determinants of WTP.

3.2 Method

We searched for related studies in May 2018 using Scopus with the following keywords: (willingness to pay OR contingent valuation) and (urban green space OR urban forest OR urban landscape OR urban trees OR urban park and garden) (n=548). Through abstract screening, 73 papers were excluded (27 papers were published in other languages, and 46 were not articles in an

academic journal). All English language articles published in academic journals from 1975-2018 were eligible for screening. A total number of 475 papers were selected (Figure 3-1).

We screened the titles, abstracts and keywords of these 475 papers and the citations of those articles to ensure completeness of the search. Of the 349 papers excluded, 236 studies were not conducted in an urban context, (e.g., rural national parks or rural agricultural landscape). A further 92 papers didn't use the related research method (e.g., travel cost method, market cost method, hedonic price method), and 21 papers didn't study urban green space (e.g., urban river, urban ecological system, urban green system facility). After reviewing for the availability of full text, 56 more papers were excluded, and 22 papers didn't contain the value of optimizing urban heat climate.

The final 48 papers were summarized using a standard data auditing form, including country and period of research, research focus, data collection method, types of UGS, payment vehicle, type of UGS value, and mean WTP. The criteria are as follows:

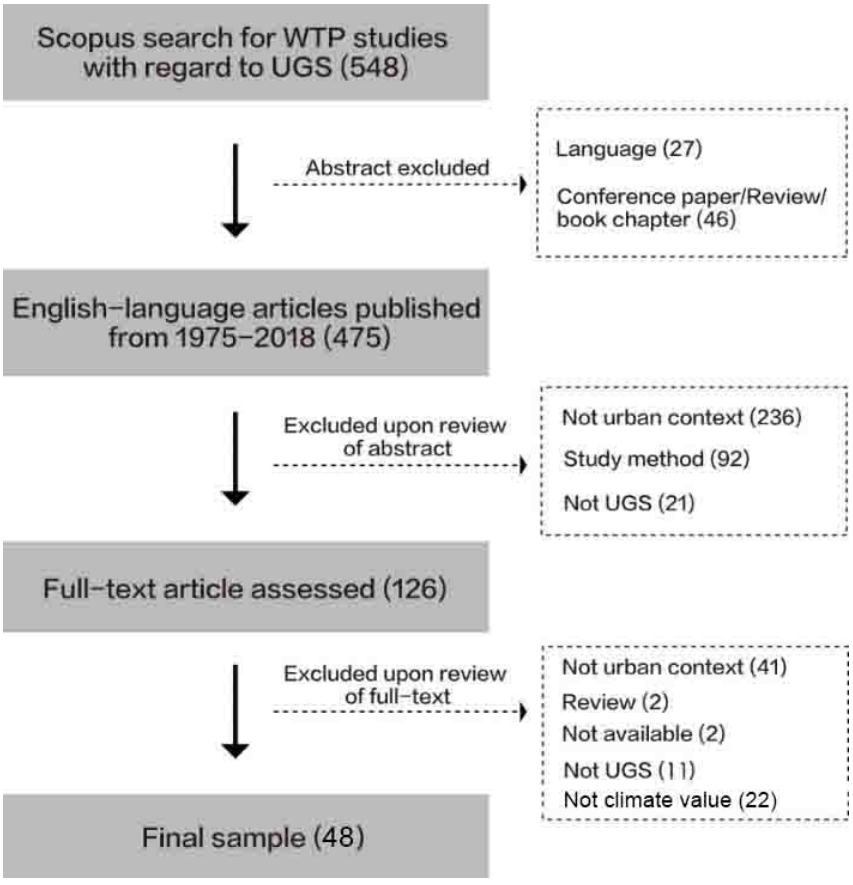

Figure 3-1. Flowchart of the systematic review process

- Country and period - When and where was the research conducted, assuming that the WTP for UGS might have different determinants and value among developed and

developing countries for the differing levels of environmental consciousness and, more importantly, the ability to pay?

- Research focus - What were the researchers trying to explore form the study? Is it the valuing of WTP or exploring its antecedent, or both?
- Data collection method - How was the data collected and WTP measured? This information may become a reference for the future studies, and researchers may consider using the same approaches, if applicable.
- Types of UGS - Was a specific kind of UGS indicated in the CV research? Examples include urban parks and gardens, natural and semi-natural green spaces, green corridor, community gardens [5]. This criterion was included because researches have shown that in some cases, people prefer a certain kind of UGS to another [6].
- Payment vehicle - Which kind of payment vehicle is used in the application of CV research? Examples include taxes, entrance fees, donations, and others. The payment vehicle is a crucial element in the application of CVM, as it provides the context for payment. Future researchers may consider using the same approaches, depending on the specific context of the study.
- Mean WTP - The mean WTP that was reported by studies. We also scanned all the papers for the antecedents with a statistically significant relationship to WTP. We summarized the methodological differences across studies with the antecedents of WTP, then examined and discussed then antecedents of WTP.

Among the 48 studies reviewed, a considerable number of choice experiment (CE) researches were recognized ("choice experiment" was not included in the search terms). Like CV, CE belongs to the family of SP method. In CV research, the characteristics of a selected product are fixed, while in CE these characteristics are flexible. In CV research, researchers collect information from a chosen product, while in CE research, researchers generate information from the product which is not chosen. Discrete choice CV can be, to a certain extent, regarded as a simplified version of CE. Both elicitation methods are included in our review.

3.3 Research result

3.3.1 General characteristic

This section focuses on the review of CV literature regarding WTP for UGS, getting an overview of its general characteristics. More details are presented in Table A1.

A total of 48 studies related to the WTP for UGS were presented through the review process described above. Table 1 provides the main findings of the review; more information is included in

Appendix A. Of all the literature, 34 studies were conducted in developed countries and 14 were in developing countries. Among the literature from developed countries, the majority of studies were contributed by the US (11 papers), while China contributed 4 of the 14 papers from developing countries. It was found that the proportion of studies from developing countries has increased by almost 35% since 2000, which may be due to the rising concern about the urban living environment in emerging economies (Figure 3-2).

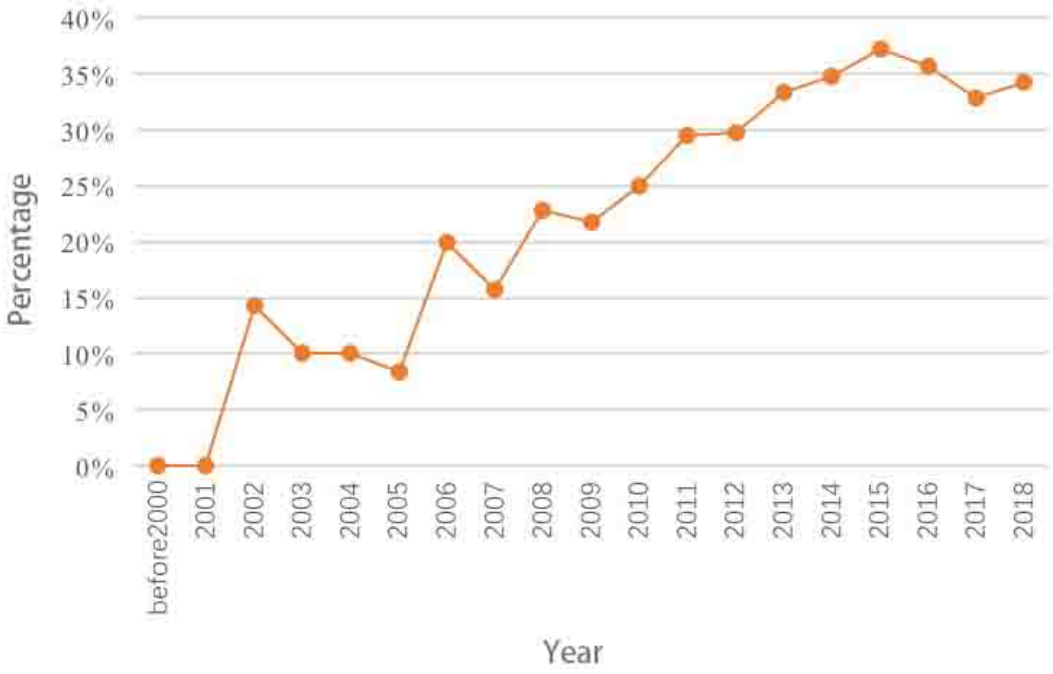

Figure 3-2. The proportion of CV studies regarding UGS from developing countries

As for the research focus of these studies, a majority of 48 papers focus on the valuation of UGS by using both WTP and its antecedents, 15 papers just focus on the WTP of UGS and one focuses solely on the antecedents. The presence of other foci was also found during the review, such as the willingness to pay for carbon credit (one study) and discussion of the validity of the CV approach in valuing UGS (one study).

Two methods of data collection are used in most of the reviewed literature (35 of 48 papers): face-to-face interviews (28 papers), and mail surveys (7 papers). Two papers use telephone surveys. Three papers use more than one method (e.g., face to face and e-mail, mail and telephone) and eight papers didn't indicated the data collection method. As for data collection method, there exists an argument about whether these approaches make a difference. The relevant literature reported mixed findings. A study by Ethier, et al. [7] reported that neither mode appears to provide more valid estimates of actual participation decision, which is in line with a study by Martínez Ibáñez, et al.

[8]. The study of Szolnoki and Hoffmann [9] indicated that face-to-face data collection delivered the best result while the online survey had significant biases concerning representativeness. However, Lindhjem and Navrud [10] and Ansolabehere and Schaffner [11] "do generally not find the substantial difference" comparing Internet surveys with other modes. In all, the face-to-face interview is most recommended, while web-based collection seems to be the most vulnerable (Figure 3-3).

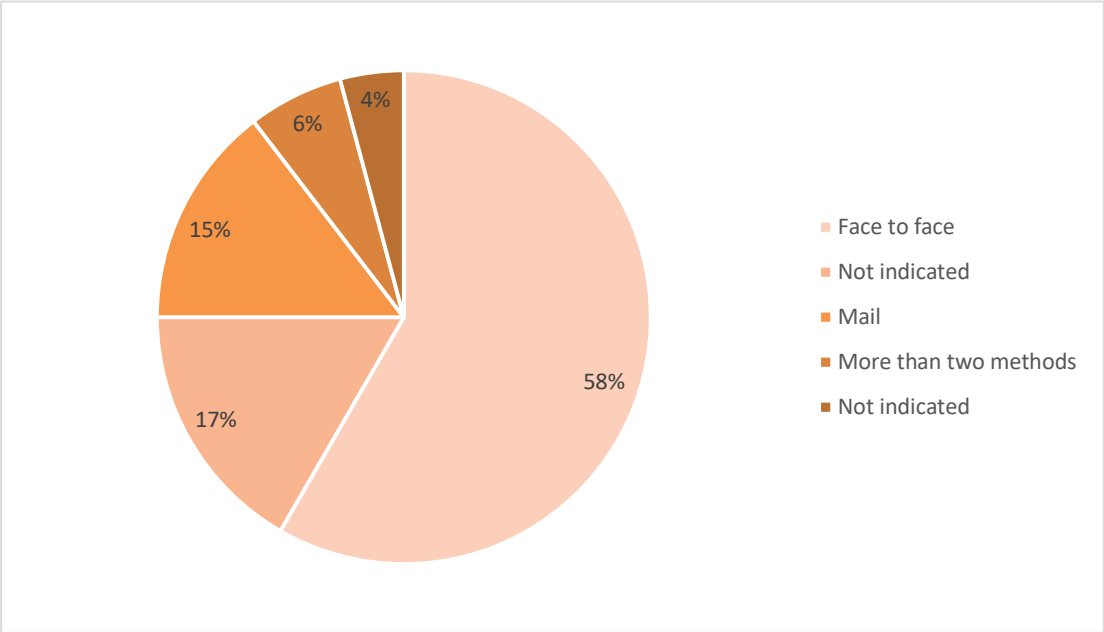

Figure 3-3. Distribution of different data collection methods

Of all the 48 papers, a majority of 36 papers studied the WTP for urban parks and gardens (12 papers) and natural and semi-natural green space (24 papers). 4 focused on green corridors, including streetscapes, riverfront landscape and urban green belts. One studied community garden and one covered urban park and gardens, community gardens and green corridors (in combination). 6 studies focus on the general green system with no specific type of UGS indicated. Predominantly, the phrase "urban park and garden" and "natural and semi-natural green space" are explicitly mentioned, mostly for their importance in compositing UGS, and consumers use these types of UGS more frequently (Figure 3-4).

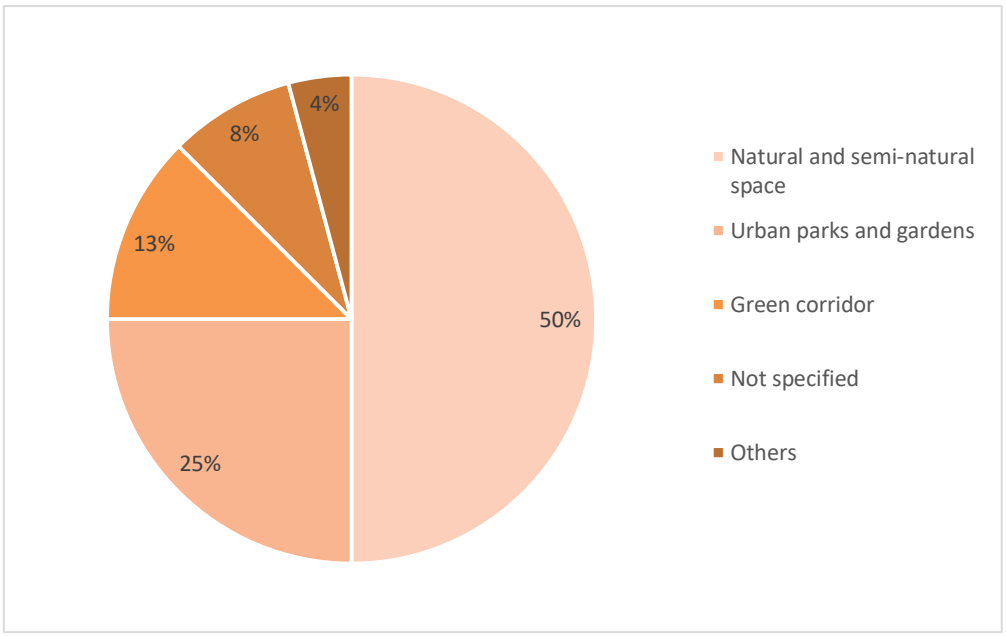

Figure 3-4. Distribution of different types of UGS

An essential part of any CV research is the payment vehicle, that is, the technique with which the fee is collected. It was found that papers choose taxes (16 papers), entrance fees (7 papers) or donations (5 papers) to provide the context for payment, while five studies choose other approaches, including carbon credit, housing expenses, a trust Fund, a water bill, and payment for installing a rain garden. Nine studies choose two or more payment vehicles mentioned as payment options, while 9 studies did not clearly indicate the payment vehicle (Figure 3-5).

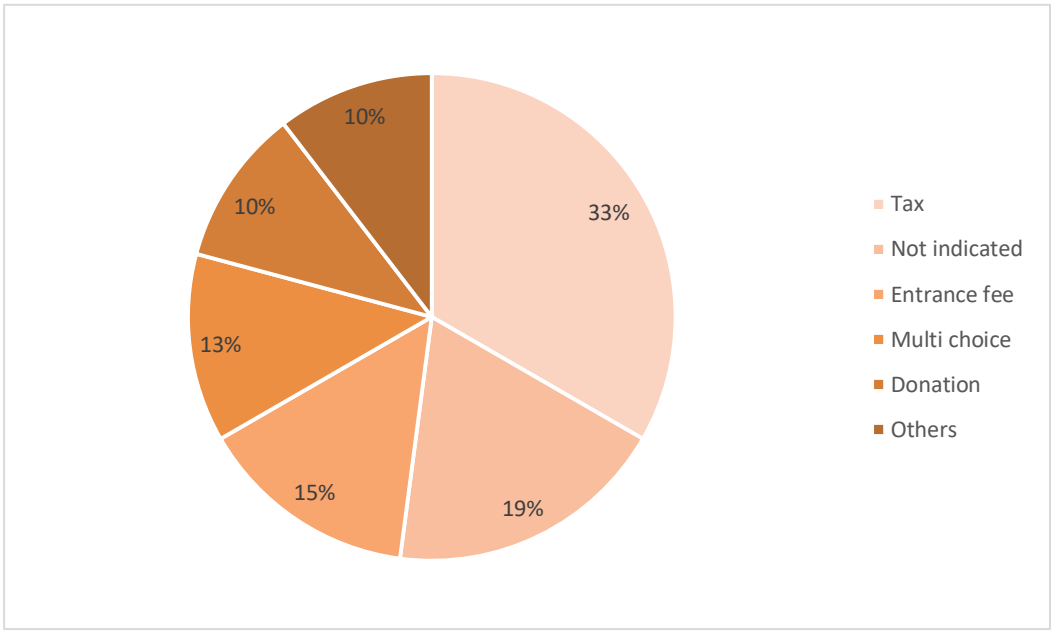

Figure 3-5. Distribution of different payment vehicles

For any CV studies, the data elicitation method is essential, which is, the format of the question posed to the respondents. Four WTP elicitation formats are currently in use in CV research:

Open-ended format (OE): each respondent is asked to state their WTP directly.

Payment card format (PC): respondents are required to choose the maximum WTP among a list of predefined numbers, and the respondent can also state their own WTP if not included.

The dichotomous choice (DC): each respondent is given only one price out of a range of predetermined prices. Respondents determine whether to accept the price offered, which is called single bounded discrete valuation (SBDC). In the so-called double-bounded discrete valuation (DBDC) format, a following bid is offered to the respondent based on the first answer.

Iterative bidding game (IB): a researcher provides a certain WTP, following with a higher or lower bid based on the acceptance of the previous question until the real WTP of the respondent is recognized.

Of all the 48 papers, three methods of data elicitation are predominantly used: 1. DC (19 studies) 2. PC (8 studies) 3. CE (6 studies). In 8 papers, the researchers chose the OE format. 3 papers choose an IB as the data elicitation approach, while 2 papers did not indicate the method used (Figure 3-6).

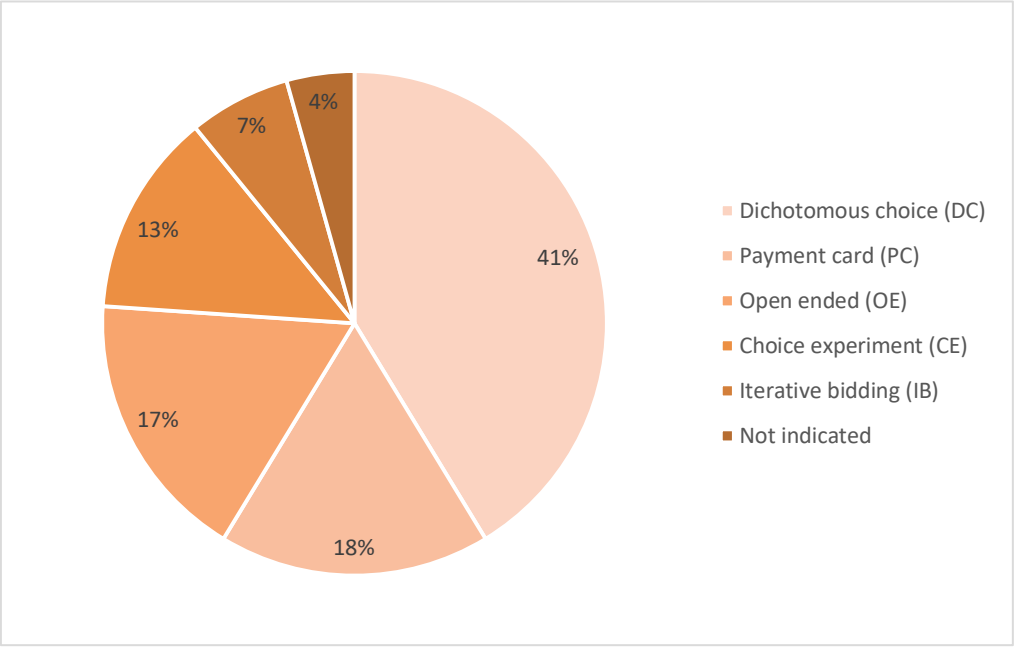

Figure 3-6. Distribution of different WTP elicitation techniques

We screened researches that reported mean WTP values. There was wide variation in the sites, from an urban street to the entire city. Most reported WTP values below 50 dollars per year. Similarly, these WTP reflect various types of UGS. As for the frequency of payment, most studies choose paying per year (14 studies), per month (eight studies) or per visit (eight studies). Five studies choose paying once per lifetime.

To further understand the discrepancies in WTP values, we examined CV studies that evaluated similar types of UGS (parks in urban central areas). WTP values have been converted into US dollars at the prevailing exchange rate. Table 1 summarizes characteristics of eight articles related to urban parks. Depending on the elicitation method, all the studies reported have a mean WTP value below 50 dollars per year. One study by Chen and Jim [12] show the divide between different payment vehicles. He found that voluntary payments provide a more conservative WTP.

Table 3-1. Mean WTP of studies regarding parks in urban central area

Author	Research object	Mean WTP
Saz-Salazar and Rausell-Köster [13]	A 114 ha urban park in Valencia, Spain	$7.6 /year
Lopez-Mosquera, et al. [14]	An 9 ha urban park in Pamplona, Spain	$14.8/year
del Saz Salazar and García Menéndez [15]	A 28 ha urban park in Valencia, Spain	$71.8/year $62.6/year
Brandli, et al. [16]	A 1.78 ha urban park in Passo Fundo, Brazil	$22.9/year
Soon and Ahmad [17]	A 7366 ha urban green land in Guangzhou, China	$2.1/month
Vecchiato and Tempesta [18]	A 18.4ha Urban Park in Thessaloniki, Greece	$4.6/2months $4.0/2months $7.9/2months $6.9/2months
Saz-Salazar and Rausell-Köster [13]	A 114 ha urban park in Valencia, Spain	$7.6 /year

3.3.2 Antecedents

In this part, we focused on the identification and classification of the antecedents of WTP for UGS. All the papers were scanned for the antecedents. Only those which had a statistically significant relationship with WTP were included. These antecedents were classified into eight groups, which are socio-economic characteristics (income, employment), respondents' characteristics (family size,

age, education level, sex, presence of Children), attitude toward the environment, attitude toward the benefits of UGS, prior knowledge of and experience with UGS, motivation of UGS project, time spent at UGS (both the length of visit and frequency of visits), accessibility, and social norms of environment protection. Table 2 presents the results of the review with examples from the literature.

The most common antecedents reported in the literatures reviewed were socio-economic characteristic, attitude (towards both the environment and value placed on the benefit of UGS), respondents' characteristic and time spent at UGS. All studies reported a positive attitude toward the environment and the UGS was positively associated with WTP. As for the socio-economic characteristic and respondents' characteristic, a vast majority of studies indicated that WTP is positive related with employment, income, education level and negative related with age and family size, which implied that respondents with a higher education level, better financial situation, and a full-time job were more willing to pay extra for UGS. As to Sex and presence of children, the review reported mixed findings, half positive and half negative results. Moreover, most studies reported a significant positive relationship between WTP and accessibility, the frequency of use, positive attitude towards UGS, environment protection, prior experience, and perceived social norm of environment protection (Table 3).

Table 3-2. Antecedents of WTP for UGS

Antecedents	**Number of studies**	**Number of statistically significant positive relationships**	**Number of statistically significant negative relationships**
Income	32	31	1
Employment	2	2	
Family size	2		2
Age	23	4	19
Education level	11	11	
Sex	10	6	4
Presence of children	2	1	1
Attitude toward the environment	8	8	
Attitude and value toward the benefits of UGS	17	17	
Prior knowledge and experience of UGS	5	5	

3.4 Discussion

The CV method is the most widely used methodology to value non-market and public goods including UGS. This technique has been developed for over 50 years with different possible errors thoroughly discussed. In this paper, we reviewed the published WTP studies regarding UGS over the past four decades. Significant variations exist between the research methodology, object of research, and respondent characteristics of each study, each of which may influence the perceived value of a test.

The perceived value of UGS seems to be affected by the way the WTP question is presented to the respondents, which is the so-called elicitation effect. CV studies of UGS predominantly used three formats: OE, the DC and the PC. While the OE approach has some obvious advantages [19], namely that it is easy for the subjects to answer and could get rid of starting-point bias, which means subjects anchor their WTP to the bid offered. The disadvantages of the OE method are that it generates a large number of zero responses and protest responses from the respondents who find it difficult or are not inclined to provide a true answer. The DC can help the respondents going through a complete valuation process, and is regarded as incentive-compatible so as to prevent a strategy-bias [20]. This method has been found to have disadvantages as well, for instance, it has been criticized for deriving the maximum WTP instead of the actual one, and is prone to starting point bias. While the PC was originally invented to avoid the starting point bias [21], it is also effective in reducing the non-response effect, Although in practice it is still subject to other forms of bias involving implied value cues, the range of values, anchoring effects, and the size of intervals displayed on the card can affect responses.

Except for few studies, previous researches have reported the divergence of WTP with different elicitation methods. In generally, SBDC generates a higher WTP than that of OE and PC, while DBDC provides the most conservative result compared with SBDC [22-25]. The meta-regression research by Soon and Ahmad [17] confirmed the systematical lower result of the DBDC method providing four possible reasons. The first explanation refers to strategic behavior, the possibility of which is relatively low in DBDC, which means people tends to report their true WTP in the DBDC test. The second explanation is that it is relatively easy to answer DBDC question, and people may find it difficult to give a number for a hypothetical market. The third explanation can be regarded as the uncertainty of people's preference; people tend to answer yes or give a bid, depending on the format, which qualified as a yes-saying bias and starting point bias. Another explanation is that people may have two aims when responding to WTP questions: they want to express that they favor the good at issue and respond to the WTP question truthfully. Although numerous studies have reported the consistently higher and lower results using different elicitation methods, it is still not clear which elicitation technique provides a more accurate estimation; that is the reason for the variety of elicitation methods in CV research regarding UGS.

Within the 54 studies, a considerable number of papers did not clearly indicate the payment vehicle [26, 27], with the underlying assumption that all the payment vehicles are feasible [28]. This lack of information indicates a need for a discussion about the role of payment vehicles in CV research.

The payment vehicle is an important factor in the design of the CV experiment because it provides the necessary payment context. CV research depends largely on people's understanding of the intrinsic characteristics of the goods to be paid. A payment vehicle is an intrinsic characteristic of a good or service because a good or service always has to be paid for, either through prior subscription or at the point of consumption, people will make different evaluations of a product based on different payment vehicles [29].

An indistinct payment vehicle may provide the respondents with some stimulatory factors to conduct strategic behavior. Carson, et al. [30] proposed that payment vehicles in the statement of preference experiment should meet the following two conditions: first, the subjects should be made aware that their decision will directly or indirectly influence the final decision. Secondly, respondents should pay attention to the final result. The experiment should be incentive-compatible. In addition, people in dichotomous choice contingent valuation (DCCV) experiments should adopt a compulsory payment vehicle to ensure incentive compatibility, when the payment vehicle is voluntary, individuals may have an incentive to exaggerate their WTP and then fail to donate when payment is collected.

For the studies that applied more than two payment vehicles, some reported a divergence of WTP with different payment vehicles [12], which is the payment vehicle effect. Many different solutions have been adopted to eliminate deviations in payment methods since the beginning of CV research. R. G. Cummings [31] pointed out that people should pay attention to the reason for specific payment vehicles in context, and in how the case would be financed if it were implemented. Prince [32] pointed out that realism and neutrality are two important criteria in selecting payment methods. Carson, et al. [33] emphasize the need to make respondents feel the credibility of payment methods, let the respondents believe that in the future they will pay for that good in that manner. Additionally, the payment vehicle effect has other implications, of which analysts should be aware. First, there is still no agreement about how to deal with the UGS users who protest the payment vehicle, nor how to separate them from the real zero responses. Second, only a few studies realized the impact of frequency of payment, and the potential payment effect is still unexplored. Third, the real-life payment vehicle may be different from the one in experiments, the potential payment vehicle effect may, therefore, be ignored, especially in experiments with several payment vehicles provided.

The theory of reasoned action (TRA) or its expansion, the theory of planned behavior (TPB) [34], have greatly inspired the CV researchers in defining the “predictor” of WTP for UGS. Initially, the

research about the antecedents of pro-environment behaviors focused on the study of the subjects' characteristics or socio-economic factors such as age, income and family size. However, these factors have been criticized as explaining only modest levels of variance in measurements of environment behavior. For this reason, researchers have recently turned their attention to other psychosocial constructs, and one of the most popular approaches is TPB. TPB is an extension of TRA. Ajzen and Fishbein formulated TRA in 1980, aiming to estimate the relationship between attitude and behavior, which has received criticism about its original limitation in dealing with behaviors over which people have incomplete volitional control. TPB is the model resulting from dealing with these limitations. According to the original TPB model, the best predictors of behavior are behavioral intentions, and these intentions are partially influenced by firstly, the attitudes which reflect the individual's positive or negative appraisal of a behavioral option; secondly, a subjective norm from the social pressure of reference group members to enact the behavior; and thirdly, perceived behavioral control which refers to the perceived ease or difficulty of performing the behavior. Our research indicates that positive attitudes do have a statistically significantly influence on respondents' pro-environmental behavior. Within our study, the control beliefs, which were indirectly measured through prior experience and knowledge about WTP, were positively related to WTP. Additionally, one study reported a significant relationship between social norms and WTP for UGS. TPB model may help to explore a theoretical framework for understanding the influencing factors of WTP.

3.5 Conclusion

Two conclusions can be derived from this literature. In the research methodology, the validity of the payment vehicle and data elicitation method needs more clarification. Regarding the antecedents of WTP, the theory of reasoned action or its expansion, the model of planned behavior, has greatly inspired the CV researchers in defining the antecedents of WTP.

This review contributes to the CV research with regarding UGS in two ways: first, the research methodologies of different studies in this field were abstracted and discussed, which could become the reference for future studies to optimize the design of their research. Second, CV research has long been criticized for a lack of construct validity. Construct validity means to what extent a test measures what it claims, or purports, to be measuring. It has two forms: convergent validity and theoretical validity. Convergent validity refers to the degree to which two measures of constructs that theoretically should be related, are in fact related. Our discussion about different elicitation methods and payment vehicles does highlight the needs for testing convergent validity of CV, and especially to what extent there exist any differences when using different techniques. Theoretical validity refers to the extent that the result of the test coincides with theoretical principles. We summarized and discussed the commonly applied antecedents of WTP for UGS, which could be

useful for testing the theoretical validity of the future studies by including these antecedents in the estimation model and achieving a more accurate WTP.

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Chapter 4

RESEARCH METHOD

4.1 Research design

4.1.1 Research site

The present study focus on Beijing, China, whose spatial location is displayed in Figure 13. As the capital, located on the North China Plain (39.26'-41.03'N; 115.25'-117.30'E), Beijing comprises 16 districts for a total area of 16411km^2. The population of Beijing was 21.5 million at the end of 2018. Notably, in these 16 districts, six districts are located in the inner city of Beijing, which is called urban area (i.e., Haidian, Chaoyang, Shijingshan, Fengtai, Dongcheng, and Xicheng), the majority of Beijing residents' distributed in these areas (Figure 4-1).

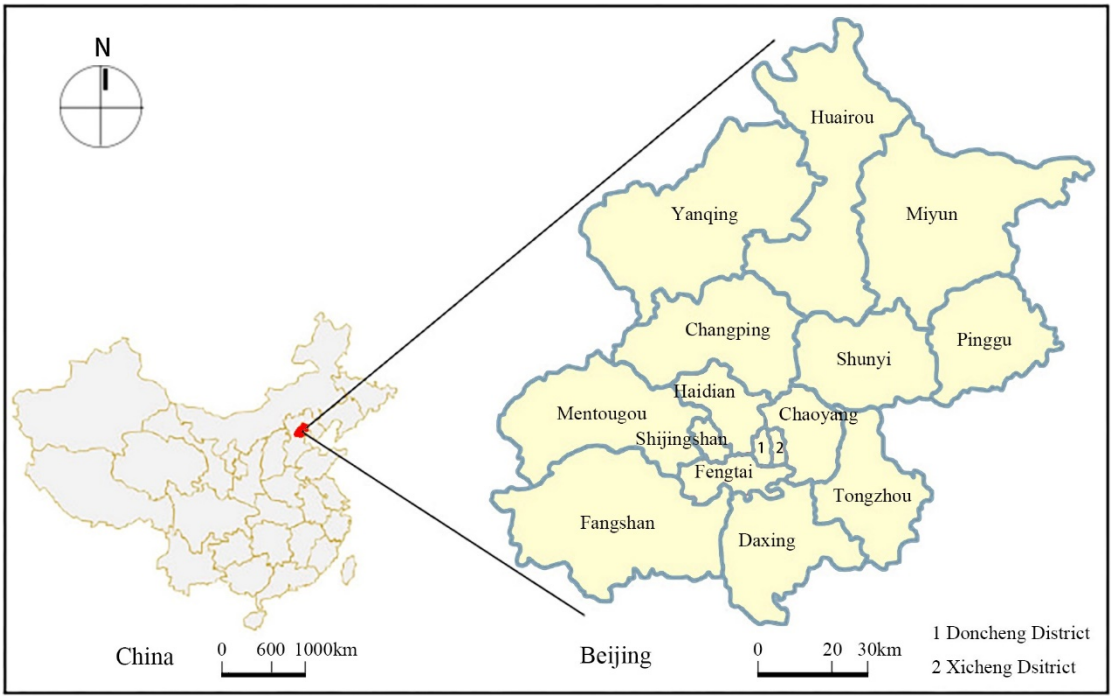

Figure 4-1. Location map of the study area

4.1.2 Sample size

The CVM research must have a sufficiently large sample to obtain a high quality statistical result, and in general, the number of samples refer to the sampling formula of Lynn, et al. [1], as follows:

$$n = \frac{\mathrm{N}}{(\mathrm{N}-1)б^2} + 1$$

In this formula, n is the number of samples; N represents the overall size; б is the sampling error. The number of households in Beijing is 5.38 million, according to the formula, sample size should

be over 401 to be statistical valid. As is mentioned by Mitchell and Carson, for the existence of hypothetical bias of hypothetical market, the sample size of CVM research should be larger that the conventional statistical threshold, and 600 samples can guarantee that the estimated WTP value and the true WTP value are controlled within 15% [2]. NOAA's report advised to have a sample capacity of more than 1000 [3].

4.1.3 Design of the questionnaire

To ensure the reliability of questionnaire, the questionnaire was revised and refined through literature review, consultation from experts, and pre-test of questionnaire (Figure 4-2).

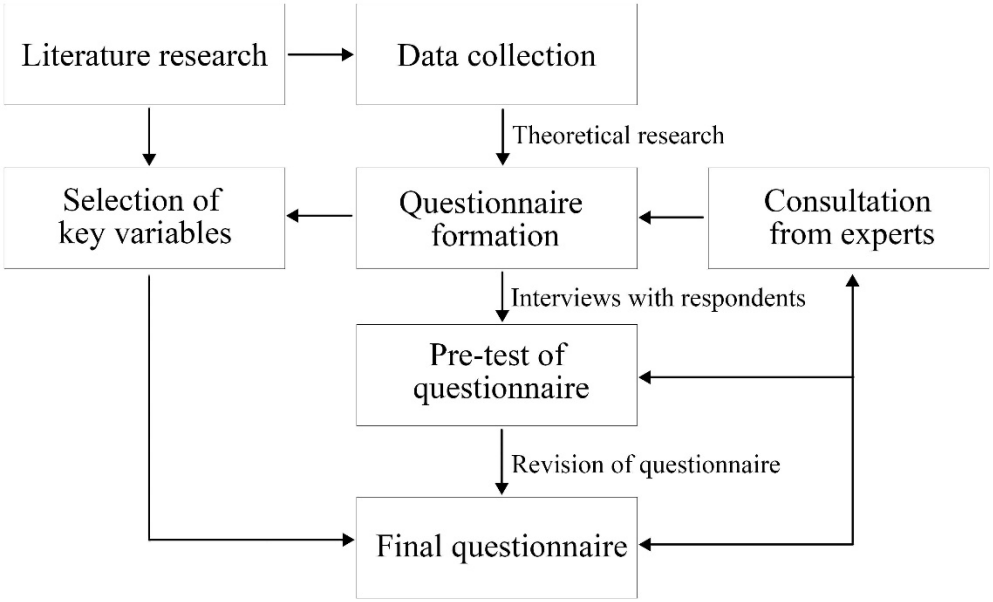

Figure 4-2. Design process of the questionnaire

4.1.4 Data elicitation method

1. Face to face interview

We used face-to-face surveys to collect information in Chapter five. The face-to-face survey has been regarded as the most reliable data collection method for many studies because it ensures a high response rate and can present more information about the participants compared with other data collection methods such as mail and telephone surveys. Szolnoki and Hoffmann [4] compared three different data collection methods while face-to-face delivered the best result. Most CVM about urban green space have also adopted face-to-face data collection methods, which is the reason we choose this method.

2. Online survey

In the research of Chapter six. The online survey method was applied. Since the 1980s, the widespread of internet technology has made it possible to conduct relatively inexpensive and convenient questionnaires, which has also improved the efficiency and flexibility of questionnaire research. A large number of online-based stated preference researches with regard to social science and business began to emerge. In the early 1990s, not everyone has the opportunity to get access to the Internet since it was a relatively new technology, especially for the elderly. As a result, online questionnaires have long been accused of lack of representative and low response rate [5]. Since the beginning of the 21st century, the number of Internet use has increased rapidly, and doubts about online questionnaires have begun to decrease. Ansolabehere and Schaffner [6] compared different questionnaire research method, pointing out that there are no significant differences between online questionnaire and conventional ones, which is also supported by Kaplowitz, et al. [7].

According to the China Internet Development Report [8], by 2017, the number of Chinese netizens has reached 772 million, and the Internet penetration rate was 55.7%. With the rapid development of network technology in China, more and more researchers have turned to choose online social platforms and online media for related researches [9].

The online questionnaire research of China began in 1995 [10]. Up to now, researches with online questionnaire have covered areas such as social behavior and psychology [11, 12], consumer behavior [13], and environmental management [9].

Since the 21st century, a number of professional online questionnaire survey system have begun to appear and update continuously. The study was supported by Ranxing Information Technology Co., Ltd., one of the leading online research organizations of China. During the research, invitation emails were distributed to 2.6 million registered members of this research institution randomly. Users who agree to receive the questionnaire interview will receive a certain monetary reward. The questionnaire organization will analyze the user's IP address and account to ensure the authenticity of the sample, and impose certain penalties on duplicate and false answers to ensure the reliability of samples.

4.1.5 WTP elicitation method

In chapter four, the WTP elicitation method was the Dichotomous choice (DC) format to elicit respondents' WTP, which is also recommended by the report of NOAA report [3]. The DC method used in this experiment is the double-bounded dichotomous choice (DBDC), in which respondents are usually presented with two bids. If one selected "yes" for the first bid, the following bid will either be higher, or if "no", followed by a lower one. Compared with the other commonly used

formats: single-bounded dichotomous choice (SBDC) and open-ended, the DBDC method provides the most conservative results in experimental research [14].

In chapter five, the WTP elicitation method was the SBDC, for it is convenient for data processing and thus suitable for establishing the predicting model.

4.1.6 Payment Vehicle

We used personal income tax as the payment vehicle. The payment vehicle played an important role in our CVM study because it provided the payment context for the CVM experiment. To avoid payment bias, the respondents must be familiar with the payment vehicle, and the payment vehicle should have a clear connection with the goods to be valued. We chose a payment vehicle with a compulsory feature such as a tax to reduce biased WTP values arising from potential behavior on behalf of the respondents (free-riding and over-pledging) [15]. Beijing citizens are more familiar with personal income tax than other types of taxation, which is the reason we chose this particular type of payment vehicle. The acceptance of this payment vehicle was tested during the pre-research.

As for the frequency of payment and duration of payment [16], we chose the annual fee with reference to the relevant research [26].

4.1.7 Common method bias

Most researchers agree that common method variance (variance that is attributable to the measurement method rather than to the constructs the measures represent) is a potential problem in behavioral research, the systematic error variance of which can have a serious confounding influence on empirical results, yielding potentially misleading conclusions [17]. The potential sources of common method biases in our research may due to respondents' propensity to maintain consistency in their responses to questions, and to attribute socially desirable behavior. Before the onsite interview, all of the interviewers were trained about how to behave and answer the possible questions that may be raised by respondents, including informing that the respondents' anonymity will be absolutely guaranteed. Each interviewers was followed with a supervisor to avoid interviewer bias. In addition, we separated WTP questions and variables with regard to respondents' attitude psychologically. In between WTP questions and TPB questions there is an 5-10mins interview about respondents' social economic characteristic, suggestions for the government, and answer the respondents' question. Following the suggestion of Podsakoff, et al. [18], Harman's single-factor test and partial correlation coefficients are employed to estimate the existence of common method bias.

4.1.8 Determinants of WTP

Over the past few decades, environmental policymakers have been increasingly concerned about personal responsibility for environmental issues, and individual behaviors have received ever greater attention [19]. Initially, the research about the influencing factors of pro-environmental behavior focused on the characteristic of socioeconomic factors such as age, income, and family size. Such research was criticized as explaining only the variables of the most modest level of pro-environmental behavior. For these reasons, researchers began to turn their attention to psycho-social constructs. One of the most popular methods is the theory of planned behavior (TPB). TPB is an extension of the theory of reasoned action (TRA). Ajzen and Fishbein established TRA in 1980 [20]. It aims to establish a connection between attitude and behavior. This theory was criticized for its limitation in dealing with behaviors of individuals with incomplete volitional control. TPB is the result of dealing with this limitation. According to the original TPB model, the most proximal predictors of behavior are behavior intention, which is partially influenced by: a) positive or negative attitude towards the behavior option b) subjective norms or society pressure c) perceived behavioral control, which is, the perceived ease or difficulty of this behavior. In experimental study, inspired by the TPB. In the study of Chapter 4, we added covariates, such as attitude, subjective norms, and perceived behavior control, to the conventional ones used in previous studies (Figure 4-3).

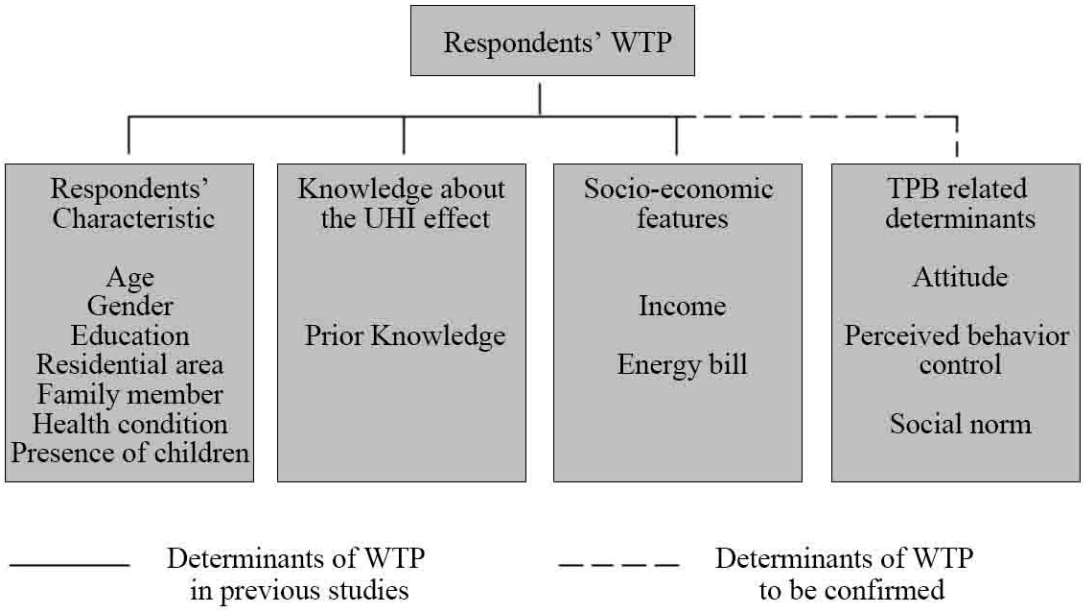

Figure 4-3. Determinants of WTP

4.2 Data analysis

4.2.1 Mean WTP or medium WTP

In the data statistics of CVM survey, there has been a lot of controversy about whether to use average or median value for value evaluation. On the one hand, the previous analysis of the theoretical basis of the willingness to pay comes from the principle of income compensation of the John R. Hicks' consumer surplus, in which the equivalence variables and compensation variables are the average value; On the other hand, in general, as the analysis of this survey shows, the willingness of residents to pay is more discrete, so the average value is more likely to be influenced by extremum.

However, Bateman and Carson argue that averages have a very solid theoretical and logical basis, and that if the reasonability and efficiency of decision-making are emphasized, averages should be used, but from a fair point of view, because the median value indicates the willingness of 50% of respondents to pay, the median value is more suitable for democratic decision-making [21]. In this paper, the average value is used as the basis for valuation.

4.2.2 DBDC plus spike model

One import issue for the reliability and validity of CVM research is that a considerable proportion of respondents in the survey are unwilling to pay, which is defined as "zero responses" [22-24]. In developing countries, due to the lack of environmental awareness and the unfamiliarity with the CVM scenario, a large number of respondents in the questionnaire are unwilling to pay. According to the underlying motivation, the zero-responses can be further divided into "real zero responses" and "protest zero responses". "Real zero responses" means that the marginal utility of environmental changes is zero, while protest responses means respondents refuse to pay because they are dissatisfied with the payment vehicles or questioned about the validity of hypothetical market [25]. The proportion of protest responses is an important indicator for measuring the effectiveness and reliability of CVM research.

Conventional distribution functions typically do not contain zero responses samples when estimating the willingness to pay. Previous studies found that the higher the zero response rate, the larger the estimated WTP deviated from the real one [26]. The conventional way of dealing with zero-response samples is to either cull them or replace them with small positive numbers. Direct deletion not only ignores the completely different economic implications between the protest response and the true zero response, but also loses the effective amount of information and is more likely to cause sample selection bias [27, 28], while replacing zero responses with small positive numbers lack of theoretical basis, which may leads to subjective randomness. Recently, there have

been concerns about the corresponding methods of identification and treatments for protest responses. [29, 30].

How to deal with zero-response problems through statistical models has become one important branch of CVM research. The Tobit model for analyzing restricted data become the earliest attempt to solve this problem. However, the regression coefficient of the Tobit model does not indicate the marginal impact of the variable, and thus it is impossible to analyze the extent to which the variable affects the probability of the respondents joining the market or paying. In addition, the Tobit model implies a more rigorous assumption that the corner points are only derived from the budget constraints of the respondents, not other factors other than income. For these reasons, B. Kristrom proposed the Spike model based on a closed survey to correct the impact of a large number of zero-response samples under single-boundary condition WTP estimation. B. Kristrom believes that the conventional distribution function can be regarded as a special case of the spike model. The higher the zero response ratio in the questionnaire and the more asymmetric the WTP distribution is, the better the fitting effect of the spike model will be [31].

1. The basic WTP model

We adopt the utility difference approaches, as suggested by Johansson, et al. [32], for modeling WTP responses. This approach specifies the utility difference using a random utility maximization model. The utility function is defined as follows:

$$U = V(S, M; T) + \omega \quad (1)$$

Where U represents the independent variables of the utility function, including the respondents' income, socioeconomic characteristics, provision state of the goods to be valued, and other factors that affect the utility. In addition, S is the provision state of the goods to be valued; the value of S is 1 if the goods are provided and 0 otherwise. Income and the other factors are M and T, respectively. V is the indirect utility function that we can obtain by inserting the solution to the utility maximization problem into the objective function of the respondents' utility. Finally ω is a random component of the utility.

The respondent will maximize his or her utility by showing that he or she is willing to pay a certain bid, which is defined as A, if:

$$V(1, M - A; T) + \omega_1 \geq V(0, M; T) + \omega_0 \quad (2)$$

Rearranging Eq (2) yields:

$$V(1, M - A; T) - V(0, M, T) \geq \omega_0 - \omega_1 \quad (3)$$

The left side of Eq (3) is the utility difference, which is defined as $\Delta V(A)$, and this is the systematic and deterministic part; in contrast, while the right side is the non-systematic and random part. Let $\omega_0 - \omega_1$ be θ and $H_\theta(.)$ be the cumulative distribution function (cdf) of θ. We can express the probability of achieving an answer "yes" to a given bid as:

$$Pr\{response\ is\ "yes"\} = Pr\{\Delta V(A) \geq \theta\} = H_\theta[\Delta V(A)] \quad (4)$$

We can introduce the WTP, X, as a random variable into the description of the probability of the responding "yes" to a presented bid:

$$Pr\{response\ is\ "yes"\} = Pr\{X \geq A\} \equiv 1 - G_C(A) \quad (5)$$

where $G_C(A)$ is the cdf of X. Comparing Eq (3) and Eq (4) yields:

$$1 - G_C(A) = H_\theta[\Delta V(A)] \quad (6)$$

Usually, we assume $\Delta V = \alpha - \beta B$, where $\gamma = (a, b)$ is a parameter vector to be estimated.

2. The conventional DBDC-CVM model

The four possible responses paths in DBDC experiment were "yes-yes", "yes-no," "no-yes", and "no-no". The associated binary-valued indicator variables are $I_i^{YY}, I_i^{YN}, I_i^{NY}, I_i^{NN}$, respectively.

I_i^{YY} (ith respondents' sample is 'yes-yes')

I_i^{YN} (ith respondents' sample is 'yes-no')

I_i^{NY} (ith respondents' sample is 'no-yes')

I_i^{NN}(ith respondents' sample is 'no-no')

WTP (denoted as C) is recognized as a random variable with a cumulative distribution function (cdf), defined here as $G_C(A;\gamma)$, where A is the bid value and γ is a vector of parameter. The log-likelihood function takes the form:

$$\ln L = \sum_{i=1}^{N} \{I_i^{YY} \ln[1 - G_C(A_i^u;\gamma)] + I_i^{YN} \ln[G_C(A_i^u;\gamma) - G_C(A_i;\gamma)] + I_i^{NY} \ln[G_C(A_i;\gamma) - G_C(A_i^d;\gamma)] + I_i^{NN} \ln G_C(A_i^d;\gamma)\}$$

Formulating $1 - G_C(.)$as logistic cdf and combining this with $\gamma = (a, b)$yields:

$$G_C(A_i;\gamma) = [1 + \exp(a - bA]^{-1}$$

Let C^+be the mean WTP, where Ccan be positive or negative. Welfare measures can be computed as $C^+ = a/b$.

3. Spike model

We applied the spike model, which is suggested by Kristrom [31] and Yoo and Kwak [33], to deal with zero responses. For people who gave a "no-no" response, a following question was asked: Are you willing to pay any for this project? For each respondent *I*, I_i^{NN} can be classified into I_i^{NNY} and I_i^{NNN}, as follows

$I_i^{NNY} = 1$(ith respondent's response is "no-no-yes")

$I_i^{NNN} = 1$(ith respondent's response is "no-no-no")

The log-likelihood function for the DBDC spike model is given by:

$$\ln L = \sum_{i=1}^{N} \{I_i^{YY} \ln[1 - G_C(A_i^u;\gamma)] + I_i^{YN} \ln[G_C(A_i^u;\gamma) - G_C(A_i;\gamma)] + I_i^{NY} \ln[G_C(A_i;\gamma) - G_C(A_i^d;\gamma)] + I_i^{NNY}[\ln G_C(A_i^d;\gamma) - G_C(0;\gamma)] + I_i^{NNN}[G_C(0;\gamma)]\}$$

where

$$G_C(A;\theta) = \begin{cases} [1 + \exp(a - bA)]^{-1} & if A > 0 \\ [1 + \exp(a)]^{-1} & if A = 0 \\ 0 & if A < 0 \end{cases}$$

The spike is defined by $[1 + exp(a)]^{-1}$, and the mean WTP can be calculated as $C^{+} = (1/b)\ln[1 + \exp(a)]$.

4.2.3 Structural equation modelling

In chapter 6, we applied the structural equation model, SEM to establish the predicting model of people's WTP.

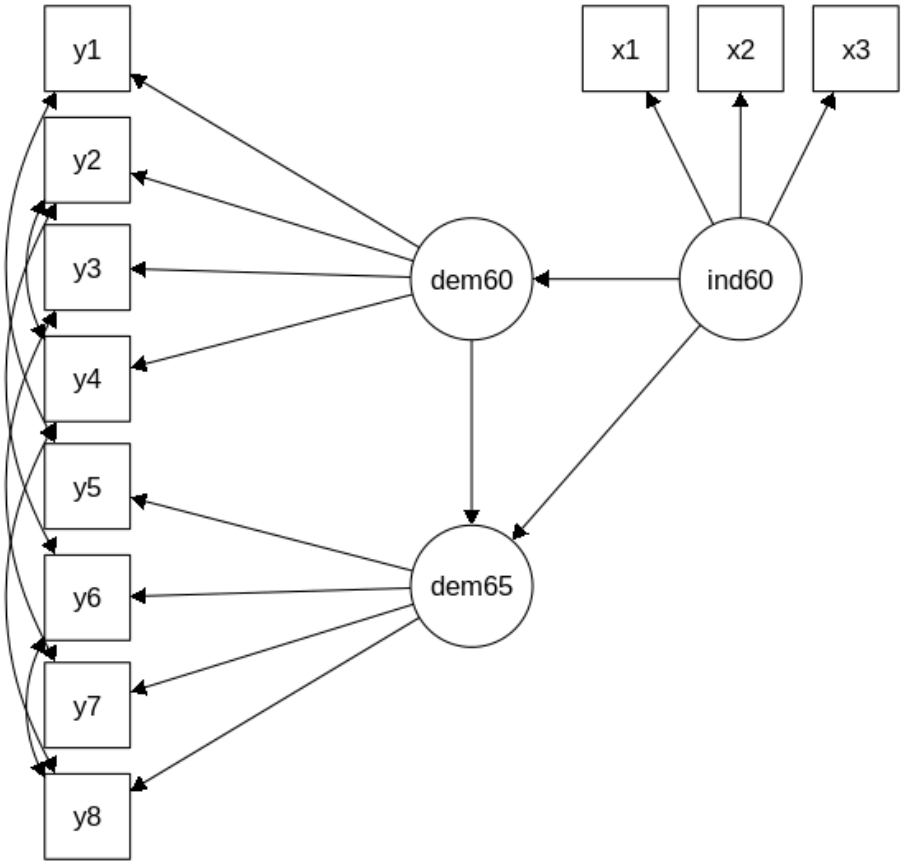

Figure 4-4. Structural equational model

Structural Equation Model (SEM) is a very general and commonly used linear statistical modeling technique [34]. It is a comprehensive statistical method for analyzing the relationship between variables based on the covariance matrix of variables. It is also called covariance structure analysis. It is widely used in the fields of psychology, economics, sociology, etc. It is currently one frontier research areas in multivariate statistical analysis. Some scholars have pointed out that the structural equation model is a composite in the process of economic measurement, social measurement and psychometric development [35]. It is the comprehensive application and improvement of statistical methods such as factor analysis, path analysis, multiple regression and analysis of variance. In

research fields such as psychology, sociology, and other related area, a number of variables such as satisfaction, motivation, ability, etc., cannot be directly and accurately measured, which need to be measured indirectly through some direct observation variables. Conventional statistical methods cannot process these latent variables, while the development of structural equation models make up for this vacancy can has become an important tool for multivariate statistical analysis.

A complete SEM model including measurement model and structural model. The former one describes the relationship between latent variables and observed variables, while the latter describes the relationship between the latent variables and the variance that cannot be explained by other variables in the model. SEM has several main concepts: 1. Observed variables, also known as dominant variables, index variables, can be obtained through directly observation or measurement. 2. Latent variables are variables that cannot be directly obtained through directly observation or measurement.

The fitness index of the structural equation model is an important indicator for evaluating whether the hypothesis model fits the actual data. According to the study of Hair, et al. [36], the fitness index is divided into three categories: absolute fitness index, incremental fit index, and parsimonious fit index.

Before testing the model fitness index, whether the model parameter have irregularity estimation should be checked. The main aspects are as follows: 1. whether there is a negative error variance; 2. whether the standardized parameter coefficient is greater than or equal to 1; 3. is there big standard error. It there is no violations, the following model fit index test can be performed.

The absolute fitness index mainly includes the chi-square value, the ratio of chi-square and degree of freedom, the adaptive fit index, the adjusted fit index, the residual mean square and square root, and the mean and square root of the progressive residual, which are used to determine the model. The degree of covariance matrix and correlation matrix can be predicted.

The incremental adaptation index mainly includes the comparative fit index (CFI), the normed fit index (NFI), the Tucker-Lewis index (TLI) and the incremental fit index (IFI), which are used to measure the fitness of hypothetical theoretical model and he baseline model.

The simple adaptation index mainly includes the parsimonious goodness fit index (PGFI) and the parsimonious normed fit index (PNFI) to evaluate the simplicity of the model.

The indicators and their evaluation criteria are shown in the table:

Table 4-1. Fitness index of structural equation model

Types of model fit index	Fit index	Adaptability standards or Critical value
Absolute fit index	χ^2	$p<0.05$
	χ^2/df	<3
	GFI	>0.9
	AGFI	>0.9
	RMR	<0.05
	RMEA	<0.08
Incremental fit index	CFI	>0.9
	NFI	>0.9
	TLI	>0.9
	IFI	>0.9
Parsimonious fit index	PGFI	>0.5
	PNFI	>0.5

The structural equation model has the following advantage:

1. Allow the existence of measurement errors within independent and dependent variables. Latent variables often contain unavoidable errors due to they are unable to be measured directly or cannot be measured with a single indicator. Regression analysis assumes that there is no error in the independent variable and only allows measurement errors in the dependent variable. The structural equation model allows both the independent variable and the dependent variable to contain measurement errors, and the latent variable can also be measured with multiple indicators, making the model fitting results more accurate.
2. It is able to handle multiple variables at the same time. In the conventional regression analysis and path analysis, the processing of multiple variables needs to be calculated one by one, so that when calculating a dependent variable, the existence and influence of other dependent variables are neglected, while the structural equation model can consider and process multiple variables simultaneously.
3. It is able to estimate the relationship between latent variables and observed variables, and the relationship between each latent variable. In order to measure a latent variable using conventional methods, firstly, it is necessary to conduct exploratory factor analysis to obtain the relationship between the latent variable and the observed variable, which is regarded as the observed value of the latent variable. Then the correlation coefficient is calculated using the observed value, which is the correlation coefficient between the latent variables. The above steps are independent of each other, and the calculation of a certain factor is not considered while the influence of other related factors is not considered. The structural equation model can make the above steps simultaneously, which is, considering the relationship between the latent variables and the measured indicators and the relationship between the various potential variables.

4. Traditional statistical modelling methods have many restrictions for the model setting. For example, an observed variable can only belong to one latent variable. The structural equation model has few limitations, and the SEM modelling and analysis is itself is a dynamic process. Each analysis is based on the original adjustment. Each analysis structure can be the basis for the next adjustment. In addition, the same observed variables can be subordinate to multiple latent variables.
5. It is possible to estimate the fitness of the entire model. The structural equation model is a combination of factor analysis and path analysis. Different models can be designed and fit from the same sample data. According to the fitting parameter values, it is determined which model can reflect the relationship between the sample data more accurately, and optimized fit model and more realistic model interpretation can be obtained.

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Chapter 5

BEIJING HOUSEHOLDS' WILLINGNESS TO PAY FOR URBAN HEAT ISLAND MITIGATION

Urban heat island effect has become a serious environmental problem posed to Beijing citizens. As important measures to alleviate the urban heat island effect, Beijing government plans to replace the conventional paving surface with permeable materials within 20% of the constructed area by 2020, and promote the construction of green roof and cool roof. In order to elicit policy implications, I applied the contingent valuation method to investigate the Beijing households' willingness to pay for the benefit of these three techniques in alleviating the heat island effect. We chose double-bounded discrete choice format with spike model to collect and process the research data for a considerable number of zero responses appeared during the interview. In addition, this research added covariance of attitude, perceived behavior control, and social norm, which is inspired by the theory of planned behavior, other than conventional ones. This research will also provided suggestions for encouraging public participation in heat island effects mitigation.

5.1 Willingness to pay for green roof

The Beijing government plans to promote the construction of urban green roofs of 100,000-120,000 m^2 per year from 2015 to 2020. Since there has been limited attention on the economic benefits of mitigating this phenomenon, this section empirically investigates the willingness of Beijing residents to pay for the benefits of green roofs in mitigating the urban heat island effects and their determinants.

5.1.1 Research background

The city of Beijing has experienced rapid expansion during the past few decades and is suffering from serious air pollution. The UHI effect is one of the best-known climate features caused by urbanization. A long term study from 1961 to 2014 indicated that the UHI effect is significant in Beijing. Its urban-to-rural temperature difference can reach as much as 8℃ in the winter at night [1], which has been regarded as one of the major environmental problems confronting the city's residents.

The UHI effect has been proven to impair the urban environment and human health in a number of ways [2]. The rise in temperature may increase the temperature of standing water and affect the diversity of life within. It may cause changes in patterns of wind and rain. Moreover, it has also been associated with urban haze. The UHI effect can be expected to decrease worker productivity in the city by as much as 10 % during the daytime [3]. It is also responsible for several mortalities, especially for the elderly [4]. In addition, the UHI raises energy consumption, which results in deteriorated air quality and increased greenhouse gas emissions [5, 6].

Among the methods proposed for alleviating UHI, expanding urban green space has proven to be very effective [7-9]. The evapotranspiration process of plants consumes solar energy and could cool

the surrounding environment through plant transpiration and evaporation from the soil surface beneath the plants [10]. The ability of green roofs to cool building surfaces has been reported in a large numbers of studies. The study of Karachaliou, et al. [11] reported that the surface temperature of a green roof is 15℃ lower than that of a conventional roof. The study of Bing [12] revealed that a green roof can reduce the urban surface temperature by 30-60℃. Sun, et al. [13] compared surface temperature reductions of green roofs in different regions; their results showed that hot and dry regions reported the maximum reduction. In addition, a number of urban heat studies within the Beijing context recommend the installation of green roofs [14, 15].

The Beijing government has undertaken the construction of a public green system, however, since most of the central area is occupied by various buildings, the strategy of creating an urban forest cannot be easily applied due to the high cost. One way to overcome this limitation is the “urban vertical greening project”, which entails transforming building roofs into green ones. The Beijing government started this project in 2011 and by 2017 one million m² more building roofs have been transformed (the total area of the green roof in Beijing has reached two million m²) [16]. By 2020, Beijing government is planning to construct additional 100,000-120,000 m² of green roofs annually [17].

The "urban vertical greening project” has expanded rapidly due to governmental policy. At the same time, policymakers need more information on the benefits of this project, if they are to decide whether to invest in it. The positive externalities of green roofs (mitigating UHI effect, purifying air, absorbing noise, etc.) cannot be assessed through market mechanisms. In addition, according to China’s Agenda 21 [18], the government is also willing to promote the public awareness and participation in sustainable development. However, due to the long-term governance characteristics of top-down governance, public participation in environmental protection has not been fully developed. Some studies have shown that people's awareness of the deterioration of the urban environment may offer a chance for public participation in environmental policy making [19]. Therefore, information on public valuation and acceptance of the green roof should be fully considered.

Willingness to pay (WTP) refers to the maximum willingness to give in exchange for a specific good or service, or avoid something undesirable. This paper focus on public WTP for green roof for its effect in UHI effect mitigation. It provides information about whether the public favors the benefits of green roof and the degree to which it will contribute to such a benefit. In order to get information about the external benefits of the urban green roof policy, we applied the contingent valuation method (CVM), which has been widely applied in evaluating the WTP and consumers’ valuation for the attributes of a specific object. The CVM belongs to the stated preference (SP), which involves the direct questioning of people to elicit their WTP for a particular good or a service that meets with their satisfaction. This method was initially applied in valuing the outdoor recreation

and cost-benefit analyses of public water infrastructures. Later, it was applied in areas such as water resources management, wetland restoration, oil spill assessment and health risk reduction. This approach has become the one of most commonly used approaches for estimating non-use value or non-market value.

The primary purposes of this part are to explore: 1) How much Beijing urban households in Beijing value the UHI mitigation of green roof systems in an urban context using the CVM? 2) What motivates Beijing residents to contribute to a green roof system? The remainder of the paper is as follows: Section two explains the methodology adopted in this study. Section three reports and discusses the result. The paper is concluded in section four.

5.1.2 Research method

1. Goods to be Valued

Facing the increasing demand for mitigating UHI effects, the Beijing Government plans to promote the urban vertical greening project, which involves installing 100,000-120,000 m^2 of urban green roofs annually by 2020. As of 2017, the total area of green roofs in Beijing is 2 million m^2. Goods to be valued in this paper are the mitigation of green roofs on Beijing's UHI (any other positive externalities should not be considered). The negative effects of UHI effect, the benefits of the urban green roof in reducing these effects, and a brief introduction of the urban vertical greening project of Beijing were presented to each respondent during the onsite interviews.

2. The Design of the Survey

We arranged the CVM field survey to run from June 2nd to June 21st of 2018. Residents in the city of Beijing were interviewed to obtain their households' WTP for the mitigating benefits of a green roof. Seventy-two residential blocks in Beijing were randomly chosen with the help of the Beijing Municipal Bureau of Statistics. In each block we selected 10 to 15 households from the household address notation. During the interview, only one member of the household, who had to be between 18 and 65, was selected as a decision maker and interviewed face-to-face. The length of each interview was between 10 and 20 minutes. Before the interview, we explained the purpose of the study and explained respondents' rights. Then the respondents were asked about whether they wished to participate in our survey. Those who questioned the reasonability of this survey and refused to continue were considered as protest responses and excluded. The final number of valid responses was 1040. Because the average socio-economic background of varies widely across different districts in Beijing (for example, the average income in Dongcheng district is almost twice than that of Yanqing), we conducted the sample according to population distribution to avoid representative bias (Table 5-1).

Table 5-1. Distribution of Beijing residents and questionnaire samples

(Source: Beijing Municipal Bureau of Statistic http://edu.bjstats.gov.cn)

District	Distribution of Beijing residents in 2017 (Unit: million people)	Distribution of questionnaire samples
Xicheng District	1.3 (6.0%)	67 (6.4%)
Dongcheng District	0.9 (4.2%)	43 (4.1%)
Shijingshan District	0.7 (3.0%)	32 (3.1%)
Haidian District	3.7 (17.0%)	217 (20.8%)
Chaoyang District	4.0 (18.2%)	181 (17.5%)
Fengtai District	2.3 (10.6%)	100 (9.7%)
Changping District	2.0 (9.4%)	92 (8.8%)
Pinggu District	0.4 (2.0%)	21 (2.0%)
Mentougou District	0.3 (1.5%)	14 (1.5%)
Shunyi District	1.0 (4.6%)	45 (4.3%)
Fangshan District	1.1 (4.7%)	44 (4.2%)
Daxing District	1.6 (7.1%)	69 (6.6%)
Tongzhou District	1.4 (6.3%)	60 (5.8%)
Yanqing District	0.3 (1.4%)	15 (1.4%)
Huairou District	0.4 (1.8%)	20 (1.9%)
Miyun District	0.5 (2.2%)	20 (1.9%)
Total	**21.7 (100.0%)**	**1040 (100.0%)**

We provided sufficient background information to our investigators and instructed them on how to answer all the possible questions that may be raised during the interview. In the onsite survey, there are five groups of investigators in total. Each group was composed of one interviewer and one supervisor [20]. To ensure reliable answers, only respondents between 18 and 70 years old were selected and interviewed in this survey.

The study consisted of five parts. In the first part, we introduced the purpose of the study and other related information. The second part dealt with the individual's motivations and behavior. The third part gathered socioeconomic information (income and employment). The forth part was about the respondents' demographic characteristics (age, gender, education, etc.). In the final part, the question was: "How much is your household willing to contribute for the green roof installation for in order to mitigate UHI effects in Beijing by increasing your personal income tax for the next 3 years, assuming that the project will definitely go ahead? Then, the determinants for WTP were estimated with the maximum likelihood estimation function with policy implications provided

(Figure 5-1).

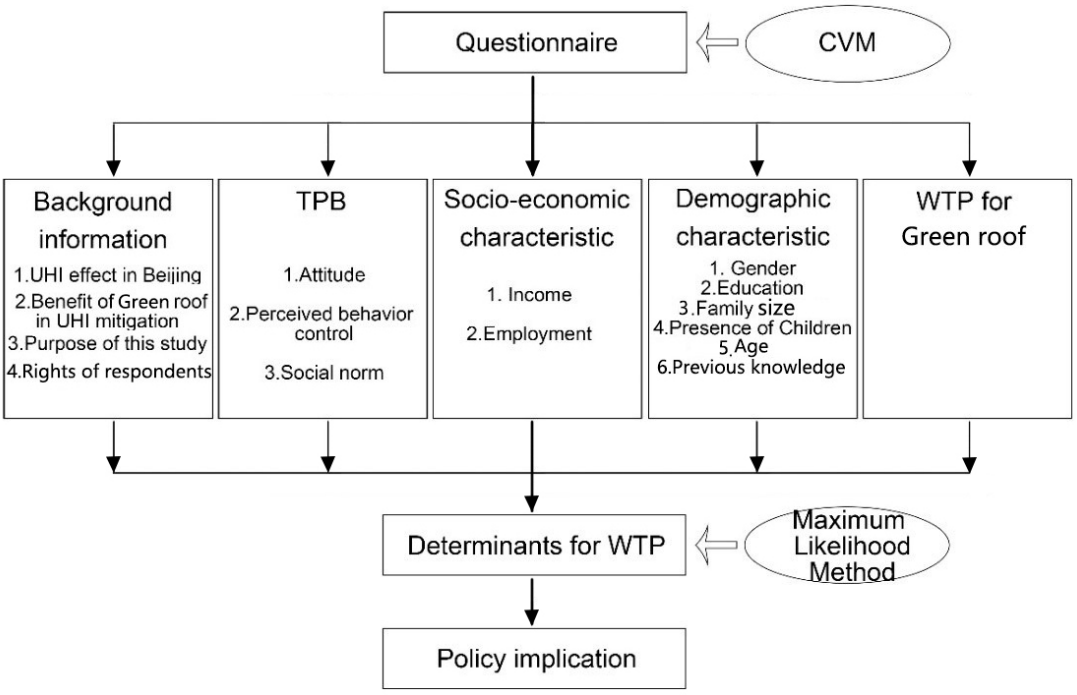

Figure 5-1. Research flow

We set up different bid combinations: (100/200/400), (400/800/1500), (800/1500/3000), and (1500/3000/5000) Chinese yuan (CHY). The middle figure in each three-number set is the initial bid, the third is the higher second bid when the individual responds with "yes" to the first bid, while the first figure is the lower bid when the responses is "no" to the first bid. The range of bids was pre-tested with an open-ended format before the main survey. We trimmed 10% off both tails of bid distribution, and then four bid combinations for the main survey were selected from the remaining distribution.

As for the frequency of payment and duration of payment, we chose the annual fee with reference to the relevant research [21]. The cut-off year of the vertical greening project is 2020, so the payment duration we chose was three years.

5.1.3 Result and discussion

1. Data

The demographic characteristic of samples are as follows:

Table 5-2. Gender of samples

	Number	Percent	Valid Percent	Cumulative percent
Male	525	50%	50%	50%
Female	515	50%	50%	100%

Table 5-3. Age of samples

	Number	Percent	Valid Percent	Cumulative percent
Older than 55	156	15.00%	15.00%	15.00%
In between 35-55	489	47.00%	47.00%	62.00%
Younger than 35	395	38.00%	38.00%	100.00%

Table 5-4. Education level of samples

	Number	Percent	Valid Percent	Cumulative percent
Master degree or higher	97	9.30%	9.30%	9.30%
Bachelor degree	298	28.70%	28.70%	38.00%
High school or vocational High School	541	52.00%	52.00%	90.00%
Middle school or lower	104	10.00%	10.00%	10.00%

Table 5-5. Family size of samples

	Number	Percent	Valid Percent	Cumulative percent
More than 4	182	17.50%	17.50%	17.50%
2-4	728	70.00%	70.00%	87.50%
1	130	12.50%	12.50%	100.00%

Table 5-6. Family size of samples

	Number	Percent	Valid Percent	Cumulative percent
More than 8000	137	13.20%	13.20%	13.20%
5000-8000	295	28.40%	28.40%	41.60%
3000-5000	348	33.40%	33.40%	75.00%
less than 3000	260	25.00%	25.00%	100.00%

Table 5-7 explains the distribution of WTP. A total of four bidding combinations were defined, which were (100/200/400), (400/800/1500), (800/1500/3000), CHY. (1 CHY=0.15 USD). The total investigation number is 1040, which is equally assigned with four bidding sets. The number and proportion of “yes-yes" responses fall roughly as each bid increases, which is accompanied by a rapid increase in the proportion of "no-no-no” responses. For example, for the (100/200/400)

bidding combination, the proportion of “yes-yes” responses accounted for 15%, while in the (1500/3000/5000) set he proportion dropped to 1%. At the same time, the "no-no-no" responses rose from 32% to 73%. Of all the samples in this study, zero-responses samples in this study accounted for 57%, which indicated the necessity to apply the spike model.

Table 5-7. Distribution of bids

Bid Amount	Sample Size	Yes-Yes	Yes-No	No-Yes	No-No-Yes	No-No-No
100/200/400	260	39(15%)	75(29%)	36(14%)	26(10%)	84(32%)
400/800/1500	260	13(5%)	36(14%)	37(14%)	26(10%)	148(57%)
800/1500/3000	260	7(3%)	14(5%)	31(12%)	34(13%)	174(67%)
1500/3000/5000	260	3(1%)	8(3%)	13(5%)	47(18%)	189(73%)
Total	**1040**	**62(6%)**	**133(13%)**	**117(11%)**	**133(13%)**	**595(57%)**

Table 5-8 shows the definitions and analyzes the sample variables. The Beijing Statistical Office only provides values of gender, family size, education level, and age. Within our samples, respondents were evenly distributed between males (49.6%) and females (50.4%). The 30-55 age group made up 37.4% of the sample, while and 33% and 29.6% of the respondents were, respectively, above 55 and below 30 years old. As for household size, two to four family members are the most common (61.7%), followed by more than four (21.8%) and only one (16.5%). Thirty-eight of respondents had attained reached college or higher-degree education level, which are closed to the official statistics.

Table 5-8. Definitions and sample statistics of the variables.

Variables	Mean	Dev	Census
Gender (male=1,female=0)	0.50	0.50	0.50
Education (college or higher=1,high school or lower=0)	0.38	0.49	0.36
Age (more than 55=3,30-55=2,<30=1)	1.77	0.99	1.84
Family size (more than 4=3,2-4=2,<2=1)	2.05	0.99	1.90
Income (less than 300=1,3000-8000=2,more than 8000=3)	1.88	0.79	-
Employment (have a job=1,don’t have a job=0)	0.63	0.49	-
Presence of Children (have a child younger than 12=1,don’t have a child younger than 12=0)	0.51	0.50	-
Attitude (Regarding urban environment as important=1,Regarding urban environment as not important=0)	0.49	0.50	

Social norm (Family or friends won't support respondents' pro-environment behavior=0,Family or friends will support respondents' pro-environment behavior=1)	0.42	0.49
Knowledge (Know well about the effect of green roof in mitigating UHI effects=1, Don't know about the effect of green roof in mitigating UHI effects=0)	0.19	0.39
Perceived behavioral control (Considering improving urban environment as not difficult=1,Consider improving urban environment as difficult=0)	0.14	0.34

2. Descriptive Analysis

In terms of the individual option for mitigating UHI effects, 89% of the respondents reported their preference option. "Support the UHI mitigation project financially" was the option that most respondents preferred, accounting for 49% of the answers. About 20% of the respondents opted for participating in activities that alleviate UHI effects. In addition, 18% of respondents said they would promote knowledge about the UHI effect, while 13% said they would not do anything. The public willingness to participate in mitigating UHI effects is great (Figure 5-2).

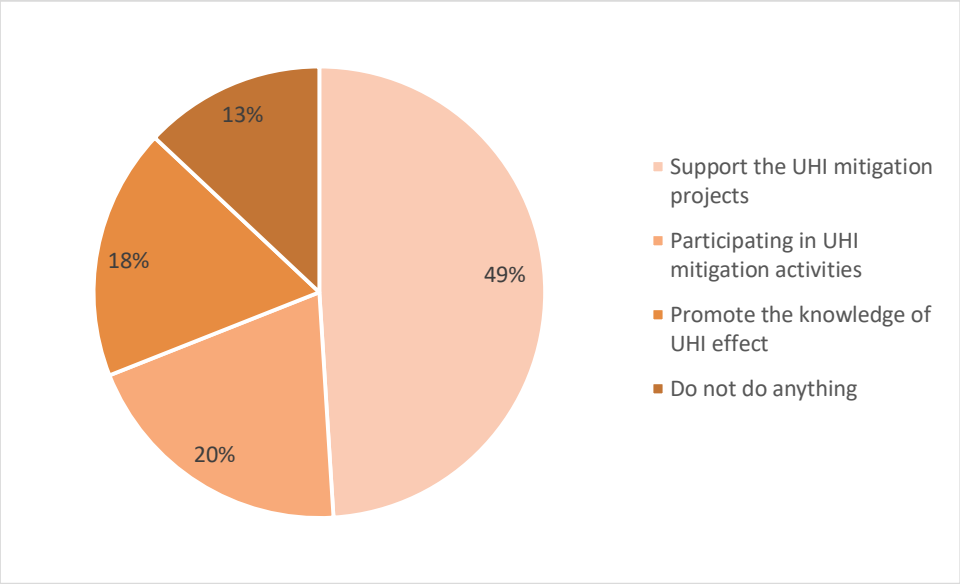

Figure 5-2. Respondents' preferred option in participating in UHI mitigation.

We also investigated suggestions for enhancing participation in mitigating UHI effects. "Full disclosure of environmental monitoring information", and "Disclosure of environmental protection funds" accounted for 88% of the responses, reflecting the public's strong desire for information transparency. "Establishing a reward mechanism for pollution reporting with strong legal protection" accounted for 5% of the responses, and 3% of the respondents preferred legal services to provide

environmental protection (Figure 5-3).

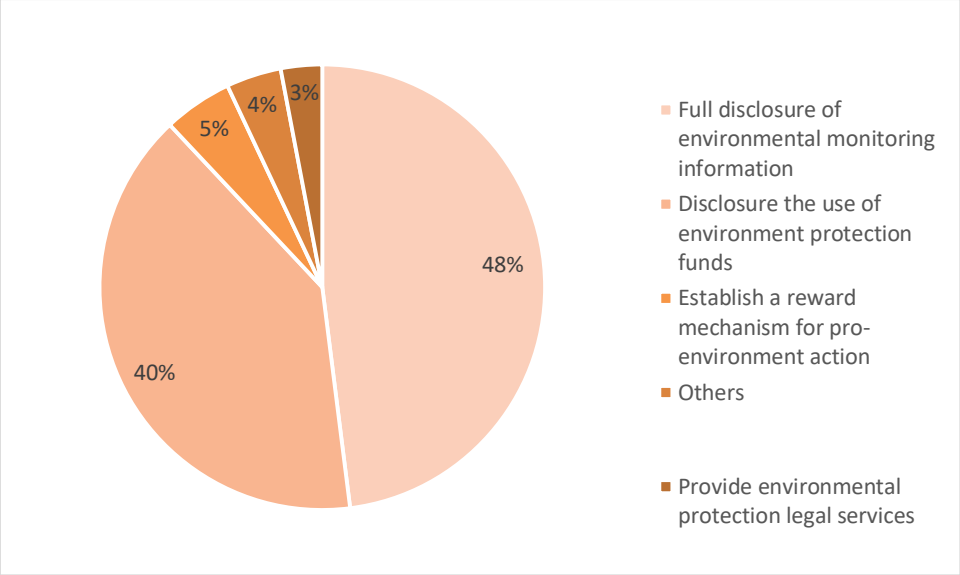

Figure 5-3. Suggestions for increasing residents' participation in UHI effect mitigation.

As for the motivations for 595 samples of "no-no-no" responses, over half of the respondents chose "It is government's responsible to manage the urban environment" and "distrust the use of the fund", which is 24% (143 samples) and 27% (161 samples), respectively. These 304 samples were considered as "protest responses" samples and were excluded when processing the data. Other than that, "unable to bear the cost currently" accounts for 42%. 21 respondents (4%) refuse to pay for other reasons and 20 (3%) respondents value the benefit of the green roof in mitigating UHI effect as zero (Figure 5-4).

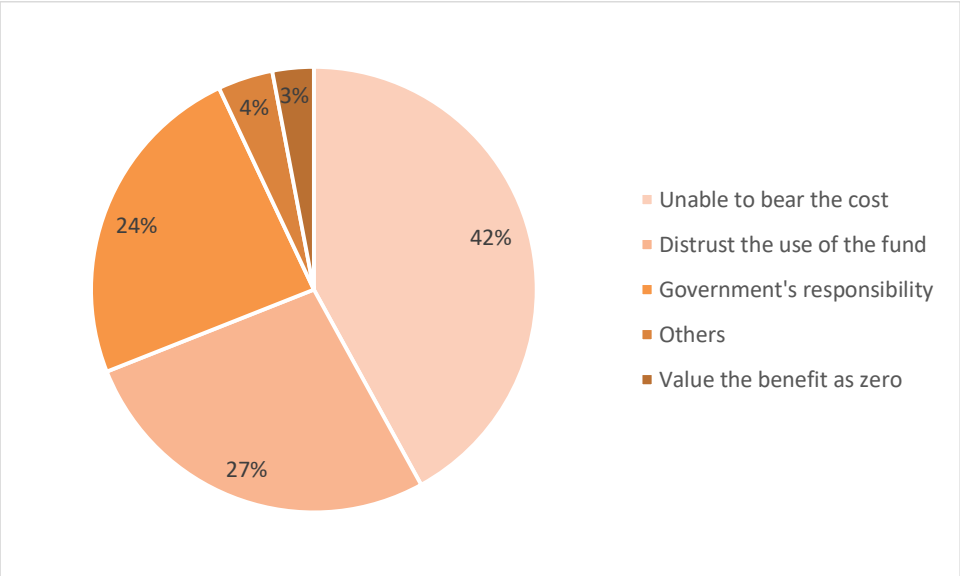

Figure 5-4. Motivation for zero responses

3. Estimation Result of the Model

Table 5-9 explains the estimation result. The parameter can be estimated with the maximum likelihood estimation function. The second column in the table provided the estimation results without covariates. The coefficient of the bid value is statistically significant (at the 1% level). This means a larger bid decreases the likelihood of a "yes" response, as expected. The third column displays estimations results with covariates and variables that may affect the likelihood of a "yes" response. Among the estimated coefficients, attitude and social norms have a statistical significance at the 10% level. Perceived behavioral control, education and income are statistically significant at the 5% level. This indicates respondents who believe that they have enough time and resources to participate in pro-environment activities, and who have a higher income and better education, are more willing to contribute for this project. At the same time, attitudes towards urban environmental issues and the social norms of environment protection also affect residents' WTP to some extent. In particular, the estimate for the spike is 0.56 (model without covariates) and 0.57 (model with covariates), which is similar to the proportion of zero response provided in Table 2. The average willingness to pay is 148.58 CHY (estimation without covariance) and 146.39 CHY (estimation with covariance) per household per year.

Table 5-9. Estimation results of the model.

Variable	Model without covariates	Model with covariates
Constant	-0.08 (-0.99)	-1.36 (-3.20)***
Bid	-0.49 (12.19)***	-0.52 (13.54)***
Gender		-0.06 (-0.21)
Income		0.13 (2.01)**
Education		0.87 (2.01)**
Age		0.17 (0.17)
Family size		-0.07 (-0.41)
Employment		0.15 (0.03)
Presence of children		0.31 (0.41)
Attitude		0.42 (1.67)*
Knowledge		0.15 (0.38)
Social norm		1.32 (1.89)*
Perceived behavioral control		0.28 (2.05)**
Spike	0.56 (22.57)***	0.57 (21.27)***
Mean WTP	148.58 CHY	146.39 CHY
log-likelihood	-1011.48	-992.98
Wald statistic (p-value)	593.70 (0.00)	519.88 (0.00)

Notes: the t-values, computed from the analytic second derivatives of the log- likelihood function, are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The null hypothesis is that all the parameters are jointly zero, and the corresponding p-value is reported in parentheses after the statistic.

4. Further discussion

Green roof provide a variety of benefits and this research focus only on the UHI mitigation. During the interview, all of the respondents were reminded that the good to be valued was the effect of UHI mitigation of green roof while other positive externalities should not be considered. A considerable number of pervious WTP research with regard to urban green space also reported only capturing a partial value of the urban green space. Jim and Chen [22] used CVM approach to evaluate the amenity value of urban parks and garden in Zhuhai, China. Chen and Jim [23] examined the Atlanta households' WTP for urban forests to mitigate climate change. Tran, et al. [24] assessed the economic value on the heat island-mitigating function of urban forest using choice experiment method. The implication of these studies is that individuals are able to separate different values from the urban green space consciously and state them in a hypothetical context, which is criticized by the related psychological literature [25]. However, to the best of our knowledge, comprehensive discussion about the validity of "value decomposition" in CVM studies is still limited, which may become one research direction in the future.

Non-market valuation is an approach that assigning the value to environmental goods and services, which cannot be easily traded in the market. In our case, it is the benefit of mitigating UHI effect with green roof. The CVM, which is the most widely used approach for estimating non-market, has long been criticized as methodologically flawed. One of the key issues is the existence of "protest response", which means respondents refuse to pay for protesting some aspect of the valuation process instead of valuing the environmental goods and services as zero [26]. Censoring and excluding protest response samples are a commonly shared method to avoid concept inconsistence and underestimation of WTP value. In our research, respondents who protest the valuation process, the payment vehicle, or who distrust the government and believe that paying for environmental quality is not the responsibility of citizens were considered as "protest responses" and was excluded from further analysis.

To avoid the influence of the setting of covariates to the average WTP, we used the average WTP obtained from the formula without covariates. According to the official statistics, there are all together 5.38 million households in Beijing. The present value of the total annual public WTP amounts to 799 million CHY (120.3 million USD). The construction cost of the green roof in Beijing is about 310-550 CHY per square meter, so the annual investment in constructing 100,000-120,000 m^2 of new roofs and the maintenance of the existing ones before 2020 will be in between 48.5 and 94.8 million CHY, (7.30 million-14.28 million USD). The economic benefits of this policy would be between 704.2 million and 750.5 million CHY (106.1-113.0 million USD). These numbers could be useful for evaluating public acceptance and planning for the urban vertical greening project.

Over the past few decades, environmental policy makers have been increasingly concerned about personal responsibility for environmental issues. Individuals have been increasingly regarded as consumers of environmental resources, and individual behaviors have received more and more attention [27]. Our study indicates that the theory of reasoned action [28] or its expansion, the theory of planned behavior [29] can greatly explain the respondents' pro-environmental behavior. In our study, positive attitudes do significantly influence people's pro-environmental behavior. Respondents' attitudes towards the urban environment and the social norms of environment protection are statistically significant at the 10% level, while people's perceived difficulty is statistically significant at 5% level. Our study indicates that this theory predicts respondents' pro-environment behavior quite well. In the future research, TPB theory can help subsequent researchers explore the theoretical framework for understanding the influencing factors of WTP.

5.1.4 Conclusions

The rapid urban development of the past 20 years has imposed a great environmental burden on Beijing. The municipal government is working hard to improve the urban environment, and mitigating the UHI effect is an important part of this work. Because vacant land is scarce in urban areas, Beijing launched the urban vertical greening project in 2011. By 2017, the total area of green roof in Beijing has reached two million m². From 2017 to 2020, Beijing plans to transform 100,000-120,000 more square meters of building roofs into green ones.

This paper conducted on site interviews of 1040 residents in Beijing on June 2018, in order to their households' WTP for the green roof construction and maintenance in the next three years for mitigating UHI effects. The study adopted a double-bounded dichotomous choice format to obtain their WTP. In order to deal with a large number of zero-responses in the study, we used the DBDC with the spike model. Moreover, we estimated coefficients that may influence the mean WTP.

The overall results indicate that DBDC with the spike model can fit our data well. We can confidently state that in future research, DBDC with the spike model could be a promising WTP elicitation technique in the acquisition of public WTP for a proposed project. The mean WTP for mitigating UHI effects in Beijing is 148.582 CHY (22.4 USD) per household per year while the total WTP is 799 million CHY (120.3 million USD). Taking into account the total costs, this project is economically feasible. In the analysis of the influencing factors of WTP, in addition to conventional factors such as income and education level, our findings support the TPB's assertion that personal attitudes, perceived behavioral control, and social norms can greatly determine people's pro-environmental behavior.

5.2 Willingness to pay for permeable pavement

As an important measure to alleviate the urban heat island effect, Beijing government plans to

replace the conventional paving surface with permeable materials within 20% of the constructed area by 2020. In order to elicit policy implications, this section applied the contingent valuation method to investigate the Beijing households' willingness to pay for the benefit of the permeable pavement in alleviating the heat island effect.

5.2.1 Research background

Pavement contributes highly to the development of UHI effect for it covers quite high percentage of the urban fabric [30]. Decrease of the heat released by pavements in the atmosphere requires a decrease of its surface temperature. Enhancing the evaporation process of pavements by increasing its permeability is one possible strategy. The permeable pavement includes permeable concrete, permeable bricks, and permeable asphalt. Compared with normal concrete and asphalt, the permeable pavement contains more holes, which allows water to flow to the subgrade through the surface with some of them retained. The retained water can be used to relieve the UHI effect by evaporation during the hot summer season. Permeable pavement has been widely used as a very effective technical approach against the UHI effect and has been considered as an essential part of urban planning measures to reduce the UHI effect [31].

A large number of studies have confirmed that the permeable pavement can effectively reduce the local temperature. The study of [32] indicated that the surface temperature of permeable pavement was 4K lower than that of the conventional one. A comparison of surface temperature between permeable pavement and asphalt pavement by Jiang, et al. [33] and Asaeda and Ca [34] reported that permeable pavement presented a lower temperature. The study of Satoshi, et al. [35] experimentally tested and reported the thermal performance of permeable pavement. It was found that the temperature of permeable pavement is almost 4.1 K lower than the corresponding conventional pavement. Wang, et al. [36] examined the impact of evaporative cooling of sintered ceramic porous brick. The result indicated that the wet-bulb globe temperature above the pavement were decreased by up to 2℃.

The past three decades have witnessed Beijing's rapid urbanization. Now Beijing is facing serious urban climate issues such as UHI effect. A long-term measured weather dataset from 1961 to 2014 in Beijing by [1] has indicated that the UHI effect in Beijing is significant, with an urban-to-rural temperature difference of up to 8°C during the winter nighttime. The UHI effect has become one of the major urban environmental issues posed to Beijing citizens.

In 2012, the central government of China has launched a nationwide initiative called "sponge cities". The sponge cities project aims to make full use of green space, pavement, and river system to absorb, maintain, and release water, which is expected to reduce urban flood, mitigate the UHI effect, and protect the urban eco system. In 2015 and 2016, 30 cities were selected and financially supported by the central government for the sponge cities construction and Beijing was one of them Finance

[37], [38]. In 2017, The Beijing Government released the official opinion on the implementation of sponge city construction [39], including replacing the conventional paving surface with permeable materials within 20% of the constructed area by 2020. One of the main purposes of this project is decreasing urban surface temperate and improving urban thermal condition.

Compared with conventional paving, the cost of permeable pavement is much higher. The high cost of permeable transformation of urban pavements in Beijing will inevitably increase the finical burden of urban residents. Policy makers need to understand the economic benefits of the project, with which they can evaluate the effectiveness of the investment. In addition, according to China [18], public participation in sustainable development is highly encouraged. However, individual awareness and responsibility of participating in environmental issues has not been fully developed. In addition, due to the long-term information asymmetry, and the growing number of government corruption cases in China, the local government's transparency in managing public fund is questioned. Some studies have shown that public attention to the urban environment deterioration in recent years may become a chance for arousing public participation in environment issues [19]. The residents' appreciation of the benefit of permeable pavement in UHI effect mitigation, should be given full attention.

The positive externalities of permeable pavement such as mitigating the UHI effect cannot be evaluated through market mechanisms. In order to provide price information with regard to the value of permeable pavement in mitigating the UHI effect, we employed the contingent valuation method (CVM) to evaluate the residents' willingness to pay (WTP). WTP refers to the maximum amount of a respondent will pay to receive a good or service, or avoid a specific negative effect or loss. In our study, the WTP can be considered as the benefit of permeable pavement in alleviating the UHI effect of Beijing. The CVM belongs to a wider family of stated preference (SP), which implicates eliciting respondents' WTP for specific goods or services by directing questioning, which has become the most widely used approach for non-market or non-use value evaluation.

To fill the gap of the previous studies, this study first examines the public WTP for the benefit of permeable pavement for UHI effect mitigation in Beijing. For the zero-responses often appear in CVM studies as the consumers' utility-maximization's corner solution, which is due to goods or service to be valued does not add to the individual's utility, we applied the spike model which is suggested by Kristrom [40] to deal with the problem. As for the determinants of WTP, we added and examined determinants other than conventional factors, which is inspire by the related behavior science research.

Our work will extend the exiting studies in three ways: 1. Residents' WTP for environmental goods will change with numbers of factors, such as income and education level. This study was conducted

in 2018 and provides the latest information, thereby giving policymakers a better understanding of the residents' opinion. 2. In the past CVM research there are often a large number of zero responses, and ignoring these samples will bring representative bias. This study employed the spike model to process these zero responses, which may become a reference for the future studies. 3. Third, we explored factors that may contribute to individual participation in UHI effect mitigation. We collected information about suggestions for promoting public participation and explored variables of people's WTP for UHI effect mitigation.

5.2.2 Research method

1. Sampling and survey instrument

In this study, we sought to obtain a higher response rate and present a large amount of background information on the meaning of this research, so we applied face-to-face interviews to collect the data.

Before the onsite interviews, we conducted special training for all the interviewers, giving them sufficient background information, instructing them on how to respond to the possible questions, and explaining the meaning of this CVM research to them. To ensure the reliability of the interview, we only interviewed respondents aged 18 - 65 years. The interviewers who participated in the interview were divided into five groups, each of which consisted of one interviewer and one supervisor to avoid the interviewer bias [20].

A pilot study was conducted on May to collect information such as the acceptance of payment vehicle and people's attitude about promoting cool pavement transformation. The main survey period began on August 2nd, 2018 and lasted for 23 days. Households in Beijing were investigated to get their WTP for permeable pavement in dealing with UHI effect. During the onsite interview, only one of the household member was selected as decision makers (usually the head of the household). We conducted most of the interview at weekend for more family members would be at home. The length of each interview was in between 10 to 20 minutes. A total of 1,000 interviews were conducted. After we introduced the meaning and purpose of the research, the respondents who questioned about the research method or research purpose were considered to be protest responses. 151 protest responses were excluded from the research. The socio-economic characteristics of respondents from different districts of Beijing is inconsistent, for example, the residents' monthly income in urban central districts is almost twice than of some rural districts. In order to avoid representative bias, we conducted the sampling according to the distribution of population. Of the final 849 valid questionnaires, 179 were from the Chaoyang District, 183 from the Haidian District, and 131 from the Fengtai District, 44 From the Xicheng District, 58 were from the Dongcheng

District, 51 were from the Shijingshan District, and 203 were from the remaining suburban areas, which is in line with the distribution of residents in Beijing.

Table 5-10. Distribution of Beijing residents and questionnaire samples

(Source: Beijing Municipal Bureau of Statistic http://edu.bjstats.gov.cn)

District	Distribution of Beijing residents in 2017 (Unit: million people)	Distribution of questionnaire samples
Xicheng District	1.3 (6.0%)	44 (5.2%)
Dongcheng District	0.9 (4.2%)	58 (6.8%)
Shijingshan District	0.7 (3.0%)	32 (6.0%)
Haidian District	3.7 (17.0%)	183 (21.6%)
Chaoyang District	4.0 (18.2%)	179 (21.0%)
Fengtai District	2.3 (10.6%)	131 (15.4%)
Changping District	2.0 (9.4%)	50 (5.8%)
Pinggu District	0.4 (2.0%)	14 (1.5%)
Mentougou District	0.3 (1.5%)	9 (1.0%)
Shunyi District	1.0 (4.6%)	21 (2.3%)
Fangshan District	1.1 (4.7%)	21 (2.2%)
Daxing District	1.6 (7.1%)	33 (3.6%)
Tongzhou District	1.4 (6.3%)	39 (4.3%)
Yanqing District	0.3 (1.4%)	10 (0.9%)
Huairou District	0.4 (1.8%)	11 (1.0%)
Miyun District	0.5 (2.2%)	14 (1.4%)
Total	**21.7 (100.0%)**	**849 (100.0%)**

The composition of questionnaire was as follows: The first part was the introduction section, the study purpose, the rights and welfare of respondents, hazards of the UHI effect, the effect of

permeable pavement in mitigating the UHI effect, and related policy of promoting the installation of permeable pavement in Beijing were explained to the respondents. After that, in order to reduce hypothetical bias, those who accepted the interview were asked to swear on their honor to give honest answers [41]. The second part contained the individual's motivation and behavior. The third part comprised the respondents' source of knowledge about UHI effect, suggestions for public participation in UHI effect mitigation, and preferred role in participating in UHI effect mitigation. The forth part contained questions relating to the respondents' socio-economic characteristics (income, employment), the fifth part related to respondents' demographic characteristic (gender, education, residential area, family member, presence of children, and health condition). The WTP question was as follows: Beijing government is planning to replacing the conventional paving surface with permeable materials within 20% of the constructed area by 2020, how much will your household contribute annually for the permeable pavement for alleviating the UHI effect in Beijing within the next 3 years by raising the personal income tax, supposing that the project will be accomplished? Then, we applied the maximum likelihood estimation function to estimate the determinants for WTP and provided policy implications (Figure 5-5).

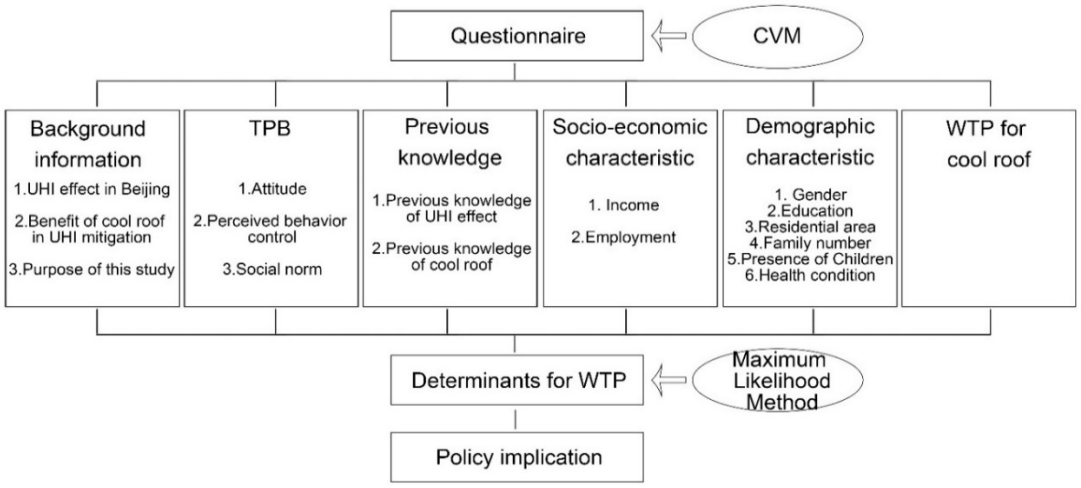

Figure 5-5. Research flow.

We have set four bid combinations (100/200/400, 400/800/1500, 800/1500/3000, and 1500/3000/5000), which were decided from pre-test outcome. The median value in each set is the initial bid. If the initial bid was refused, the lower bid on the left was presented to the respondent; otherwise, the higher bid on the right was made.

5.2.3 Result and discussion

1. Data

The demographic characteristic of samples are as follows:

Table 5-11. Gender of samples

	Number	Percent	Valid Percent	Cumulative percent
Male	427	50%	50%	50%
Female	422	50%	50%	100%

Table 5-12. Age of samples

	Number	Percent	Valid Percent	Cumulative percent
Older than 55	96	11.30%	11.30%	11.30%
In between 35-55	493	58.10%	58.10%	69.40%
Younger than 35	260	30.60%	30.60%	100.00%

Table 5-13. Education level of samples

	Number	Percent	Valid Percent	Cumulative percent
master degree or higher	130	15.30%	15.30%	15.30%
Bachelor degree	286	33.70%	33.70%	49.00%
High school or vocational High School	357	42.00%	42.00%	91.00%
	Number	Percent	Valid Percent	Cumulative percent

Table 5-14. Family size of samples

	Number	Percent	Valid Percent	Cumulative percent
4 or more	315	37.10%	37.10%	37.10%
2-3	338	39.80%	39.80%	76.90%
1	196	23.10%	23.10%	100.00%

Table 5-15. Family size of samples

	Number	percent	Valid Percent	Cumulative percent
More than 8000	163	19.20%	19.20%	19.20%
4000-8000	431	50.80%	50.80%	70.00%
3000-4000	110	12.90%	12.90%	82.90%
less than 3000	145	17.10%	17.10%	100.00%

Table 5-11 shows the distribution of WTP value. We defined four bidding combinations, namely 400/200/100, 1500/800/400, 3000/1500/800, 5000/3000/1500 CHY. The internal consistency was checked with no items missing. The total investigation number was 849, which was assigned equally with four bidding sets. From Table 1, we can find that the proportion of "YY" responses declined significantly with the value of the given bid increases. There were 25% (210) respondents who refused to pay for the permeable pavement, which indicated the need for applying the spike model for dealing with zero-response samples.

Table 5-16. Distribution of bids

	YY	YN	NY	NNY	NNN	SUM
400/200/100	87(41%)	45(21%)	19(9%）	19(9%)	42(20%)	212(100%)
1500/800/400	62(28%)	46(22%)	27(13%)	42(20%)	36(17%)	213(100%)
3000/1500/800	51(24%)	41(19%)	19(9%)	38(18%)	64(30%)	213(100%)
5000/3000/1500	42(25%)	39(18%)	19(9%)	43(20%)	68(32%)	211(100%)
sum	242(28%)	171(20%)	84(10%)	142(17%)	210(25%)	849(100%)

The definitions, mean values, and standard deviations of variables are included in Table 5-12. Of all the variables, gender, age, family size, residential area and education level were all available from the Beijing Statistical Office. The variables of gender, age, residential area, and family size were closed to the official data of the whole population, while the gap between the education level of our samples and official data was comparatively big. The possible reason is that the most people who refused to be interviewed had low education level. However，no evidence has indicated that educational level is significantly related with WTP. For the socioeconomic factors of the

respondents were not significantly different from the general except for education, we consider that our sample is suitable for estimating WTP of the whole population.

Table 5-17. Definition and sample statistics of the variables

Variable	Mean	Dev	Census
Gender (Male=1,female=0)	0.50	0.50	0.50
Education (College degree or higher =1,Others=0)	0.49	0.50	0.36
Age (Older than 55=3,30-55=2, younger than30=1)	1.79	0.99	1.84
Family size (More than 3 members=1, others=0)	0.37	0.48	0.31
Residence (Living in urban central area =1, Living in urban suburban area = 0)	0.60	0.49	0.59
Income (More than 4000=1,less than 4000=0)	0.70	0.46	
Job (Have a job=1, others=0)	0.75	0.44	
Children (Raise a child younger than 12=1, others=0)	0.48	0.50	
Attitude (Regarding urban environment protection as important=1, others=0)	0.82	0.38	
Social norm (Family, friends or colleagues would support your pro-environment behavior=1,others=0)	0.82	0.38	
Energy cost (Annual family energy cost larger than 3000 CHY =1, others =0)	0.60	0.49	

2. Descriptive analysis

As for the individual participation option for UHI effect mitigation, a total number of 798 respondents (94% of the samples) reported their preference for participating in the UHI effect mitigation. Most respondents preferred the option “Support the UHI mitigation project finically”, accounting for 65% of the response. 19% of the respondents chose participating in UHI effect mitigation activities. Moreover, 13% of respondents reported that they would popularize knowledge with regard to the UHI effect， while 6% respondents would not do anything. (Figure 5-6).

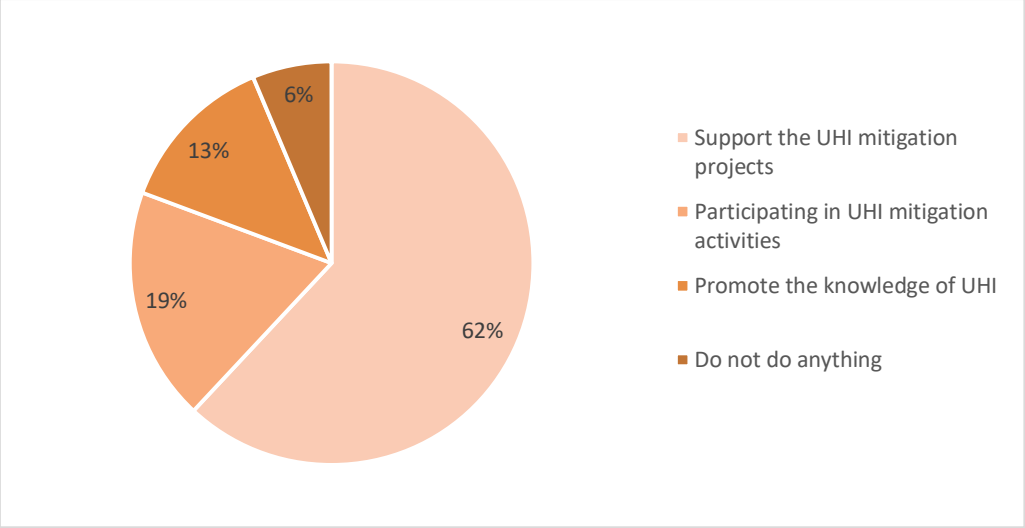

Figure 5-6. Residents preferred option of participating in UHI mitigation.

Although the concept of UHI effect has been discussed for a long time in the academic field, it is still relatively new to the public, especially in developed context like China. Therefore, it is important to understand how the public get knowledge about the UHI effect. The interview results showed that about 39% of the respondents have never heard of the UHI effect, which may partially because the UHI effect is relatively difficult to be recognized comparing with other urban environmental problems (sandstorms, haze, flood, etc.), thus unlikely to raise public awareness. Online inquiry was the main channel by which to learn about the UHI effect, with 22% of the respondents selected that option. In addition, 17% of the respondents got information from the other people (family, friends, teachers, community members, etc.). Television and others ranked forth (17%) and fifth (9%), respectively. The promotion of knowledge with regard to UHI effects needs to be strengthened, and various information dissemination programs are needed to improve citizens' understanding of UHI effect (Figure 5-7).

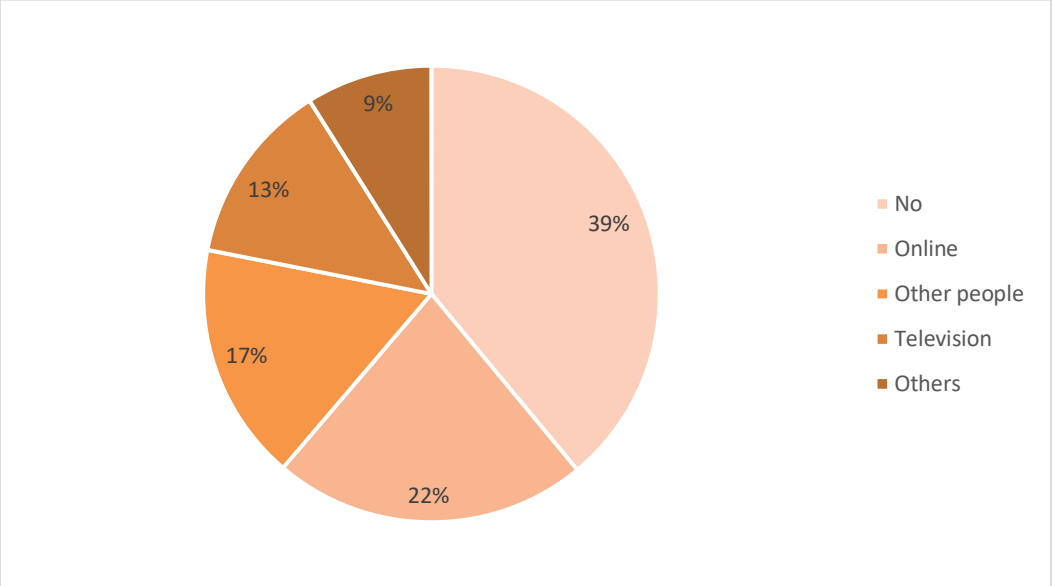

Figure 5-7. Public information sources of the UHI effect

We also investigated the public suggestions for the government in increasing public participation in UHI effect mitigation. "Environmental protection funds disclosure" and "Environmental monitoring information disclosure" accounted for 91% of the total responses, which indicates that public willing to have information transparency is strong. 6% of the responses opted for "Establishing a reward mechanism", and 1% of the respondents chose receiving legal services about environmental protection (Figure 5-8).

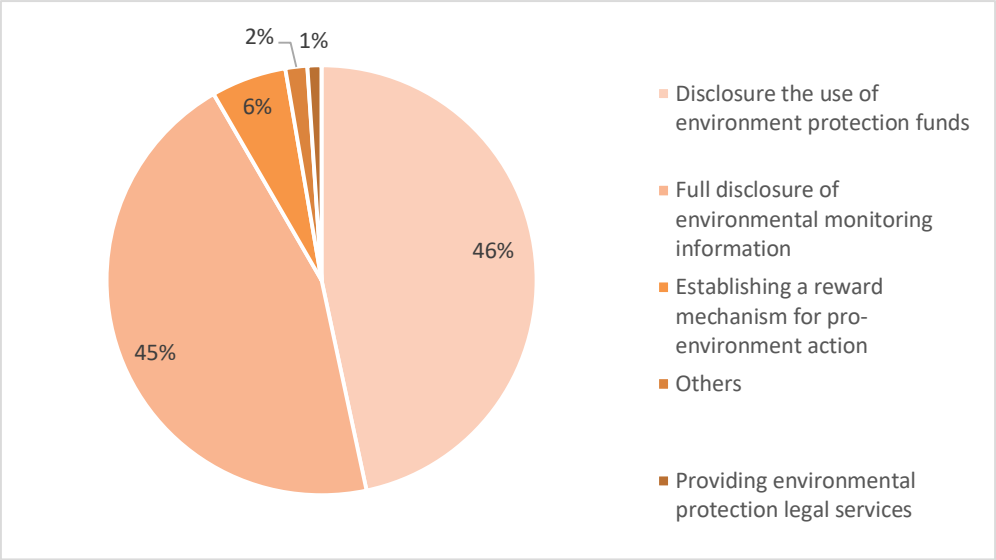

Figure 5-8. Suggestions for promoting public participation in mitigating UHI effects.

3. Estimation results

Table 5-18 gives the estimation result with and without covariance. The parameter can be estimated by applying the maximum likelihood estimation function. Table three describes the estimation result without covariance. The coefficient of the spike is 0.2510, which is closed to the proportion of zero responses (25%). The Wald statistic showed that the hypothesis that the estimated question is insignificant can be rejected.

The mean annual WTP was calculated to be 1640.2040 CHY (239.7110 US dollars [USD]) per household (1 USD=6.85 CHY). The t value was 27.781, indicating that the result was statistically significant at the 1% level. The confidence intervals of this value are also reported in Table 3. These are estimated using Krisky and Robb's approach [42].

We also estimated the model, including covariates. A total of 14 variables are included. Within all the coefficients, "income", "residential area", "education" are statistically significant at 5% level, while "age", "presence of children", "previous knowledge", "perceived behavior control", and "social norm" are statistically significant at 1% level. This implies that people who have higher income, live in rural area, know about the UHI effect, believe he/she has enough resources in protecting the urban environment, have the pro-environment social norm, and are raising children currently are more likely to response "yes" to a given bid. The result that "knowledge" and "social norm" are positively related with WTP indicates the necessary of promoting pro-environment education and publicity. The coefficient "education" is negatively related with the likelihood of

accepting a given bid, which indicates that people with higher education level are more likely to reject an amount for promoting cool pavement in mitigating UHI effect, which is not expected.

Table 5-18. Estimation results of the model.

Variable	Model without covariates	Model with covariates
Constant	0.890(14.293)***	-1.508 (-3.764)***
Bid	0.001(104.321)***	-0.001 (304.907)***
Gender		0.035(0.233)
Residence		-0.316 (-2.009)**
Income		0.404 (2.093)**
Education		-0.477 (-2.292)**
Healthy		0.299 (1.349)
Job		-0.271 (-1.373)
Age		0.691 (3.654)***
Energy cost		0.025 (0.167)
Family size		-0.098 (-0.615)
Presence of children		0.834 (4.495)***
Attitude		0.153 (0.775)
Knowledge		0.150 (0.380)
Social norm		1.320 (1.890)*
Perceived behavioral control		1.363 (9.288)***
Spike	0.251 (22.635)***	0.271 (24.950)***
95% confidence interval	1527.039-1753.260	1369.723-1561.504
99% confidence interval	1493.320-1788.246	1342.921-1590.182
log-likelihood	-1472.300	-1390.380
Wald statistic (p-value)	41827.280 (0.000)	93084.59 (0.000)

Notes: the t-values, computed from the analytic second derivatives of the log- likelihood function, are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The null hypothesis is that all the parameters are jointly zero, and the corresponding p-value is reported in parentheses after the statistic.

4. Discussion of the results

We used the mean WTP estimated with no covariates to calculate the total WTP since the covariates setting may influence the mean WTP value. The mean WTP is 1640.204 CHY (239.711 USD) per year. According to the official data of the Beijing government, there are 5.38 million households in Beijing by 2018, if we expand the mean WTP to the entire city. The total annual number of Beijing

households' WTP for the permeable pavement amounts to 8.8232 billion CHY (1.288 billion USD). The annual economic benefits with 95% and 99% WTP intervals are 8.2154 -9.4325 billion CHY (1.119 - 1.377 billion USD) and 8.0341-9.6208 billion CHY (1.173 - 1.405 billion USD), respectively. There is a considerable amount of WTP among the residents of Beijing. We can judge that Beijing residents are ready to bear a share of the financial burden for improving air quality.

Individual awareness and responsibility in participating in environmental issues has not be fully developed. This paper explored information that may contribute to public participation in mitigating UHI effect. We collected information about what the government should do to promote public participation from the viewpoint of the public. The results indicated that environmental information disclosure is urgently needed, nearly 40% of respondents didn't know anything about the UHI effect, and there is great willingness to participating in pro-environment activities. Form the government's perspective, we explored determinants that motivated individuals' WTP. For the determinants of WTP, we added and tested the covariates of attitude, perceived behavior control, and social norms other than conventional ones, as inspired by the TPB. It was found that social norms were statistically significant at the 1% level. These information implies the importance of social norm intervention and education with regard to UHI effect. The study of Huber, et al. [43] focused on two ways of people's perception of social norm: group information (what others in their respective social group are doing) and institutional signals (the socially desirable behavior motivated by institutions). The result indicated that the combination of these two interventions could motivate pro-environmental behavior substantially, while the group related interventions are difficult, especially when pro-environmental behavior is not wide spread. The emerging online social network may offer a chance for promoting group related social interventions, which should be given full attention.

5.2.4 Conclusion

The rapid urbanization in the past 20 years has brought Beijing great environmental burden. As an important aspect of improving urban environment, the Beijing Government is working hard to mitigating the UHI effect. In 2017, The Government released the official opinion on the implementation of sponge city construction, including replacing the conventional paving surface into permeable materials within 20% of the constructed area by 2020. One of the main purposes of this project is to decrease the urban surface temperate and improve the thermal condition of the city. This paper interviewed 849 households in Beijing on August 2018, obtaining their households' WTP for the permeable pavement for UHI effects mitigation by 2020. The study employed the DBDC format to collect the WTP data. For there exists a considerable number of zero responses, we employed the DBDC format with the spike model. In addition, we explored the possible factors that may contribute to public participation in UHI effect mitigation, thus enhance sustainable development. The four major findings of this paper are listed, as follows:

The four major findings of this paper are listed, as follows:

1. The annual WTP for permeable pavement was estimated to be 1640.204 CHY (239.711 USD) per household. The total amount of annual WTP reaches 8.823 billion CHY (1.288 billion USD). Residents' WTP value will change according to various factors (respondents' current income, health condition, age, etc.). This experiment was conducted in summer of 2018 and can provide the latest information for policy making and investment in UHI effect mitigation.

2. The DBDC plus spike model tends to be an effective way of examining respondents' WTP. There are two ways of improving statistical efficiency in CVM research. One is increasing the sampling size, which is usually costly. The other is asking a follow-up question, which was applied in our research. In our study, all the coefficients needed for estimating the mean WTP were statistically significant at the 1% level, which indicated that the spike model fits the data quite well. The strategy of eliminating the WTP question with the DBDC question format and processing the zero responses with the spike model could be effective in measuring the public's WTP in future studies.

3. There is great willingness among Beijing citizens to participate in UHI mitigation activities, while information disclosure, including environment monitoring and management of the environment protection fund, is of great importance in promoting public participation in environment issues.

4. Previous knowledge, perceived behavior control, and social norms were statistically significantly related with WTP, which implies the importance of education and publicity for UHI effect. Future studies may consider including these determinants in their WTP estimation models to explore the determinants of the pro-environmental behavior.

5.3 Willingness to pay for cool roof

As an important measure to alleviate the urban heat island effect, cool roof is recommended in relevant Evaluation Standard for Green Building of China. In order to elicit policy implications, this paper investigates Beijing residents' willingness to pay for promoting cold roofs to alleviate the urban heat island effect and its determinants.

5.3.1 Research background

Replacing conventional roofs with high albedo materials to reduce the absorption of solar radiation has become an important mean to alleviate the UHI effect [44]. Cool roof is defined as the roof with high solar reflectance (ability to reflect sunlight, spectrum 0.3–2.5 μm) and high thermal emittance (ability to emit thermal radiation, spectrum 4–80 μm) [45]. The effectiveness of this approach has been tested in situ and simulated with different urban scales in China.

Jiang [46] indicated that if the roof solar reflectance was increased from 0.18 to 0.82, the surface

temperature of a dormitory in Guangzhou province can be reduce by 10-15K in summer afternoon. Study on a natural ventilated factory in southern China in the summer of 2011 indicated that white coating can reduce the outer surface temperature by as much as 17 degrees [45]. An experimental research of Yang [47] in Beijing indicated that cool roof can reduce building roof surface temperature by as much as 17 degrees by increasing solar reflectance form 0.20 to 0.80.

As one important UHI effect mitigation method, cool roofs are also encouraged in relevant building energy efficiency standards [48]. In 2010, China's Ministry of Housing and Urban-Rural Development (MOHURD) and the US Department of Energy (DOE) formed a cool roof working group, aiming at evaluating the potential value of applying cool roofs in China. Lawrence Berkeley National Laboratory, USA, together with Chongqing University of China and Guangdong Academy of Building Research, China, conducts general research on the science and policies of cool roof within the US-China Clean Energy Research Center Building Energy Efficiency Consortium.

The role of government and the public sector in promoting new techniques in dealing with UHI effect has been found in numerous studies [45, 49], while the policy makers needs information associated with the value of cool roof mitigating UHI effect. The benefit of UHI mitigation, which is a non-traded product, has no market price. Due to the difficulty of measuring the economic value of the benefits of the UHI effect mitigation, evaluating the willingness to pay (WTP) has become a common measurement of its economic value [50]. WTP refers to the maximum amount a consumer will pay for a specific utility, or to avoid undesirable things. In our research, it refers to the effect of cool roof in UHI effect mitigation. Moreover, supporting public participation is considered as essential part of sustainable development strategy of [5]. However, due to China’s governance structure, individual participation in urban environmental issues is relatively rare. The study of [51] have shown that the urban environment deterioration is widely concerned by the public, which may become an important opportunity to promote public participation in urban environmental governance. In addition, there has been increasingly concerned about the factors affecting individual pro-environmental behavior among the world's environmental policy makers, which could contribute to a more effective environmental policies [27]. Therefore, the acceptance of residents in promoting cool roof for mitigating the UHI effect, especially the WTP, should be fully concerned.

In a hypothetical market, WTP can be elicited with contingent valuation method (CVM) [52]. CVM is part of a wider family of statement preference method, which is a survey based economic valuation method. The CVM is able to obtain the total economic value of a specific public good which has no market value. Nowadays, it has been widely applied in fields like environmental resource management, cultural goods evaluation, health risk reduction, public policy as well as many other fields [53-56].

A considerable numbers of researchers have investigated the public WTP for mitigating UHI effect

or urban heat waves. Zhang, et al. [57] used the CVM to find the WTP for the protective measures of heat waves provided by the market and the government. The result indicated that the annual WTP accounts for 40 Chinese yuan (CNY). In addition, they also reported that the WTP is correlated with the factors of gender, income, district, heat wave experience, chronic non-communicable disease, and air conditioner ownership. Kim, et al. [58] applied the choice experiment to assess the WTP for mitigating UHI effect with urban forest. The derived WTP are 56.88-76.59 US dollars for every increase of the urban forest by $1m^2$. Ihara, et al. [59] evaluated the WTP to avoid heat disorders caused by UHI effect. Morawetz and Koemle [60] applied CVM method to estimate the WTP for trees and fountains as measures against UHI effect in Vienna, Austria, with limitation of the research method discussed. To the best of our knowledge, in this strand of research no studies have explored the social acceptance and WTP for the main technologies for UHI effect mitigation along with its determinants.

In this study, we assessed Beijing household's willingness to pay for the promotion of cool roof to mitigating the UHI effect. In comparison with previous studies, there are two elements that differentiate this research with the others. The first point is that we combined the double-bounded discrete choice (DBDC) format with spike model to process zero-response samples, which has been proved to outperform the conventional model in processing zero-response samples [40]. The second is that we extended the determinants of WTP. In addition to conventional social-economic factors, we added and estimated covariates associated with environmental knowledge and the theory of planned behavior (TPB) [29, 61], which may provide new evidence for understanding individual's pro-environment behavior.

5.3.2 Research method

1. Method of Assessing the WTP

CVM has been widely used to evaluating non-market value [52]. There are no limitation on the objects to be assessed. CVM is superior to other non-market evaluation method for it can capture the non-use value or existence value. The environment goods of our research is the effect of cool roof in alleviating the UHI effect, as explained before.

Some scholars has questioned about the practicality and reliability of CVM, and raised and discussed possible bias. Regarding this, the blue ribbon National Oceanic and Atmospheric Administration (NOAA) points out that related bias can be eliminated by technical means, and CVM could provide reliable quantitative evaluation results. NOAA has proposed several guidelines to ensure the reliability of relevant CVM research [62].

2. The Design of Survey

The CVM field survey was conducted from July 10th -August 5th of 2018. A total of 1050 Beijing

households was interviewed and the final valid responses was 841, the response rate was 80%.

Table 5-19. Distribution of Beijing residents and questionnaire samples (Source: Beijing Municipal Bureau of Statistic http://edu.bjstats.gov.cn)

District	Distribution of Beijing residents in 2017 (Unit: million people)	Distribution of questionnaire samples
Xicheng District	1.30 (6.0%)	44 (5.2%)
Dongcheng District	0.91 (4.2%)	58 (6.8%)
Shijingshan District	0.65 (3.0%)	32 (6.0%)
Haidian District	3.69 (17.0%)	183 (21.6%)
Chaoyang District	3.96 (18.2%)	179 (21.0%)
Fengtai District	2.32 (10.6%)	131 (15.4%)
Changping District	1.96 (9.4%)	50 (5.8%)
Pinggu District	0.42 (2.0%)	14 (1.5%)
Mentougou District	0.31 (1.5%)	9 (1.0%)
Shunyi District	1.02 (4.6%)	21 (2.3%)
Fangshan District	1.05 (4.7%)	21 (2.2%)
Daxing District	1.56 (7.1%)	33 (3.6%)
Tongzhou District	1.38 (6.3%)	39 (4.3%)
Yanqing District	0.31 (1.4%)	10 (0.9%)
Huairou District	0.38 (1.8%)	11 (1.0%)
Miyun District	0.48 (2.2%)	14 (1.4%)
Total	**21.70 (100.0%)**	**849 (100.0%)**

Before the onsite interview, each interviewer has received some training, including how to explain the purpose of the experiment, the related rights of respondents, and how to answer possible questions that respondents might ask [20]. To derive reliable decision making, only 18-70 years old respondents were selected and interviewed in this survey.

The survey instrument consists of five parts. The first part was the introduction section, explaining the general background information, including the definition of UHI effect, the current situation of UHI effect in Beijing, the hazard of UHI effect, and the effect of cool roof in alleviating the UHI effect. The rights of each respondent was introduced before the interview. The second part contained the information of individual's motivation and behavior. The third part contained questions relating to the respondents' previous knowledge (previous knowledge of UHI effect and cool roof). The fourth and fifth part comprised the socio-economic characteristic and demographic characteristic, respectively (Fig.1). The WTP question is: If Beijing government is going to replace 10% of building roof of Beijing into cool roof (approximately 20 million m^2) , is your household willing to

pay a certain amount by increasing the personal income tax for the next 7 years? Then, the SPSS 24 and R version 3.5.3 were applied to conduct descriptive analysis and estimate the determinants for WTP. At last, policy implications was proposed.

Four bid combinations were set, which is (100/200/400) (400/800/1500) (800/1500/3000) (1500/3000/5000) CHY. The middle figure is the initial bid, the first element is the lower bid while the third element is the higher bid. If the initial bid was rejected by the respondent, the lower bid will be presented, or otherwise, the higher bid will be presented. US dollar (USD) 1.0 was approximately equal to CHY 6.68 with the current exchange rate.

At last, payment frequency and payment duration should be decided. According to Egan, Corrigan and Dwyer [21], we chose annual fee as the payment frequency. The payment duration of this research is 7 years, which is the minimum expected duration of benefits from a cool roof.

5.3.3 Research result and discussion

1. Data

The demographic characteristic of samples are as follows:

Table 5-20. Gender of samples

	Number	Percent	Valid Percent	Cumulative percent
Male	413	49%	49%	49%
Female	428	51%	51%	100%

Table 5-21. Age of samples

	Number	Percent	Valid Percent	Cumulative percent
Older than 55	88	10.50%	10.50%	10.50%
In between 35-55	505	60.10%	60.10%	70.60%
Younger than 35	274	29.40%	29.40%	100.00%

Table 5-22. Education level of samples

	Number	Percent	Valid Percent	Cumulative percent
Master degree or higher	136	16.20%	16.20%	16.20%
Bachelor degree	302	35.90%	35.90%	52.10%
High school or vocational School	352	41.90%	41.90%	94.00%
Middle school or lower	51	6.00%	6.00%	100.00%

Table 5-23. Family size of samples

	Number	Percent	Valid Percent	Cumulative percent
4 or more	302	35.90%	37.10%	37.10%
2−3	335	39.80%	39.80%	76.90%
1	204	24.30%	23.10%	100.00%

Table 5-24. Family size of samples

	Number	percent	Valid Percent	Cumulative percent
More than 8000	167	19.90%	19.90%	19.90%
4000-8000	431	51.20%	51.20%	71.10%
3000-4000	99	11.80%	11.80%	82.90%
less than 3000	144	17.10%	17.10%	100.00%

Table 5-25 explains the distribution responses for each bid combinations. A total of 242 respondents gave “NNN” responses, suggesting that it is suitable for applying the spike model to deal with the zero response samples in this study. The proportion of “Yes” response to the initial bid declines as the magnitude of the bid increases. A total of 132 (62%) respondents were willing to pay 200 CHY, while 85 (41%) respondents were willing to pay 3000 CHY.

Table 5-25. Distribution of Responses

Bid combination	YY	YN	NY	NNY	NNN	SUM
400/200/100	72(34%)	60(28%)	10(5%)	18(8%)	51(24%)	211(100%)
1500/800/400	39(19%)	50(24%)	15(7%)	35(17%)	71(34%)	210(100%)
3000/1500/800	32(15%)	54(26%)	19(9%)	36(17%)	69(33%)	210(100%)
5000/3000/1500	52(25%)	33(16%)	16(8%)	58(28%)	51(24%)	210(100%)
sum	195(23%)	197(23%)	60(7%)	147(18%)	242(29%)	841(100%)

The definitions, mean values, and standard deviations of variables are included in Table 2. Of all the variables, gender, age, family size, education level, and residential area were all available from the Beijing Statistical Office. The variables of gender, age and family size were closed to the official data of the whole population, while the gap between the education level of our samples and official data was comparatively big, indicating a limitation of our sampling. The possible reason is that the most people who refused to be interviewed had low education level. For the socioeconomic factors of the respondents were not significantly different from the general except for education, we

consider that our sample is suitable for estimating WTP of the whole population.

Table 5-26. Sample statistics and definition of variables

Variable	Mean	Dev	Census
Gender (Male=1, female=0)	0.49	0.50	0.50
Education (Have a college degree =1,Others=0)	0.52	0.5	0.36
Age (More than 55=3,30-55=2,<30=1)	1.81	0.99	1.84
Family size (More than 3 members=1, others=0)	0.36	0.48	0.31
Residence (Living in urban central area =1, Living in urban suburban area = 0)	0.60	0.49	0.59
Income (More than 4000=1,less than 4000=0)	0.71	0.45	
Job (The respondent has a job currently=1, Others=0)	0.78	0.41	
Children (Raising a child younger than 12 currently=1, others=0)	0.52	0.5	
Attitude (Regarding UHI effect mitigation as important=1, Others =0)	0.85	0.36	
Subjective norm (People that important for respondent would support his/her pro-environment behavior=1, Others=0)	0.83	0.38	
Knowledge of UHI (Know well about the UHI effect =1, others =0)	0.39	0.49	
Perceived behavioral control (Have enough resources for participating in UHI mitigation activities=1, Others=0)	0.72	0.45	
Knowledge of cool roof (Know well about the cool roof = 1, Others=0)	0.40	0.49	
Health (Health condition is good=1,Others=0)	0.84	0.37	

2. Descriptive analysis

Although the concept of UHI effect has been discussed for a long time in the academic field, it is still relatively new to the public, especially in developed context like China. Therefore, it is important to understand how the public get knowledge about the UHI effect. The interview results showed that about 39% (331 respondents) of the respondents had never heard of the UHI effect, which may partially because the UHI effect is relatively difficult to be recognized comparing with other urban environmental problems (sandstorms, haze, flood, etc.), thus unlikely to raise public awareness. Among the respondents that understand the knowledge of the UHI effect, online inquiry was the main channel by which to learn about the UHI effect, with 24% (199 respondents) of the respondents selected that option. In addition, 17% (140 respondents) of the respondents got information from the other people (family, friends, teachers, community members, etc.). Television and others ranked forth (16%) and fifth (4%), respectively. The promotion of knowledge with regard to UHI effects needs to be strengthened, and various information dissemination programs are needed to improve citizens' understanding of UHI effect (Figure 5-9).

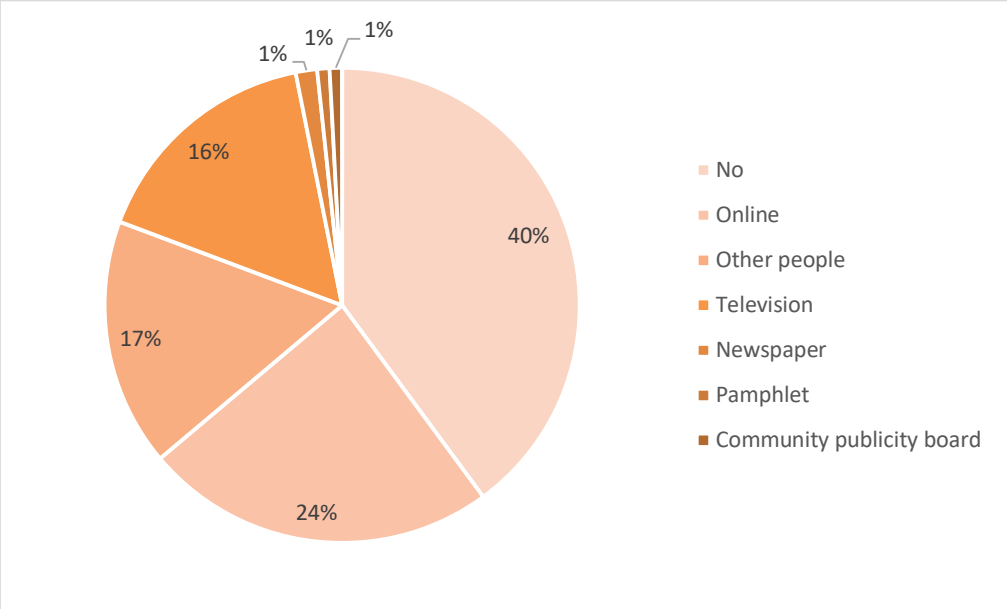

Figure 5-9. Public information sources of the UHI effect

In promoting public participation in UHI effect mitigation. More than 80% of respondents reported that government should enhance transparency in urban environmental management, including the disclosure of urban environmental monitoring information (42%) and the use of environmental protection fund (40%). 11% of respondents preferred establishing a rewarding mechanism to stimulate individual pro-environmental behavior, and 5% respondents preferred legal services offered by the government with regard to public supervision and public funding for urban environment issues (Figure 5-10).

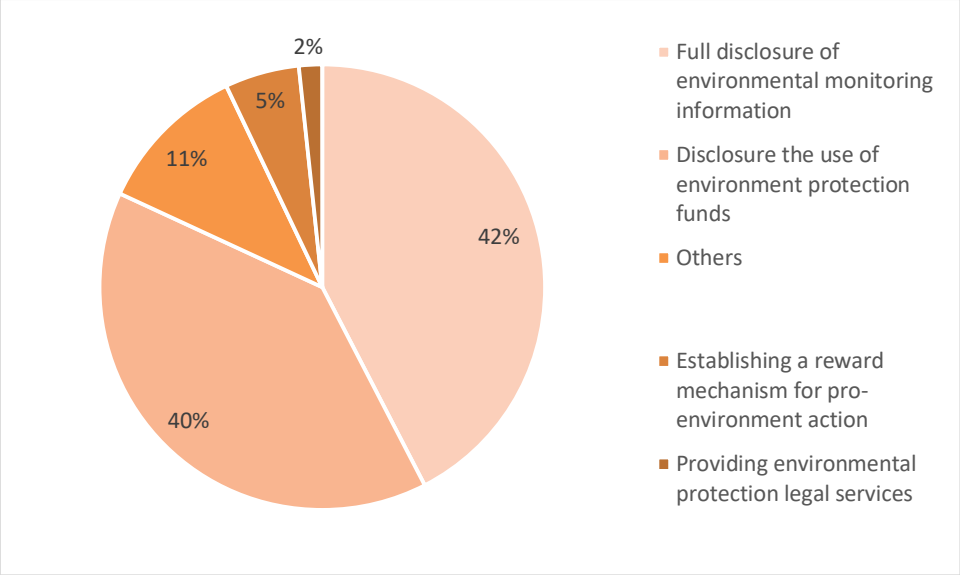

Figure 5-10. Suggestions for government for promoting citizens' participation UHI effect mitigation.

3. Estimation results

The estimation result with and without covariance are presented in Table 5-27. Maximum likelihood estimation function was applied to estimate the parameter. The spike is 0.297, which is similar to the zero responses (29%) provided in Table 1. The Wald statistic rejected the null hypothesis that the estimated parameter are zero since the p-value is less than 0.01.

The mean annual WTP was estimated to be 1510.854 CHY (220.560 USD) per household. The t-value is 26.747, thus the result is statistically significant at the 1% level. We also obtained the 95% and 99% confidence intervals for the estimate, using Krisky and Robb's parametric bootstrapping method approach with 5000 replications [42].

Independent variables was divided into three groups, and therefore three estimation models are established (Table 4). In model one, only eight demographic attributes were included. According to Kaiser and Fuhrer [63] and Kollmuss [64] People who has a deeper knowledge of environment issues and the remedies are more likely to take actions to protect the environment. Variables with regard to environmental knowledge were added in model two (previous knowledge of UHI effect and previous knowledge of cool roof). Model three included attributes with regard to personal belief and perceived resources, which is inspired by the theory of planned behavior [29]. This study applied the partial correlation coefficients analysis prevent common method bias, while the result reported no obvious outliers.

In terms of demographic attributes, all of the three models indicated that females are more likely to fund for cool roofs, while the education level and presence of children are also positively related to

the likelihood of paying for cool roofs. In model two and model three, respondents aged over 55 are less willing to pay. In model one and model two, health condition has significant impact on respondents' WTP. As for variables with regard to environmental knowledge, model two and model three indicated that WTP increases with an increase in knowledge with regard to UHI effect and cool roof. The results presented in model 3 suggest that respondents' perceived resources in contributing for cool roof construction and pro-environmental social norm have a positive and significant effect on WTP, while there is no significant linkage between respondents' attitude and WTP.

Table 5-27. Estimation result of the model

Variables	Model without covariates	Model with covariates
Constant	-0.623 (11.677)***	-1.275 (-3.366)***
Gender		-0.260 (-1.788)*
Income		-0.074 (-0.387)
Age 55		-0.517 (-1.673)*
Residence		-0.023 (-0.148)
Job		0.131 (0.653)
Family size		-0.148 (-0.881)
Education		0.423 (1.955)*
Presence of children		0.576 (2.991)***
Healthy		0.116 (1.034)
Knowledge of UHI		0.369 (2.269)**
Knowledge of cool roof		0.666 (4.196)***
Attitude		0.192 (0.578)
Perceived behavior control		1.173 (7.111)***
Subjective norm		0.417 (2.067)**
Bid	0.001(202.520)***	0.001 (320.992)***
spike	0.327(24.747)***	0.290 (24.560)***
MTP	1510.854(26.747)***	1240.286 (28.036)***
95% confidence interval	1395.888-1624.057	1154.656
99% confidence interval	1368.400-1663.974	1120.939
Wald statistic	41055.180***	103074.778 ***
Log-likelihood	-1468.083	-1423.276

Notes: the t-values, computed from the analytic second derivatives of the log- likelihood function, are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The null hypothesis is that all the parameters are jointly zero, and the corresponding p-value is reported in parentheses after the statistic.

4. Discussion of the results

The annual mean WTP obtained with no covariates was chosen for calculating the total WTP since the setting of covariates may affect the mean WTP. The mean annual WTP is 1510.854 CHY (220.563 USD), which accounted for 1.2% of the disposable income of Beijing household. According to the official data, the number of households in Beijing amounts to 5.38 million at the survey time. Expanding the mean annual WTP value to the population of Beijing, Beijing households are willing to pay 8.128 billion CHY (1.187 billion USD) for promoting the construction of cool roof for UHI effect mitigation. The corresponding 95% and 99% WTP intervals are 7.510 - 8.738 billion CHY (1.096 – 1.276 billion USD) and 7.335 – 8.952 billion CHY (1.071 – 1.307 billion USD), respectively. Overall, we can conclude that there is great economical potential for promoting cool roof for UHI effect mitigation.

Due to governance mode and cultural reasons, public participation in urban environmental management is rare. The result of our research that may offer new evidence for promoting public participation in UHI effect mitigation. Descriptive analysis indicated that the majority of residents have great expectation of government affairs openness with regard to urban environment management, which reflects that the transparency and credibility of government should be enhanced. For the determinants of WTP, we added the covariates of attitude, perceived behavior control, social norms, and previous knowledge with regard to UHI effect and cool roofs to the conventional ones. The results indicated that residents' previous knowledge, perceived resources in participating in UHI mitigation activities, and social norms were statistically significant with the likelihood of “yes” response to a given bid, which implies the necessity of publicity and education with regard to UHI mitigation.

5.3.4 Conclusion

The purpose of this paper is to assess the economic benefits of promoting cool roofs for mitigating the UHI effect. 841 households in Beijing were interviewed in 2018. DBDC format and spike model is adopted to obtain residents’ WTP and reveal the determinants. The results show that most respondents are willing to pay for the cool roofs. Average annual WTP amounts to 1510.854 CHY (220.563 dollars) per household and the total WTP is 8.128 billion CHY (1.187 billion USD). As for the determinants of WTP, other than conventional socio-economic variables, our findings indicated that respondents’ previous knowledge, social norm, and perceived resources has great influence on people's pro-environmental behavior.

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Chapter 6

AN EXTENTION OF THE THEORY OF PLANNED BEHAVIOR TO PREDICT WILLINGNESS TO PAY FOR URBAN HEAT ISLAND MITIGATION

In this chapter, we established a predictive model based on the theory of planned behavior to predict the willingness of Beijing urban residents to protect urban lakes in mitigating the heat island effect. This study adds the factor of environmental concern to the conventional model of TPB. The result indicated that the predictive power of the conventional model has been improved with introducing environmental concern.

6.1 Introduction

Water bodies, as one of the important part of the urban ecosystem, were proved to be effective in mitigating the UHI effect. Lai, et al. [1] compared different methods to alleviate the UHI effect, the results show that the urban water body can reduce the temperature of the surrounding area up to 1.8K. The study of Manteghi, et al. [2] has shown that urban lakes can reduce peripheral temperatures by up to 1-2 ℃. The study of [3] indicated that if the pond in the city is parallel to the dominant wind direction in the city, then the surrounding average temperature can be reduced by up to 1.6 ℃ in summer. Sun and Chen [4] studied 197 urban water bodies in Beijing, with the result that urban water bodies can reduce the ambient air temperature by an average of 0.54 ℃, while the effect is related to the location, shape, size, and surrounding constructions.

The effect of the urban water bodies on mitigating UHI effect has been reported by numbers of studies, but its role in urban climate control has not be put enough attention, one of the main reasons is that its economic value cannot be easily evaluated. At the same time, according to China's agenda 21 [5], residents are encouraged to participate in the urban sustainable development, while residents' pro-environmental behavior has not been fully discovered due to the long-term top-down governance model and other reasons. The main purpose of this study is to use the stated preference method, a widely used non-market value evaluation method to assess residents ' willingness to pay (WTP) for the conservation of urban lakes for UHI effect mitigation. The stated preference method assesses the economic value of environmental goods that cannot be traded directly on the market by obtaining its WTP. Contingent valuation method (CVM) belongs to the family of stated preference method, which obtains the WTP for an environmental goods by directly asking questions to the respondents. It is one of the most widely used non-market value evaluation method.

At the same time, this study attempts to explore the factors that affect residents ' WTP for UHI effect management. At first, the study with regard to the nature of pro-environment behavior was limited to socio-economic factors such as education, gender, age, income, etc. [6][7]. However, these social structural variables have been criticized for only explain the modest variances in measures of environmental behavioral intention and behavior [8]. Then researchers have turned to focus on psycho-social constructs, such as attitude, subjective norm, and belief, research shows that these factors can better predict people's pro-environmental behavior [9][10]. The common feature of these researches is that they are all based on the idea that people's behavior is influenced by their thoughts

and feelings about the environment and pro-environment behavior. The most popular approach in this kind of research is the theory of planned behavior (TPB), which was introduced and developed by Ajzen in 1991. It reflects that individual's attitude, subjective norms, and perceived resources with regard to a specific behavior can help us better understand pro-environmental behaviors [11].

Although many studies support the original TPB in predicting people's pro-environmental intentions and behaviors, others point out that there is still a considerable percentage of variance that does not explain one's intention and behavior. As a result, many studies have introduced extended TPB model to increase its explanatory power. It has been suggested that exploring the impact of environmental concerns could improve the understanding of people's pro-environment intention and behaviors, which have not be taken into consideration in the original TPB model [12][13][14]. For these reasons, we add a variable (environmental concern) on the basis of the original TPB model to explore the intention and behavior characteristics of people in supporting UHI effect mitigation.

The environmental goods in this study are 15 urban lakes with an area of more than $3hm^2$ in the central area of Beijing (within five rings road). We aim to assess people's WTP for these urban lakes for their UHI mitigation effects, and to identify the underlying motivation. These information will be of great significance to policymakers for their investment on UHI management and promoting public participation in urban environmental governance.

This paper is different from the previous researches from two aspects, one, this paper expands the original TPB model, studies their relationships with the components of original TPB model, and explores its relationship to the motivation of pro-environmental behavior. Second, there are many studies that applied the extended TPB model in order to explain people's behavioral intention for improving the urban environment. For example, Lopez-Mosquera, et al. [15] focus on the WTP for the protection of urban parks, Zahedi, Batista-Foguet and van Wunnik [13] analyzes residents' WTP for reducing air pollution and greenhouse gases generated by private road traffic, Spash, Urama, Burton, Kenyon, Shannon and Hill [9] analyzes people's WTP for improving the ecological diversity in the water system, Wang, et al. [16] analysis of people's WTP for the protection of African elephants. To the best of our knowledge, studies with regard to the WTP for conserving urban water bodies in order to alleviate the UHI effect is limited, and no studies have used the extended TPB to explore the influencing factors for the payment.

The organization of this paper is as follows: In Section 2, the theoretical framework is presented, Section 3 presents the research method, Section 4 contains research results along with discussion, and Section 5 summarizes the main conclusions.

6.2 Research method

6.2.1 Environmental goods to be evaluated

The total area of the urban lake within the 5th ring road of Beijing city is about 716.17hm^2 (Figure 6-1). Among the total water surface, about 11hm2 is distributed within 2nd ring road, about 172.66 hm2 is distributed in between 2nd and 4th ring roads, and about 354.4hm2 is distributed in between 4th and 5th ring road [17]. The environmental goods of this study are the UHI mitigation effect of urban lakes of Beijing.

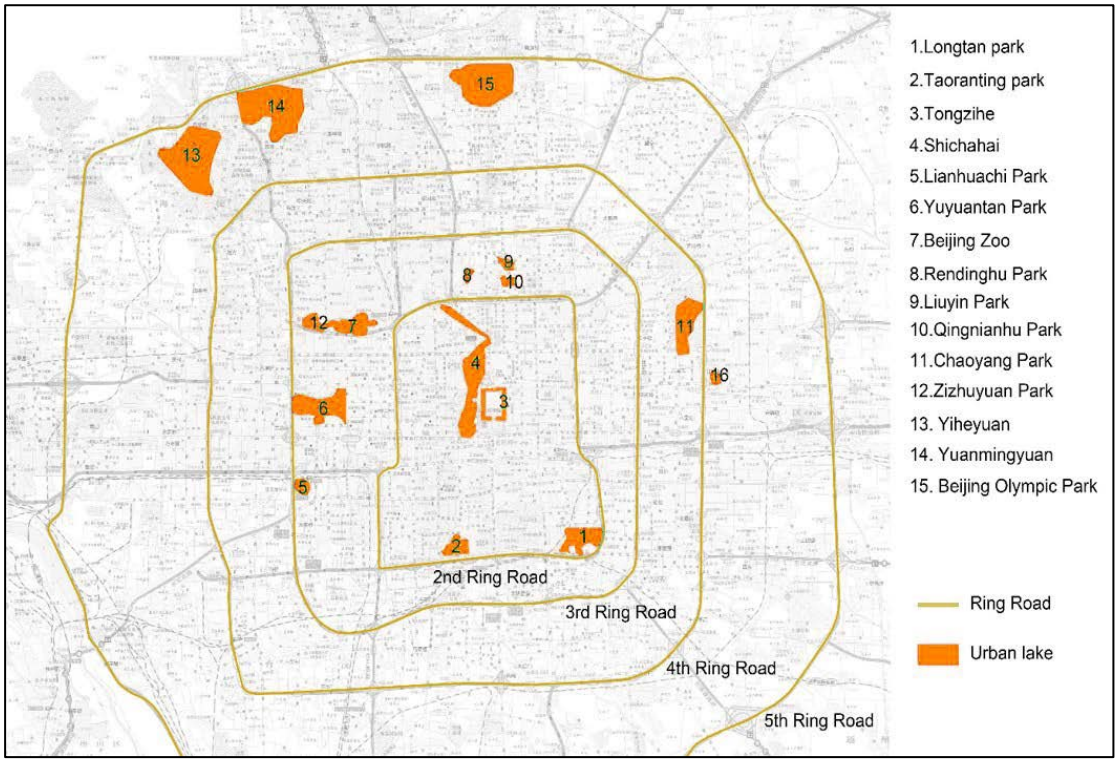

Figure 6-1. The distribution of urban lakes in Beijing

6.2.2 The design of the survey

We conducted a pre-research before the main research, aiming to determine the acceptance of CVM research and bid range. The pre-research was conducted with the open-ended format, and about 100 respondents were interviewed in the pre-survey. The formal study began on February 9, 2019, and lasted for 12 days. The online questionnaire was randomly distributed to Beijing citizens, and the final valid samples were 1055.

A large number of studies indicated that WTP elicitation method could greatly affect people's WTP [18]. The dichotomous choice format was selected to be the WTP elicitation method. The advantage of the dichotomous choice format is that it can help respondents go through a complete evaluation process. Moreover, as an incentive-compatible elicitation method, it can prevent

strategical bias [19]. As for payment vehicle, Carson, et al. [20] pointed out that the payment vehicle should have some relationship with the goods to be valued, and respondents should be familiar to the payment vehicle. Taxation was applied in this research for it is a mandatory payment method, which could reduce the risk of free riding and over pledging of respondents [20]. Compared with other kinds of taxations, Beijing citizens are more familiar with personal income tax, which is the reason we chose income tax as the payment vehicle. As for the frequency of payment, according to the study of Egan, et al. [21], the payment frequency of this study is annual.

Before the questionnaire, each respondent was provided with information with regard to the purpose of the study, the distribution of urban lakes in Beijing, the effect of urban lakes in UHI effect mitigation, the hazards of UHI effect, and related rights of respondents within the survey. The questionnaire consists of three parts, the first part contains the respondents' socio-economic characteristic， the second part elicits respondents' WTP for conserving the urban lakes for the effect of UHI effect mitigation. The WTP question is: If the Beijing municipal government needs funding for conserving the urban lakes within 5 ring roads of Beijing to alleviating the UHI effect, based on your personal experience and the information mentioned above, considering your households' actual annual income, are your household willing to pay _ Chinese Yuan (CHY) annually through increasing the personal income tax? Four bid values: 50 CHY, 100 CHY, 200 CHY, and 500 CHY were randomly assigned to all of the respondents. These four bid values were decided according to the result of pre-research. The third part refers to the attitudinal profile of respondents' pro-environment behavior with regard to payment for UHI effect mitigation on 7 point Likert scales (1=strongly disagree, 7=strongly agree).

6.2.3 Data analysis

1. Estimation of WTP

In this research, the contingent valuation method was applied to calculate the WTP to conserve urban lakes for alleviating the UHI effect. The dichotomous choice format was used to elicit residents' WTP. The mean WTP was calculated based on the formulation provided by Hanley [22].

Mean WTP = $\int_0^T [1 - G_{WTP}]\, dW$

G_{WTP} is the distribution function of WTP. T is infinite for the true intention to pay and is truncated at some value for the purpose of estimation.

2. Structural and measurement model

This study applied the structural equation model to calculate the psycho-social factors that affecting WTP. In this study, AMOS 24.0 was used to process the data and SPSS 24.0 was used for descriptive analysis. Following the suggestion of Anderson and Gerbing [23], this study employed Confirmatory factor

analysis (CFA) to assess measurement quality of the model, and used structural equation modeling (SEM) to verify the hypothetical conceptual model. As for the results of the CFA test, the robustness of mean squared error approximation (RMSEA) is expected to be located in between 0.05 and 0.08. Comparative fit index (CFI), normed fit index (NFI), and goodness fit index (GFI) should be close to 0.9 or 1. Finally, the Sobel test and bootstrapping method are used to calculate the indirect effect.

6.3 Theoretical framework and hypothesis

TPB is designed to predict and explain an individual's behavior in specific situations [11], Researchers agree that if people believe that their actions will lead to specific outcomes, if their important relatives (family, friends, relatives, colleagues, etc.) will support their behavior, and if people think they have the resources and the ability to perform a certain behavior, people will tend to conduct specific behavior.

TPB is an extension of the theory of reasoned action [24]. Theory of reasoned action is considered to be effective only in the context that people's behavior is under volitional control, while most human behavior is controlled by some non-volitional factors [25-27]. TPB expanded the boundaries of the theory of reasoned action, introduces some variables that are not related to volitional factors, and compensates for the shortcomings of the theory of reasoned action in the context of non-volitional control. As indicated by the original TPB theory, the most proximal predictor of people's behavior is the behavioral intention, and the behavioral intention is affected by the following three: 1) attitudes: people's positive or negative evaluation of a certain behavioral option. 2) Subjective norms: perceived pressure from related social group 3) Perceived behavior controls: perceived ease or difficulty in performing a behavior. A more positive attitude, a more positive social norm, and a stronger perceived behavioral control can enhance people's intention of conducting specific behavior [28].

The original TPB model has been widely used in environmental research to analyze various behavioral intentions and behaviors, such as participating in environmental activities [29], conserving the forest [30], protecting wild animals [16] , and consuming urban environmental goods [15][9][31].

According to the original TPB model, if the respondent holds a positive attitude on the behavioral option, if the respondent’s family and friends support his behavior, and if the respondent believes he/she has the ability to participate in the activities of protecting urban lakes to alleviate the UHI effect, he/she is more likely to fund environmental goods. Based on the above discussion, we made the following assumptions:

H1: If attitude towards conserving urban lake for alleviating the UHI effect is more positive, people's WTP would increase.

H2: If subjective norms regarding conserving urban lake for alleviating the UHI effect is more positive, people's WTP would increase.

H3: If perceived behavioral control for conserving urban lake for alleviating UHI effects increase, people's WTP would increase.

Few studies have explored the potential relationship between attitude, perceived behavioral control, and subjective norm [32] [33]. People will take social norm into consideration when forming their attitudes and perceived resource for a specific behavioral option. So we have the following assumptions:

H4: If subjective norms regarding conserving urban lake for alleviating the heat island effect is more positive, people's attitude towards the behavioral option is more positive.

H5: If subjective norms regarding conserving urban lake for alleviating the heat island effect is more positive, people's perceived behavioral control towards the behavioral option increases.

In spite of that many studies have pointed out that the original theoretical framework of behavioral planning can be useful for predicting people's behavioral intentions and behaviors towards environmental protection, a considerable number of studies, however, indicated that a substantial percentage of variance was left with no explanation in intention and behavior [11][34]. For this reason, many studies have proposed an extended version of the TPB model by adding new variables, aiming to enhance its explanatory power [35][36][37]. Among these variables, some researches focuses on the status of environmental concerns in predicting behavioral intentions [38][39][6][37].

Environmental concerns are defined as the extent of individuals to aware of environmental issues and their willingness to solve environmental issues. A large number of studies have shown that environmental concerns play an important role in predicting people's environmental intentions and behaviors [40][38][6][41]. In addition, the study of Zahedi, Batista-Foguet and van Wunnik [13] shows that environmental concerns are positively related with three main factors of the TPB model: attitudes, perceived behavioral control, and subjective norms, and the study of Kollmuss and Agyeman [42] indicates that environmental concerns may affect people's environmental intentions and behaviors in an indirect way other than direct way by affecting relevant variables. Based on these discussions, we propose the following hypothesis: Environmental concerns are positively related to people's attention to paying for UHI effect management. We further propose the following assumptions:

H6: Environmental concern is positively related to people's attitudes toward UHI effect management.

H7: Environmental concern is positively related to the subjective norms of paying for UHI effect

management.

H8: Environmental concern is positively related to the perceived behavioral control towards UHI effect management.

H9: If Environmental concern is more positive, people's WTP would increase.

Figure 6-2 and Figure 6-3 depicted the original TPB and extended TPB model for WTP, respectively.

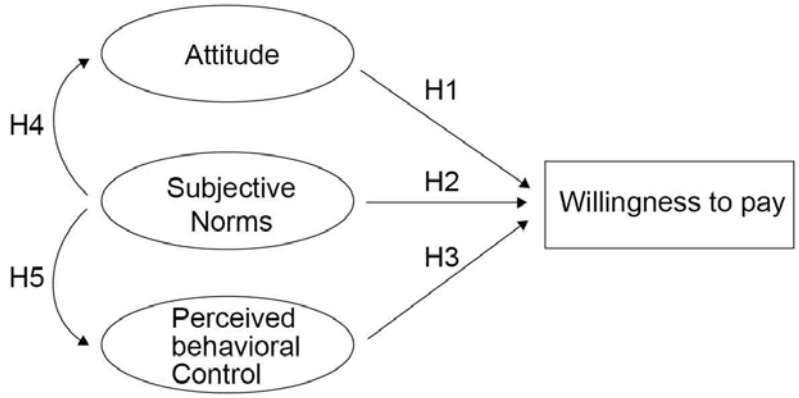

Figure 6-2. Initial TPB model for WTP. (Squares represents observed variables, elliptic represents latent constructs)

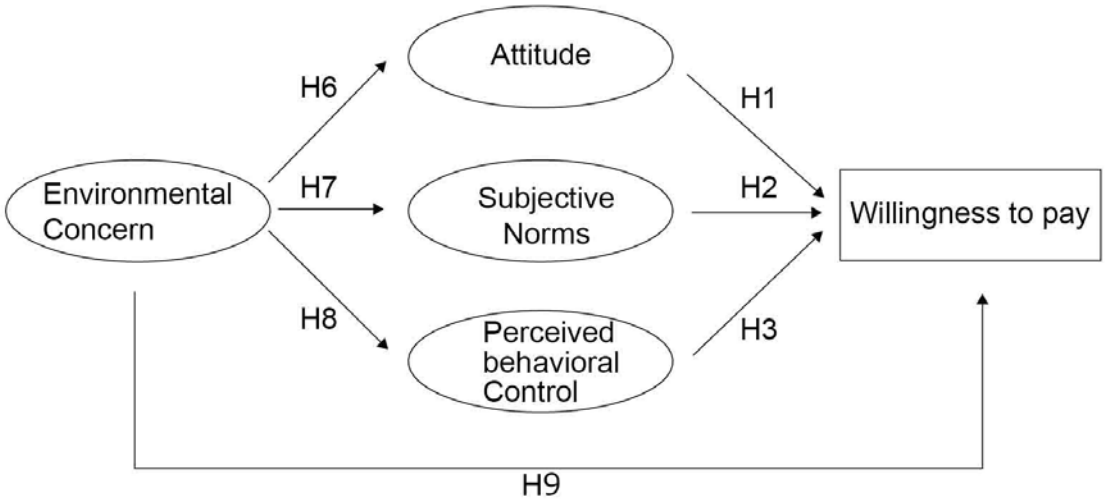

Figure 6-3. Extended TPB model for WTP. (Squares represents observed variables, elliptic represents latent constructs)

In addition, H9 environmental concern may affect WTP through attitude, subjective norm, and

perceived behavior control, the assumptions are:

H10: environmental concern affect WTP through attitude

H11: environmental concern affect WTP through subjective norm

H12: environmental concern affect WTP through perceived behavior control

The setting of extended TPB structural equation model with AMOS was as follows:

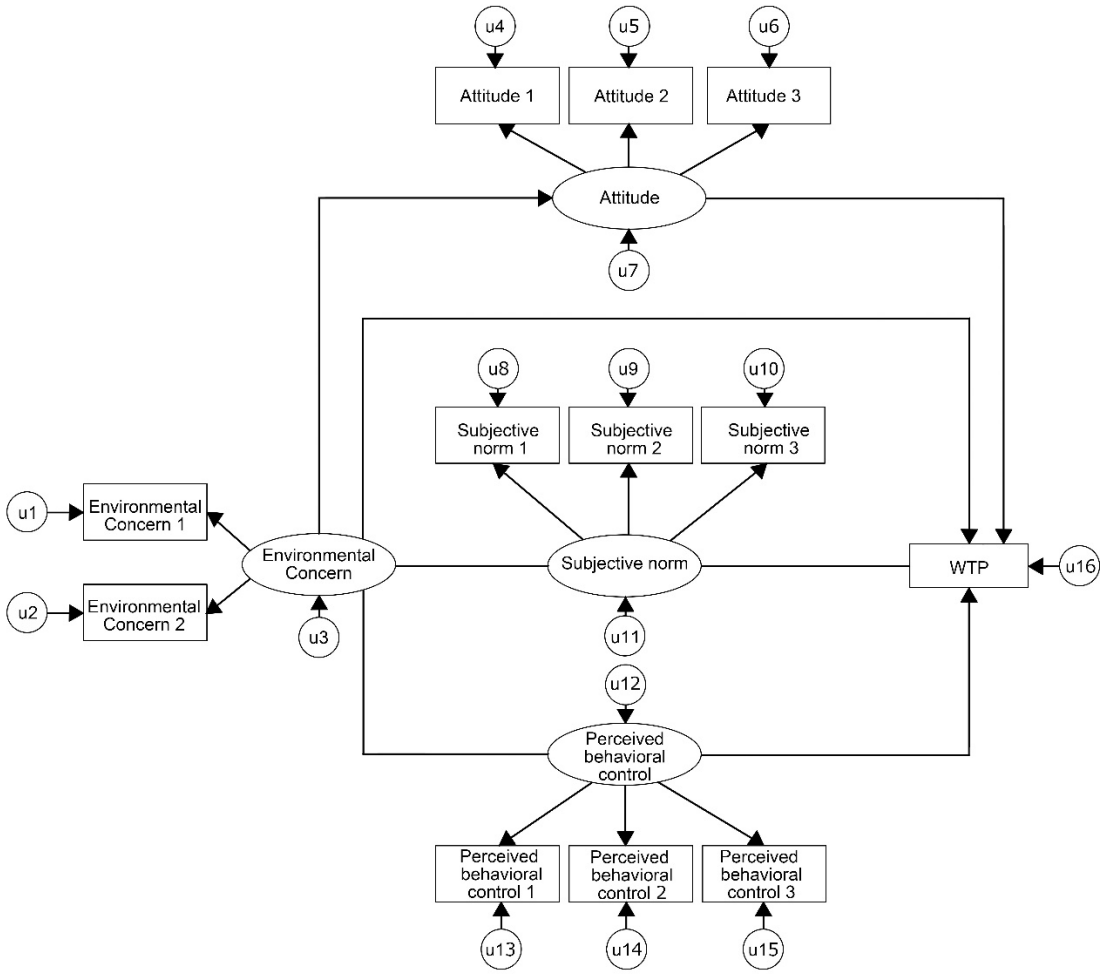

Figure 6-4. Structural equation model in AMOS. (Squares represents observed variables, elliptic represents latent constructs, and square represents residual)

6.4 Results and discussion

6.4.1 WTP analysis

The distribution of WTP for different bids is presented in Table 6-1. As the bid value increases, the proportion of positive responses decreases gradually. Among the zero response samples, a total of

276 respondents refused to pay because they thought "it is the government's responsibility" and" do not believe the proper use of environmental fund". These samples were defined as “protest responses”. Respondents who chose the option such as "I don’t have the ability to pay for the fund" and "I don’t think the UHI mitigation effect worth that much" is considered to be "real zero responses" (Figure 4). Only “real zero responses” were included when processing the data. The mean annual WTP for conserving urban lake for UHI effect mitigation is calculated to be 162.97 CHY (23.79 US dollars). Respondents with higher incomes are more likely to pay (β=0.53, P<0.01).

Table 6-1. Distribution of WTP responses

WTP	50. 0	100.0	200.0	500.0	TOTAL
Positive	183(69.8%)	184(70.2%)	142(54.0%)	142(53.0%)	651(61.7%)
Negative	20(7.6%)	21(8.0%)	45(17.1%)	42(15.7%)	128(12.1%)
Protest zero	59(22.5%)	57(21.8%)	76(29.9%)	84(31.3%)	276(23.9%)
Total	262(100. 0%)	262(100.0%)	263(100.0%)	268(100.0%)	1055(100.0%)

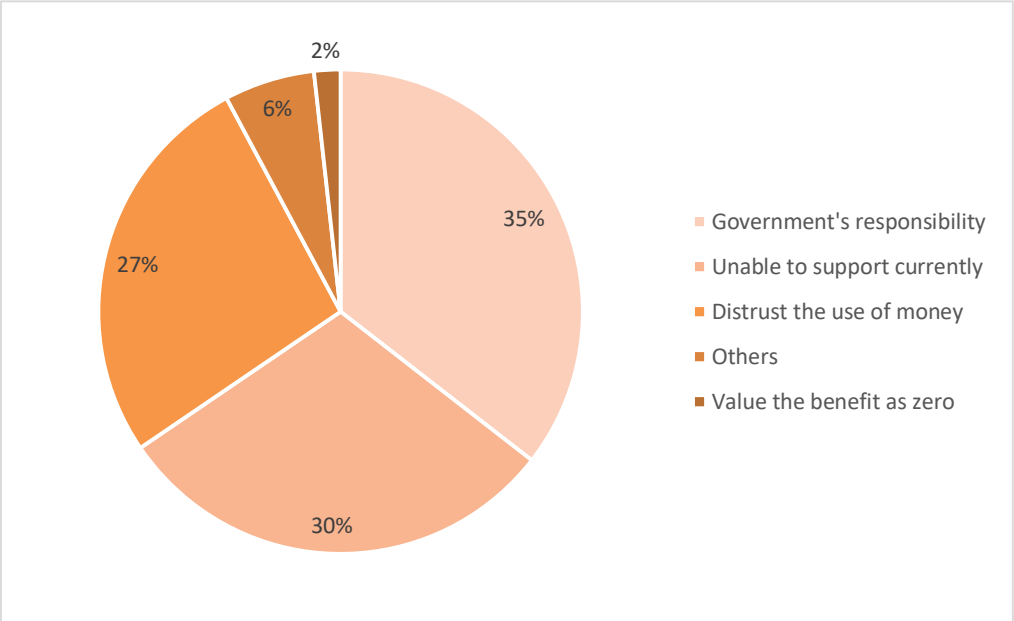

Figure 6-5. Motivation for zero responses

6.4.2 Measurement models

Firstly we conducted the CFA on the original TPB model, including components such as attitude, subjective norm, and perceived behavior control (Table 6-2). The results showed that the model fits the data well (Chi -square=251.9, GFI=0.943, CFI=0.964, NFI=0.958, RMSEA=0.08). Then all the four components were included (attitude, subjective norm ， perceived behavior control, environmental concern) and tested. In general, it exhibited good psychometric properties. All standard regression coefficients were statistically significant in 0.01 level. In addition, all the scales

satisfied the internal consistency.

Table 6-2. Reliability and CFA for the extended TPB model

Scales	Mean (s.d.)	β	CR	AVE
Attitude (α=0.89)			**0.89**	**0.73**
I think paying for conserving urban lakes is very positive	5.35(1.58)	0.85		
I think paying for conserving urban lakes is responsible	5.46(1.60)	0.86		
I think paying for conserving urban lakes is ecological	5.54(1.55)	0.85		
Subjective norm(α=0.90)			**0.90**	**0.74**
I think people who are important to me will pay for conserving urban lakes	4.73(1.67)	0.85		
I think people who are important to me will support the action of paying for urban lakes conservation	4.91(1.69)	0.89		
I think people who are important to me will support me paying for urban lakes conservation	5.00(1.67)	0.84		
Perceived behavioral control (α=0.84)			**0.84**	**0.64**
I think my payment will improve the urban environment	5.17(1.66)	0.75		
It is not difficult for me to pay for urban lakes conservation	4.62(1.93)	0.79		
I think I have time, money, and resources to pay for urban lakes conservation	4.63(1.80)	0.85		
Environmental concern (α=0.71)			**0.71**	**0.55**
I care about urban environmental issues very much	5.47(1.61)	0.76		
I think I will reduce other expenses for urban environment improvement	4.79(1.76)	0.72		

α reliability (Cronbach's alpha coefficient); β (standard regression weight); s.d (Standard deviation); CR (composite reliability); AVE (average variance Extracted)

Finally, we performed the scales' discriminant validity test. According to Fornell and Larcker [43], if the squared correlations of different constructs are less than the AVE of each constructs， then the

discriminant validity can be confirmed, as is shown in table 3.

Table 6-3. The scales' discriminant validity

	Attitude	Subjective norm	Perceived behavior control	Environmental concern
Attitude	**0.73**			
Subjective norm	0.50***	**0.74**		
Perceived behavior control	0.45***	0.50***	**0.64**	
Environmental concern	0.40***	0.44***	0.44***	**0.55**

*** p <0.01

6.4.3 Hypothesis testing

The fitness of the initial model was acceptable（chi-square 249.1, RMSEA=0.08, GFI=0.943, CFI=0.958, NFI=0.90). Most of the structural coefficients are statistically significant (p<0.01). According to the result, perceived behavior control is the only factor that affecting respondents' WTP (β=0.600，p<0.01). So H3 can be accepted, while H1 and H2 are rejected. At the same time, the influence of subjective norm on attitude (β=0.769 p<0.01) and perceived behavior control (β=0.692 p<0.01) are confirmed, so H4 and H5 can be accepted. The initial model can explain 23.9% of the variance in WTP (Figure 6-5).

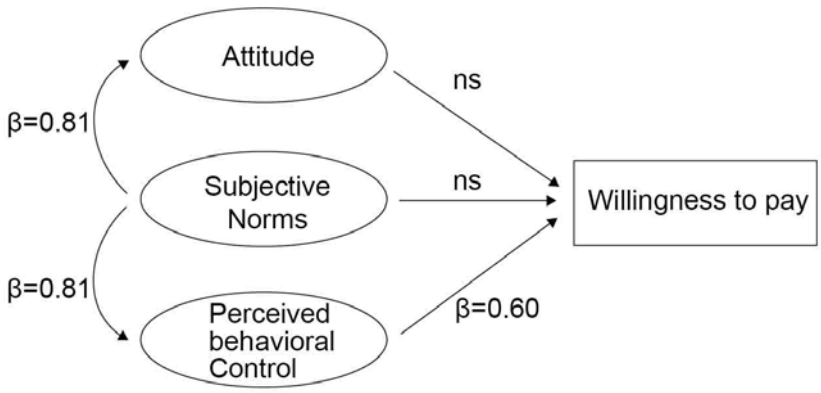

Figure 6-6. Initial TPB model for WTP. (β represents standard regression weight)

The fitness of the expanded structural model can be accepted (chi-square 291.70, RMSEA=0.08 GFI=094, CFI=0.96, NFI=0.96), most of the structural coefficients are significant (p<0.01). Of all

the coefficients, environmental concern appears to have the greatest effect on WTP (β=0.51 P<0.1), followed with perceived behavior control (β=0.43 p<0.01), so H3 and H9 can be accepted. Moreover, the relationship of environmental concern and attitude (β=0.86 p<0.01), subjective norm (β=0.89 p<0.01), and perceived behavior control (β=0.88 p<0.01) can be confirmed, thus accepting H6, H7, and H8. The extended TPB model is able to explain 26.10% of the variance of WTP (Figure 6-6).

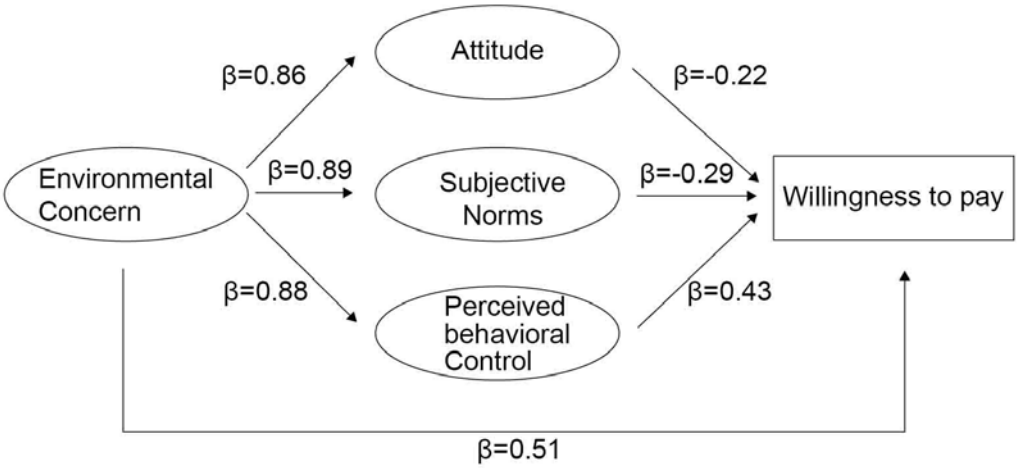

Figure 6-7. Extended TPB model for WTP. (β represents standard regression weight)

6.4.4 Analysis of mediation effects

The indirect effects between constructs were examined. In figure 3, attitude, subjective norm, and perceived behavior control mediate the effect between environmental concern and WTP. Table 4 lists the mediation effects of different mediator. The p-value of the Sobel test indicates that all indirect effects are significant. So we can conclude that attitude (β=0.11 p<0.01), subjective norm (β=0.16 p<0.01), and perceived behavior control (β=0.47 p<0.01) can significantly measure the relationship between environmental concern and WTP. Then H10, H11, and H12 can be confirmed (Table 6-4).

Table 6-4. Indirect effect

variable	Mediator	Dependent variable	value	se	p
Environmental concern	attitude	WTP	0.11	0.01	0.01
Environmental concern	subjective norm	WTP	0.16	0.01	0.00
Environmental concern	perceived behavior control	WTP	0.47	0.01	0.00

6.4.5 Further discussion

The TPB model, which was proposed by I. Ajzen, has been widely used in researches with regard to residents' WTP for environmental goods [11]. This study applied the TPB, for the first time, in predicting residents' WTP for UHI effect mitigation. Since a number of researches indicate that introducing additional constructs to the original TPB model, such as environmental concern, could effectively improve its explanatory power in specific [35, 39, 44], this study estimated and compared the extended TPB model and conventional TPB model. The result has shown that the extended TPB model proposed in this research provides an effective model for predicting WTP for UHI effect mitigation.

The mean WTP indicated that Beijing households are willing to pay 162.97 CHY (23.79 US dollars) annually for urban lake conservation for UHI effect mitigation, which is consistent with the previous CVM study with regard to UHI mitigation [45]. According to the official data, the number of households in Beijing amounts to 5.38 million. If we extended the mean WTP to the entire city, then the total WTP is 877 million. We can judge that the WTP for UHI effect mitigation is strong among Beijing citizens.

It is worth noting that a total of 61.7% of respondents expressed their WTP for UHI effect mitigation, which lies within the ranges obtained in other online questionnaire survey, such as the study of Wang, Gong and Mao [16], where 53.36% of respondents were willing to pay, and Lei and Yang [46], where 70.1% of respondents were found willing to pay. Among those respondents who gave zero responses, about 276 respondents refused to pay because they thought "improving the urban environment is the responsibility of the government", and "the use of the environmental fund is questionable". These protest responses were excluded when processing the data. In addition, the socioeconomic characteristic of residents will also affect their WTP, respondents with higher income are more likely to give positive responses to WTP question.

The extended model of planned behavior reveal the factors that influence the respondents' WTP for UHI mitigation. Firstly, residents' environmental concern was the strongest determinant for predicting respondents' WTP within regard to conserving urban lakes for UHI effect mitigation. The influence of environmental concern has been reported in a number of researches [13, 14], the general conclusion is that environmental concern is the fundamental factor which decides that whether respondents will behave in a pro-environmental way. In our case, it is found that environmental concern will affect the residents' WTP for conserving urban lakes both directly and indirectly, which is in line with previous studies [6, 37, 39].

The next determinant that greatly influences respondents' WTP is perceived behavior control, which is also found in previous TPB studies [9, 47]. Obviously, if residents thought they have the extra resources to contribute to the UHI mitigation, they will be more willing to consume the

environmental goods. Therefore, it is necessary to strengthen the positive belief of those who already thought they are able to contribute for this issue, and change the negative belief of those who thought they do not have the corresponding resource currently.

Compared with the original TPB model, the extended TPB model that included environmental concern has improved the explanative power of WTP, from 23.9% to 26.1%. As for the previous TPB studies, the squared multiple correlations of WTP is mostly in between 20% and 35% [48, 49][50]. It is thus demonstrated that environmental concern contributes to a better explanation of Beijing residents' WTP for UHI mitigation.

Finally, what needs to be emphasized is that the research object of this study is the value of urban lakes in UHI effect mitigation. Therefore, the results cannot be generalized to all approaches that alleviate the UHI effect (urban green space, cool roof, permeable pavement).

6.5 Conclusion

The TPB model proposed by Ajzen [11] was adopted to predict Beijing residents' WTP for conserving urban lakes for UHI effect mitigation. This study provides an extended TPB model by employing the component of environmental concern. According to the experimental result, environmental concern and perceived behavior control significantly and positively affected respondents' WTP. In addition, environmental concern could influence people's pro-environmental behavior directly and indirectly. As is indicated by Wang, et al. [51], the increase in WTP depends on the combined effect of environmental concern and other factors of the extended TPB model. As for socio-economic determinants, residents' income positively correlated with WTP.

Urban managers and environmental activist should try to inform citizens about the causes, hazards of UHI effect along with its mitigation measures. Various media carriers: television, radio, and online media are all helpful in promoting environmental knowledge and pro-environmental behavior, thus increasing citizens' environmental concern. The enhancement of environmental concern will make people feel they have more resources for pro-environmental behavior, which could promote their participation in UHI effect mitigation. At the same time, residents’ WTP various according to their income, policymaker may consider taping the potential source of money for UHI mitigation according to different income level.

Moreover, a large number of protest responses appeared within the questionnaire for respondents doubt the use of the environmental fund, it is necessary to disclose the use of environmental taxation and related information with regard to urban environmental management, which will also enhance public participation.

Concerning future research perspective: 1. Ajzen and Fishbein [52] pointed out that there is a gap

between the intended WTP and the actual WTP, it is necessary to detect how these influencing factors proposed in this study affect the true WTP. 2.This study elicits the value of urban lakes in mitigating the UHI effect, the underlying assumption is that respondents have the ability to distinguish different values of urban lakes (leisure value, aesthetic value, and social value, et al.) within a hypothetical context, which has been criticized by related social-psycho research [53]. More discussion on this "value decomposition" issue is necessary. 3. There are cultural differences among territories. Comparing the influencing factors for supporting UHI mitigation within various cultural backgrounds worth further exploration.

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Chapter 7

CONCLUSION AND POLICY IMPLICATIONS

According to the United Nations report, about 4 billion people in the world live in urban areas in 2011, and by 2050, the urban dwellers are expected to exceed 60%. At the same time, the biophysical characteristics of the city are also changing, which is defined as urban sprawl. This phenomenon is combined with changes in the urban land use.

A number of mitigation and adaption techniques have been proposed, including the installation of cool roof, green roof, and permeable pavement.

However, urban climate factors are often overlooked in urban construction and renewal. One of the important reasons is that policy makers and/or experts responsible for public resources (local municipalities) tend to be more concerned about the economic consequences of a certain urban transformation strategy. Since the total public resources for urban development are limited, if the value of urban heat climate improvement cannot be quantified, then urban development decision makers lack effective evidence for investment. There a missing link between fundamental urban heat climate studies and the economic consequences.

The value of UHI effect mitigation cannot be easily quantified through market-based means. The value of UHI effect mitigation should be defined as non-market value.

Our studies have employed the contingent valuation method – one of the most widely used approach for measuring non-market value, to estimate the value of urban thermal environment improvement. In addition, the theory of planned behavior was applied to explore factors than affecting residents' willingness to pay.

7.1 Conclusion

The research flow of this thesis follows theoretical study – methodological study – experimental study.

Chapter 1 is general introduction, mainly focus on the research background and research purpose. The research of urban heat island mitigation techniques has little effect on urban development policy making, one important reason is that researchers concern about the effect of a specific technique while urban policy makers care more about the economic result of public investments. The purpose of this research is to establishing a missing link between urban climate researchers and policy makers by evaluating the economic value of urban heat island mitigation, and exploring the factors that affecting respondents' willingness to pay.

Chapter 2 is theoretical study, explained the related theoretical background. In this chapter, the reason why urban heat island mitigation has economic value, what is the composition of its economic value, and other related theoretical background with regard to contingent valuation method and theory of planned behavior are introduced. I explained the economic value of urban heat island mitigation from the utility

theory of value and labor theory of value. As for the composition of value of urban heat island mitigation, this study points out that its value is mainly composed of direct use value and non-use value.

Chapter 3 is methodological study, in this chapter a literature review with regard to contingent valuation study of urban green space is conducted. The characteristic of previous studies, the possible flaws of contingent valuation studies, and antecedents of willingness to pay are concluded. It is found that the proportion of studies from developing countries increased rapidly since 2000, the effect of payment vehicle has long be overlooked, and the theory of planned behavior has greatly inspired the researchers in defining the antecedents of willingness to pay.

Chapter 4 explains information with regard to research design, including research site, sample size, design of questionnaire, data collection method, willingness to pay elicitation method, payment vehicle, common method bias, and determinants of willingness to pay. In addition, details of data analysis process are explained, especially the application of spike model with double bounded dichotomous choice format.

Chapter 5 contains three experimental studies in Beijing, which is willingness to pay for promoting green roof, cool roof, and permeable pavement for its effect for mitigating urban heat island effect. The research result indicated that Beijing residents are willing to pay 799 million, 8.823 billion, and 8.128 billion dollars respectively for this three techniques. Compared with the investment of these projects, it can be confirmed that these projects are economically feasible.

Chapter 6 focused on the exploration of factors that affecting residents' willingness to pay. In this chapter we established a prediction model for predicting residents' willingness to pay for the conservation of urban lakes for their effect of mitigating urban heat island effect on the basis of theory of planned behavior. I added the factor of environmental concern other than attitude, perceived behavior control, and social norm. The result indicated that the predictive power of extended prediction model is better compared with the conventional one, and environmental concern can affect residents' willingness to pay both directly and indirectly.

In terms of the theoretical level, this study combs and discussed about the reason why the UHI effect mitigation has economic value through labor economic value theory and subjective economic value theory, proposing that its economic value is composed of use value and intrinsic value. In terms of the methodological level, this study points out that the impact of payment instruments in CVM research has long been overlooked. Among the factors that determining WTP of residents, TPB theory can greatly explain the behavior of residents'' pro-environmental behavior. In terms of the experimental level, the study focus on Beijing residents'' willingness to pay for green roof, cool roof, and permeable pavement in mitigating the UHI effect. The results indicated that Beijing residents are willing to pay 799 million, 8.8232 billion, and 8.128 billion CHY respectively for the promotion of these three techniques.

7.2 Policy implications

Based on the experiments and discussions above, this research provided policy implications as follows:

7.2.1 Establish an environmental public fund

Beijing residents have great willingness to pay for mitigating the UHI effect, a special environmental fund might be established to tap the potential source of money for improving urban thermal environment.

A large number of studies have shown that in China, urban residents have sufficient willingness to support techniques with regard to improving the urban environment [1]. The contingent valuation method is used to explore the willingness of Beijing residents to pay for urban heat wave countermeasures. 637 urban residents and 591 suburban residents were conducted face-to-face interviews. 41.1% of the residents are willing to pay for the protection measures provided by the government, and 39.5% of the residents are willing to pay for the protection measures provided by the market. Most of them are willing to pay 40 CHY per year to support the government's thermal protection measures. In addition, residents' residential area, gender, income, the ownership of air conditioner, past heatwave experience, and whether chronic non-communicable disease will affect residents' willingness to pay at certain degree. In Wang and Mullahy [2], China The residents of Chongqing, China, were asked to pay for improving air quality to reduce fatal risk. 500 Chongqing residents accepted face-to-face interviews. 96% of the residents said they are willing to pay a certain amount of money. The results of the study indicate that each resident is willing to pay an average of 14.3 CHY per year for urban air quality improvement. Residents' willingness to pay will increase as the age of the residents, the monthly income, and the education level increases. Sun, et al. [3] focus on the willingness of Beijing residents to eliminate urban smog. 1051 Beijing residents have accepted a face-to-face questionnaire survey. The results of the study indicate that Beijing citizens are willing to pay an average of 1905.36 CHY per year for smog relief, which accounts for 1% of annual income. The effect of not in my backyard is closely related to residents' willingness to pay. Other determinants, such as average household income, energy expenditures, and economic losses due to haze, have largely affected WTP. In Lo and Jim [4] The willingness of Hong Kong citizens to pay for the protection of urban green space was studied. A total of 495 urban residents were interviewed and the results showed that 70% of respondents have used urban green space during the past week. Most urban green space users were accompanied with family members or children. Exercising and enjoying the fresh air is the main purpose of visiting the urban green space. Respondents were asked if they were willing to pay a certain amount of money to prevent about 20% of the green space loss in their surrounding area. 80% of respondents indicated that they are willing to pay a certain amount of money, and the average monthly payment amount is 9.9 USD. Chinese residents are increasingly willing to pay extra money for high-quality urban habitats.

Public funds can help to improve the urban environment to a large extent, while some studies indicate that there might be problems during the employment of public funding. Dinnie and Holstead [5] pointed out that public funding is very important for sustainable development, especially when it was based on community-based initiatives, and indicate the technical and management problems that community-based initiatives may encounter in accepting public funding, including how to balance the rights and obligations of the recipients and the funders. Some studies have shown that in some citizen co-funding public projects, government intervention can increase the information asymmetry between operators and investors, and greatly improve the success rate of such projects. Based on this, the third party organization accepts public funding, while the government acts as a coordinator to reduce the information asymmetry seems to be a viable way to use public funds for improving the urban thermal environment.

7.2.2 Promote related CVM studies

Although WTP research on urban environment has made great progress in recent years, WTP research with regard to UHI effect mitigation is very limited. More CVM research on mitigating the UHI effect is necessary for these studies can provide a new evidence for the formulation of relevant policies.

As for researches on Chinese residents' willingness to pay for urban environment. Most of the previous studies focuses on the improvement of urban air quality [6-8], protection of urban green space and water system [4, 9, 10], and urban waste treatment [11-13]. However, there is no research on the willingness to pay with regard to urban thermal environment improvement.。

This study is only a preliminary exploration. The limitation is that residents of different residential types may act differently when paying for heat island effect mitigation techniques, such as green roofs and cold roofs. Residents living in detached houses may be more inclined to pay for their own roofs, while residents in high-rise apartments are more reluctant to pay for such projects because of the lesser gains from rooftop benefit. In addition， Non-market valuation is an approach that assigning the value to environmental goods and services, which cannot be easily traded in the market. In our case, it is the benefit of mitigating UHI effect with green roof. The CVM, which is the most widely used approach for estimating non-market, has long been criticized as methodologically flawed. One of the key issues is the existence of “protest response”, which means respondents refuse to pay for protesting some aspect of the valuation process instead of valuing the environmental goods and services as zero [14]. Censoring and excluding protest response samples are a commonly shared method to avoid concept inconsistence and underestimation of WTP value. In our research, respondents who protest the valuation process, the payment vehicle, or who distrust the government and believe that paying for environmental quality is not the responsibility of citizens were considered as “protest responses” and was excluded from further analysis. Finally, more possible

variables of the predictive model of residents' willingness to pay needs to be explored. Other than the new variables proposed in this study, some studies have shown that variables such as environmental knowledge have considerable effects on residents' pro-environmental behaviors [15-17]. The impact of these variables on residents' willingness to pay deserves further exploration.

7.2.3 Timely disclosure of environmental information

More than 80% of respondents said they need more information about relevant environmental monitoring data and government information on managing environmental funds, which can be regarded as insufficient trust for the government. In order to improve residents' participation in urban environmental improvement, timely disclosure of related information is necessary, especially the use of environmental protection funds.

Many scholars and institutions have already made certain explorations in the disclosure of environmental information of the Chinese government, especially the disclosure of environmental information. The study of MEP [18] shows that the Chinese government's information disclosure has made some progress since the promulgation of the Government Information Transparency Act. The Institute of Public & Environmental Affairs (IPE) and the Natural Resources Defense Council (2009) developed a Pollution Information Transparency Index (PITI) assessed the degree of government information disclosure in 113 cities in China. The results show that the eastern developed provinces have higher government information disclosure than the less developed provinces in the central and western regions. Zhang, et al. [19] studied the information disclosure status of the environmental protection departments of different provinces and the Ministry of Environmental Protection after six months of the promotion of the Chinese Government Information Disclosure Act. Research results show that the government information disclosure system is still need to be perfected. Kosajan, et al. [20] employed entire-array-polygon to assess the performance of the Chinese government in the disclosure of environmental information The results show that the environmental information disclosure status of all provinces in China can only be rated as "general", and no province can be rated as "excellent", which indicates that the Chinese government's environmental information disclosure system still needs further improvement.

The future direction of improvement should be the promotion of relevant regulations to promote public participation and establish an independent monitoring and evaluation system [21], and enhancing the exchange of experience between different environmental protection departments and strengthen the legal status of environmental information disclosure [19].

7.2.4 Promote the education with regard to urban heat island effect

The enhancement of knowledge of UHI effects is urgent. Environmental knowledge can greatly affect people's pro-environmental behavior [15]. About 70% of the residents who have an

understanding of the UHI learn about related information through television and online.

Although China's environmental protection education has made some progress in recent decades, there are still many shortcomings. Xiong, et al. [22] analyzed the curricula of 267 out of 810 public universities and colleges in China- a sample of 30% from each of the 12 different type. The results show that nearly 20% of the samples did not establish a systematic environmental education system. Compared with forestry, agronomy and related majors, linguistics, art and physical education are even more lacking in environmental protection education. In addition, compared with universities directly managed under the Ministry of Education, provincial or local municipal colleges and universities perform more poorly.

Some regional governments and institutions have made some attempts in the sustainable development education model. Gao, et al. [23] explored a regional sustainable education framework with three-levels, which is top managers of companies and policy makers of government, representatives of companies and government, and the public. The educational framework was flexible and comprehensive, endeavoring to ensure a demand-oriented and need-based approach to the local sustainability improvement.

In urban environmental education, on the one hand, green education courses need to be implemented more widely in university education and make the concept of sustainable development deeply rooted in minds [24]. Some studies have shown that the role of NGOs in environmental protection should also be fully valued [25]. Other studies have pointed out the importance of information carriers, various information carriers should be encouraged to promote the dissemination of environmental knowledge [26].

7.2.5 Enhance the individual awareness in pro-environmental activities

It is necessary to put more effort in promoting individual awareness in participating in pro-environmental activities. We should encourage various information carriers with respect to individual awareness in UHI mitigation, especially the emerging mobile electronic devices.

Some studies and show that public participation affects environmental protection and ecological efficiency to a certain extent in China. Tu, et al. [27] explore impacts of public participation on pollution and environment efficiency，with the result of government administrative measures still play essential role at current stage Public participation impact exists in the east rather than in central and west China. Zhang, et al. [28] indicated that public environmental participation behavior measured by the number of complaint letter has no impact on the public's own living environment, while the number of proposals from members of the Chinese People's Political Consultative Conference (CPPCC) does. Moreover, the public participation policy plays a significant role in improving environmental governance.

As for strategies for promoting public participation, on one hand, provincial and local governmentsshould improve their information disclosure mechanisms and establish a good interaction mechanism between citizens and bureaus of environmental protection. The Ministry of Environmental Protection (MEP) at the national level should rigorously monitor policy enforcement of BEPs at the province and local levels. In addition, government should use relevant laws and regulations that have been promulgated to further improve institutional mechanisms for public environmental participation, consolidate the public's environmental participation rights, expand the scope and channels of public environmental participation. On the other hand, the government should not only enact public environmental participation policies, but also establish a system to monitor the implementation of policies. Enforcement of public environmental participation policies can protect public participation behavior, and thus create a better environment for citizens [28].

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APPENDIX 1. REVIEW OF WTP FOR CLIMATE VALUE OF URBAN GREEN SPACE

Author(s) and year of publication	Country	Research focus	Data collection	WTP elicitation	Type of UGS	Payment vehicle
Saz-Salazar and Rausell-Köster (2008)	Spain	1 and 2	Face to face	OE	Parks and gardens	Tax
Lopez-Mosquera et al. (2014)	Spain	1 and 2	Face to face	SBDC	Parks and gardens	Tax
Treiman and Gartner (2006)	USA	1 and 2	Mail	SBDC	Natural and semi-natural	Tax
Lorenzo et al. (2000)	USA	1 and 2	Mail	OE	Natural and semi-natural	Tax
Damigos and Kaliampakos (2003)	Greece	1 and 2	Face to face	OE	Natural and semi-natural	Not indicated
Chen et al. (2006)	China	1 and 2	Face to face	PC	Not specified	Tax
Zhang and Zheng (2011)	USA	1 and 2	Mail	OE	Natural and semi-natural	Donation
Tran et al. (2017)	USA	1 and 2	Mail	OE	Natural and semi-natural	Not indicated
Soto et al. (2018)	USA	1	Not indicated	CE	Natural and semi-natural	Tax/ program fee

Jetter and Paine (2004)	USA	1 and 2	Mail / telephone	PC	Not specified	Tax
Bamber B R (1999)	UK	1 and 2	Face to face	OE	Not specified	Tax
Verbič et al. (2016)	Slovenia	1 and 2	Face to face	DBDC	Green corridor	Tax
Tyrväinen (2001)	Finland	1	Mail	PC	Natural and semi-natural	Entrance fee/ Tax
Gürlük et al. (2012)	Turkey	1 and 2	Face to face	PC	Natural and semi-natural	Not indicated
Sato et al. (2017)	Japan	1 and 2	Mail	DBDC	Natural and semi-natural	Donation
López-Mosquera and Sánchez (2011)	Spain	1 and 2	Face to face	SBDC	Natural and semi-natural	Entrance fee
Ponce et al. (2011)	Chilean	1 and 2	Face to face	OOHB	Parks and gardens	Not indicated
del Saz Salazar and García Menéndez (2007)	Spain	1 and 2	Telephone	SBDC	Parks and gardens	Tax
Kwak et al. (2003)	Korea	1 and 2	Face to face	SBDC	Natural and semi-natural	Tax
Brandli et al. (2015)	Brazil	1 and 2	Face to face	Not indicated	Parks and gardens	Tax

Vollmer et al. (2016)	Indonesia	1	Face to face	CE	Green corridor	waste collection fee/ security fee
Poudyal et al. (2015)	USA	3	Mail/web/ telephone	PC	Natural and semi-natural	Carbon credit
Giergiczny and Kronenberg (2014)	Poland	1	Face to face	CE	Green corridor	Tax
Newburn and Alberini (2016)	USA	1 and 2	Mail	SBDC	Community gardens	Payment for rain garden
Kovacs and Larson (2008)	USA	1 and 2	Mail	DBDC	Parks and gardens	Water bill
Wang et al. (2018)	China	1 and 2	Not indicated	DC	Not specified	Property fees / special securities fee
Kim et al. (2016)	Korea	1	Face to face	CE	Natural and semi-natural	Tax
Tu et al. (2016)	France	1 and 2	Face to face	CE	Natural and semi-natural	Housing expenses
Willis (2003)	UK	1 and 2	Face to face	IB	Parks and gardens	Entrance fee
Zhang et al. (2007)	USA	2	Telephone	SBDC	Not specified	Donation
Tameko et al. (2011)	Cameroon	1 and 2	Face to face	SBDC	Parks and gardens	Entrance fee
Lo (2012)	China	3	Not indicated	Not indicated	Not specified	Not indicated

Yeo et al. (2013)	Malaysia	1 and 2	Face to face	SBDC	Parks and gardens	Entrance fee
Caula et al. (2009)	France	1 and 2	Others	PC	Natural and semi-natural	Not indicated
Lopezmosquera and Sanchez (2011)	Spain	1 and 2	Face to face	SBDC	Natural and semi-natural	Entrance fee
Lopez-Mosquera and Sanchez (2012)	Spain	1 and 2	Face to face	SBDC	Parks and gardens	Entrance fee
Dare et al. (2015)	Nigeria	1 and 2	Not indicated	SBDC	Natural and semi-natural	Tax /direct collection /maintenance levy
Breffle et al. (1998)	USA	1 and 2	Face to face	SBDC	Natural and semi-natural	Not indicated
Maxwell (1994)	UK	1 and 2	Face to face	IB	Natural and semi-natural	Entrance fee/trust fund/hire fee
Pepper et al. (2005)	Australia	1 and 2	Mail	SBDC	Natural and semi-natural	Tax
Vecchiato and Tempesta (2013)	Italy	1	Face to face	CE	Natural and semi-natural	Tax
Latinopoulos et al. (2016)	Greece	1 and 2	Face to face	DBDC	Parks and gardens	Tax

Hanley and Knight (1992)	UK	1 and 2	Face to face	OE	Green corridor	Trust fund
Dumenu (2013)	Ghana	1 and 2	Not indicated	OE	Natural and semi-natural	Donation
Sirina et al. (2017)	France	1 and 2	Face to face	Not indicated	Parks and gardens	Donation
Maleknia et al. (2013)	Iran	1 and 2	Face to face	IB	Natural and semi-natural	Entrance fee
Lo and Jim (2010)	China	1 and 2	Face to face	PC	Not specified	Not indicated
Popoola and Ajewole (2002)	Nigeria	1 and 2	Not indicated	PC	Natural and semi-natural	Not indicated

Research focus: 1= willingness to pay 2= Antecedents 3= others

Dichotomous choice (DC); Open-ended (OE); Payment Card (PC); Double-bounded dichotomous choice (DBDC); Single-bounded dichotomous choice (SBDC);

One and half hounded dichotomous choice (OOHB) Iterative Bidding game (IB)

APPENDIX 2. QUESTIONNAIRE FOR ONSITE INTERVIEW (TAKE WILLINGNESS TO PAY FOR COOL ROOF AS EXAMPLE)

Beijing households' willingness to pay for cool roof for mitigating the urban heat island effect

Announcement:

This research is conducted by Fukuda laboratory of the department of Architecture Design, the University of Kitakyushu, Japan.

We will use the interview result only as research materials. Individual data will not be leaked to the outside world. We will appreciate your cooperation in the following survey.

In addition, if there is a request, we would offer the statistical processing result to institution and individual that participated in the interview. And a small gift would be offered at the end of the interview.

Thanks for your kind cooperation

Yours sincerely

Zhang Li

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Person in charge: Doctor Grade two Li Zhang Tel: (81) 090-1369-8821

Introduction:

Urban heat island (UHI) effect, which is, the significant difference of temperature between urban and suburban area. This phenomenon reduces the thermal comfort of urban residents significantly, increases energy consumption in summer and worsens air quality.

Beijing city has been developed rapidly during the past decades and the UHI effect is significant. A long-term measured weather dataset from 1961 to 2014 has indicated that the UHI effect in Beijing is significant, with an urban-to-rural temperature difference of up to 8°C during the winter nighttime, Relevant studies reported the UHI intensity of Beijing fluctuated from 5.37 ℃ to 9.27 ℃ from 1991 to 2011. UHI effect has been one of the main environmental problem posed to Beijing citizens.

Replacing conventional roofs with high albedo materials to reduce the absorption of solar radiation has become an important mean to alleviate the UHI effect. Cool roof is defined as the roof with high solar reflectance (ability to reflect sunlight, spectrum 0.3–2.5 μm) and high thermal emittance (ability to emit thermal radiation, spectrum 4–80 μm). The effectiveness of this approach has been tested in situ and simulated with different urban scales in China. Experimental research in Beijing indicated that cool roof can reduce building roof surface temperature by as much as 17 degrees by increasing solar reflectance form 0.20 to 0.80.

Questionnaire:

1.Your gender：

○Male

○Female

2.Your income：

○Less than 4000

○Over 4000

3.Your age：

○<30

○30-50

○>50

4.Your residential area：

○Dongcheng

○Xicheng

○Chaoyang

○Fengtai

○Shijingshan

○Haidian

○Fangshan

○Tongzhou

○Shunyi

○Daxing

○Changping

○Pinggu

○Miyun

○Huairou

○Mentougou

○Yanqing

5.Do you have a job currently：

○Yes

○No

6.Your family size：

○Less than 3

○Equal or more than 3

7.Your education level：

○Lower than college education level

○College level or higher

8. Are you raising children currently?

○Yes

○No

9. What is attitude towards urban environmental issues?

○Very concerned

○Not concerned so much

10. How do you know about the hazards of urban heat island effect?

○Know very well

○Don’t know very well

11. How do you know about the effect of cool roof in mitigating urban heat island effect?

○Know something about it

○Don’t know anything about it

12. Your health condition?

○Very good

○Not so good

13. Do you think you have extra energy or resources for participating in urban environmental issues?

○Yes

○No

14. Do you think your family or friends will support your pro-environment behavior?

○Yes

○Might not

If Beijing government is going to replace 10% of building roof of Beijing into cool roof (approximately 20 million m^2) , is your household willing to pay a certain amount by increasing the personal income tax for the next 7 years?（This survey is only a partial reference for the government's policy development. The sampling size is over 1000. Please answer this question according to your family's income status.）

15. Are your household willing to pay 200 CHY annually for the next 7 years?

○Yes (If people chose this, then ask question 16)

○No (If people chose this, then ask question 17)

16. Are your household willing to pay 400 CHY annually for the next 7 years?

○Yes (If people chose this, interview is over)

○No (If people chose this, interview is over)

17. Are your household willing to pay 100 CHY annually for the next 7 years?

○Yes (If people chose this, interview is over)

○No (If people chose this, then ask question 17)

18. Are your household willing to pay a certain amount for the next 7 years?

○Yes (If people chose this, interview is over)

○No (If people chose this, then ask question 19)

19. Why you refuse to pay for this project?

○Government should be responsible for this project

○Distrust the use of the fund

○Not able to support this project currently

○This project is not worth funding

○Others _____ *

Thanks for your cooperation!

APPENDIX 3. PROGRAM IN R LANGUAGE FOR COMPUTING MEAN WILLINGNESS TO PAY AND ANTECEDENTS（TAKE WILLINGNESS TO PAY FOR COOL ROOF AS EXAMPLE）

```
library(numDeriv)
data <- read.csv('data.csv',header = TRUE,sep = ',')
n = dim(data)[1]
lnL <- function(x){
   result <- 0
   x_alpha = x[1:16]
   x_beta = x[17]
   for(i in 1:n){
      data_i <- c(1,as.numeric(data[i,1:15]))
      alpha <- x_alpha %*% data_i
      Gc_u <- 1 / (1 + exp(alpha - x_beta * data[i,16]))
      Gc <- 1 / (1 + exp(alpha - x_beta * data[i,17]))
      Gc_d <- 1 / (1 + exp(alpha - x_beta * data[i,18]))
      Gc_0 <- 1 / (1 + exp(alpha))
      YY <- data[i,19]


      YN <- data[i,20]
      NY <- data[i,21]
      NNY <- data[i,22]
      NNN <- data[i,23]
      lnl <- YY * log(max(1 - Gc_u,1e-323)) + YN * log(max(Gc_u - Gc,1e-323)) + NY * log(max(Gc - Gc_d,1e-323)) + NNY * log(max(Gc_d - Gc_0,1e-323)) + NNN * log(Gc_0)
      #lnl <- YY * log(1 - Gc_u) + YN * log(Gc_u - Gc) + NY * log(Gc - Gc_d) + NNY * log(Gc_d - Gc_0) + NNN * log(Gc_0)
      result <- result - lnl
   }
   return(result)
}
```

```
par <- c(0.01,numeric(15),0.002)

opt <- optim(par = par,fn = lnL,method = 'BFGS',hessian = TRUE)
s <- numeric(0)
cov <- solve(opt $ hessian)
for(i in 1:17){
   s[i] <- cov[i,i]
}

value <- opt $ par
t <- value / (sqrt(s))
p_value <- 2 * (1 - (pt(abs(t),n - 2)))

Likehood <- -lnL(value)

spike_f <- function(x){
   result <- 0
   for(i in 1:n){
      data_i <- c(1,as.numeric(data[i,1:15]))
      alpha <- x %*% data_i
      spike <- 1 / (1 + exp(alpha))
      result <- result + spike
   }
   spike <- result / n
   return(spike)
}

WTP_f <- function(x){
   result <- 0
   x_alpha <- x[1:16]
   beta <- x[17]
   for(i in 1:n){
```

```
    data_i <- c(1,as.numeric(data[i,1:15]))
    alpha <- x_alpha %*% data_i
    WTP <- log(1 + exp(alpha)) / beta
    result <- result + WTP
  }
  WTP <- result / n
  return(WTP)
}

alpha <- value[1:16]
beta <- value[17]
spike <- spike_f(alpha)
s_spike <- t(grad(spike_f,alpha)) %*% cov[1:16,1:16] %*% grad(spike_f,alpha)
t_spike <- spike / sqrt(s_spike)
p_spike <- 2 * (1 - (pt(abs(t_spike),n - 2)))

WTP <- WTP_f(value)
s_WTP <- t(grad(WTP_f,value)) %*% cov %*% grad(WTP_f,value)
t_WTP <- WTP / sqrt(s_WTP)
p_WTP <- 2 * (1 - (pt(abs(t_WTP),n - 2)))
mtcc <- rnorm(5000,WTP,sqrt(s_WTP))
interval_95 <- quantile(mtcc,probs = c(0.025,0.975))
interval_99 <- quantile(mtcc,prob = c(0.005,0.995))

wald <- t(value) %*% opt $ hessian %*% value
p_wald <- 1 - pchisq(wald,14)

result <- data.frame(matrix(0,23,4))
result[1:17,1] <- c('constant',colnames(data)[1:15],'beta')
result[18:23,1] <-
c('spike','MTP','MTP_interval_95','MTP_interval_99','wald_statics','Likehood')
result[1:17,2] <- value
result[1:17,3] <- t
```

```
result[1:17,4] <- p_value
result[18:23,2] <- c(spike,WTP,interval_95[1],interval_99[1],wald,Likehood)
result[18:23,3] <- c(t_spike,t_WTP,interval_95[2],interval_99[2],",")
result[18:23,4] <- c(p_spike,p_WTP,",",p_wald,")
colnames(result) <- c('Variables','values','t_values','p_values')

write.csv(result,'all_variables.csv')
```