

ORIGINAL RESEARCH ARTICLE

Investigating residents' willingness to participate in urban edible landscaping: Perspectives from China

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ABSTRACT

In the context of the persistent food crisis and shifting societal dynamics, the concept of 'edible landscaping' has garnered increasing attention. Edible landscaping entails integrating food production into urban green spaces, offering a novel approach to address both food security and environmental sustainability. However, in China, conflicts regarding urban green spaces have arisen due to inadequate legal frameworks and management strategies. Gaining a better understanding of residents' behavioral intentions and willingness to participate will provide support for future intervention measures by decision-makers. This study proposes an extended model based on the Theory of Planned Behavior to investigate the effects of individual attributes on behavioral intentions. An online questionnaire survey was conducted in Hefei, China, for hypothesis verification. The findings indicate that residents' intention to participate in edible landscaping is influenced by perceived benefits and costs, attitudes, perceived behavioral control, and subjective norms. Multi-group analyses reveal the moderating effects of past behavior, age, and gender on the proposed models. This study underscores the significance of promoting the benefits of edible landscaping while mitigating unfavorable factors. Additionally, it is important to consider the specific needs of different population groups. These findings have practical implications for future planning, implementation, and management of edible landscaping initiatives.

Keywords: edible landscaping; sustainability; urban agriculture; Theory of Planned Behavior; structural equation model

1. Introduction

Humanity has faced numerous global food crises since the dawn of the twenty-first century. The Global Food Crisis Report 2023 highlights that over 258 million people in 58 countries and regions affected by food crises will require emergency food assistance by 2022^[1]. The projected increase in the world population by two billion over the next 30 years, reaching 11 billion by 2100^[2], will further intensify the demand for food, exacerbating the food crisis. Additionally, escalating global urbanization is resulting in the expansion of cities, encroaching on agricultural land, and depleting available arable land and agricultural labor. The 2019 coronavirus pandemic has further compounded the global food crisis by disrupting supply chains, agriculture, and trade activities^[3]. Strict embargo measures have triggered panic buying and supply restrictions, resulting in short-term food shortages^[4]. Future challenges such as transportation issues, export restrictions, and labor shortages resulting from disasters like pandemics will amplify the crisis^[5]. Consequently, the focus on urban

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food security and sustainable development has gained multidisciplinary attention in the face of rapid global population growth, increasing urbanization, and the post-pandemic era^[6].

In the post-pandemic era, it is essential to transform conventional cities into resilient and sustainable urban environments in response to various risks, including nationwide outbreaks of infectious diseases and global disasters^[7]. The rapid spread of COVID-19 and the resulting measures to contain it have severely disrupted people's normal lives^[8]. In many nations, individuals were asked to stay at home during lockdowns, with a significant emphasis on remote work. Those potentially exposed to the virus experienced greater social isolation, which can lead to mental health issues and heightened feelings of loneliness^[9]. According to a large-scale sample survey conducted in China, the COVID-19 pandemic may have a significant impact on people's mental health^[10]. In the post-pandemic era, it is crucial to consider people's spiritual needs with the same level of attention. This expanded perspective introduces a "new nexus" that encompasses culture, art, and exchange, in addition to the conventional focus on water, food, and energy^[7]. The new nexus concept recognizes that human well-being extends beyond survival needs and underscores the significance of spiritual affairs.

Within this context, the emerging concept of urban edible public resources offers the potential for pandemic crisis recovery and enhancing cities' resilience against future disruptions^[11]. Recent research has shown that engaging in gardening activities effectively alleviates the stress induced by the pandemic and promotes psychological well-being^[12]. The integration of urban edible landscaping (EL) resources not only lays the groundwork for a more secure and robust food system but also offers residents an enriched experience encompassing culture, art, recreation, and social interaction^[13]. **Figure 1** illustrates the relationship between the two types of nexus(es) and urban edible landscaping. EL, as a sustainable approach embedded within the new local design paradigms, fulfills not only the indispensable physical requisites for survival but also elevates the fulfillment of spiritual and cultural aspirations. This study evaluates residents' perspectives on adopting EL within the framework of both conventional and new nexuses, with a specific focus on their perceived benefits and costs.

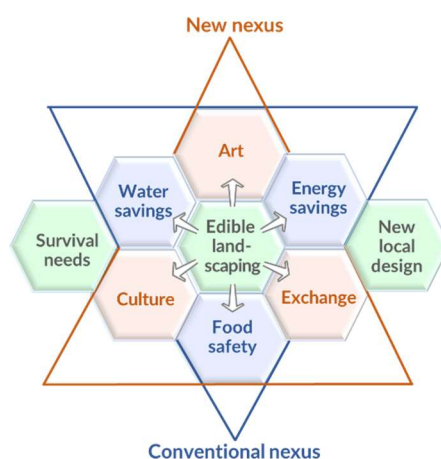


Figure 1. Relationship of nexus and edible landscaping (EL).

EL, including community gardens, has garnered international recognition and attention. In Japan, the Edible Way project utilizes public space to bring people closer to the city^[14]. In Germany, roof water farms use wastewater and rainwater to provide vegetables for local residents^[15]. Edible Garden City in Singapore builds and maintains artfully designed edible gardens for schools and communities, with the purpose of reconnecting people with nature and cultivating a profound sense of community, all while appreciating the vital roles of art and beauty^[16]. A UK study emphasized the importance of both formal and informal edible

landscapes within schools, serving as the foundation of the institutional culture^[17]. These examples highlight the benefits of EL, as studies have shown its positive impact on food security, social cohesion, health improvement, and biodiversity conservation^[18–21].

In China, the presence of EL has sparked conflicts and disputes over land use, particularly regarding the occupation of public land by new urban residents from rural areas during city expansion^[22]. These challenges stem from imperfect policies, agricultural development, and management practices. Unlike Japan, which has a well-established history of urban agriculture with laws dating back to the 1930s and specific regulations implemented in 2015^[23], China only established policies related to urban agriculture in 2015 and has yet to introduce specific regulations^[24,25]. Moreover, in China, where EL is predominantly small-scale, the organization is often community- or individually-driven, leading to potential conflicts among different interest groups. Unlike the private ownership model in many developed countries, land ownership in China is primarily state-owned or collectively owned, further contributing to disputes over land use and interests. Developed countries have implemented corresponding regulations and specialized management departments to address these issues. To mitigate gardening disputes, a comprehensive planning system and management strategy are considered potential solutions^[26]. Since city residents are the primary participants in edible landscape activities, decision-makers should pay attention to their willingness to participate in order to formulate better regulations and management systems.

Existing research on urban residents' behavior, motives, and willingness to participate in such initiatives is limited. Zheng et al.^[27] explored community residents' support for using public land for gardening activities and the underlying reasons. Another study discussed the drivers of residents' engagement in informal activities and proposed conflict resolution suggestions^[22]. However, these lack a comprehensive theoretical model to fully explain residents' behavioral intentions. A recent study by Wu et al.^[28] presented a theoretical framework for examining how residents perceive ecosystem services and disservices and how these perceptions influence their behavioral intention towards urban community gardens in China^[28]. However, the influence of individual characteristics on the behavioral intention model of residents' willingness to participate in EL has not been considered.

This study aims to understand the predictive factors of residents' willingness to participate in EL and attempts to bridge the research gap in two ways. Firstly, we develop an extended Theory of Planned Behavior (TPB) model to explore the predictors influencing residents' behavioral intention, including residents' perceived benefits and costs. Secondly, this paper identifies the moderating factors that influence the relationship between predictors and behavioral intentions, including residents' personal attributes such as past behaviors, gender, age, and education. This study seeks to inform policymakers and planners about the determining factors shaping residents' behavioral intentions, thereby facilitating the development of better policies and the resolution of existing conflicts.

2. Theoretical framework and hypothesis development

This study adapted the Theory of Planned Behavior Model (TPB) as a basic framework and proposed an extended model by considering additional factors, including perceived benefits and costs. It also considered the potential moderating effect of individual attributes on the model to adapt to the research context and enhance the explanatory power of the model to explain the underlying reasons for behavior.

2.1. Theory of Planned Behavior

The Theory of Planned Behavior is one of the most extensively utilized social-psychological models in the literature. TPB has become one of the most mentioned and influential models for predicting human social

behavior^[29]. TPB suggests that behavior is influenced by behavioral intention. Based on TPB, attitudes, subjective norms, and perceptions of behavior control are the three factors that have the greatest impact on the development of behavior^[30]. Attitudes refer to the degree to which a person positively or negatively evaluates their behavior^[30]. Subjective norm refers to the social pressure an individual experiences while carrying out a certain behavior, which significantly influences their specific behavioral choices^[31]. Perceived behavioral control refers to an individual's perception of the difficulty or ease of performing a certain behavior, as well as the extent to which the execution of such behavior is subject to personal volition^[32]. Specifically, if an individual has a more positive attitude towards a particular behavior or perceives greater external pressure to perform that behavior, they will feel more control over that behavior and be more willing to engage in it^[30]. In past research, TPB has often been used to study willingness to participate in many areas, like consumer intention^[33], sport event^[34], and green behavior^[35]. In the context of EL, the influence of residents' attitudes, perceived beliefs, perceived social norms, and perceived control beliefs towards EL can predict their willingness to participate in it. Therefore, based on the TPB theory, hypotheses 1–3 have been adopted in this research:

H1: Attitudes (ATT) toward EL have a positive influence on residents' behavioral intentions (BI).

H2: Subjective norm (SN) has a positive influence on residents' behavioral intention (BI).

H3: Perceived behavioral control (PBC) has a positive influence on residents' behavioral intention (BI).

Steg and Vlek^[36] summarized in their review that individual motivations to engage in environmental behavior are influenced by weighing costs and benefits. When individuals hold a positive evaluation of a particular behavior and believe it will lead to desirable outcomes, they are inclined to evaluate the behavior positively, resulting in a positive attitude^[37]. Similarly, if individuals perceive that a certain behavior will result in negative consequences and costs for them, it will affect their development of negative attitudes. Resident attitudes towards EL are based on their perception of potential outcomes. Residents' perceptions of the benefits of food, nutrition, and ecological regulation provided by EL can have a positive impact on their attitudes toward EL. However, perceived costs such as ecological environment damage, maintenance costs, community disruption, and controversy can have a negative impact on residents' attitudes towards EL. Hence, we define perceived benefits of EL as residents' belief that EL can bring leisure and stress relief, provide food, bring visual aesthetics, and strengthen community cohesion. Perceived costs of EL refer to residents' belief that EL could cause ecological damage, occupy public land, and bring management chaos and disputes. These lead to the following hypotheses:

H4: Perceived benefits of EL have a positive influence on attitudes (ATT).

H5: Perceived costs of EL have a negative influence on attitudes (ATT).

Awareness of consequences has an important and direct impact on individual, social factors, and intentions in TPB and indirectly affects behavior^[38]. Their willingness to engage in EL behavior is based on their pre-cognitive perception of possible outcomes. When residents perceive the benefits of EL, it exerts a positive influence on individual behavioral intentions. Conversely, instances where EL contributes to management confusion and gives rise to conflicts of interest within the group can hinder participation. Therefore, we can draw the following conclusion:

H6: Perceived benefits of EL have a positive influence on residents' behavioral intentions (BI).

H7: Perceived costs of EL have a negative influence on residents' behavioral intentions (BI).

When residents harvest food or relaxation from the EL, it can somewhat compensate for the costs of conflict and disruption, and in turn, the costs can offset some of the benefits. In a word, benefits and costs are inversely proportional to each other, so we can conclude the following:

H8: Perceived benefits and costs are negatively associated with each other.

2.2. Moderating variables

Most studies on the impact of moderating variables in TPB focus on social demographic factors, with gender and age being two commonly used demographic variables^[39,40]. The research on the gendered nature of home gardens indicates that there are indeed differences in gardening behavior and attitudes between women and men^[41]. Similarly, a study conducted in Wuhan, China, revealed that women are more supportive of community gardens compared to men^[26]. This could be due to social roles and expectations; women are frequently given nurturing and caregiving responsibilities. Women are more likely to be interested in and supportive of EL because gardening and planting are closely related to women's roles in the home. Research has shown that older people are more engaged in gardening activities, and the most common reasons for their involvement are pleasure and enjoyment^[42]. Gardening can give older people physical exercise, fresh air, and sunlight, all of which are very beneficial for their health and well-being. Community gardens allow older people to form emotional bonds with other residents, which is important because older adults have a greater need for emotional connections and community engagement.

Additionally, based on past research, we have incorporated past behavior as an additional moderating variable into the proposed model. Past behavior, as well as situational and motivational factors, may independently influence both this and future decisions^[43]. All other influences being equal, people's past behavior is usually a predictor of their future behavior^[44,45]. China's rapid urbanization has led to a massive influx of farmers into the cities, and some of these new residents retain their past farming activities or hobbies of farming and gardening. As a result, this study takes into account previous farming and gardening behaviors and preferences that may influence the behavioral intentions of eventual residents.

Based on these findings, we believe that past behavior, gender, and age may have moderating effects on the model of behavioral intention. Based on this, we propose the following hypotheses: The comprehensive model with proposed hypotheses is presented in **Figure 2**.

H9: The impact of predictive factors on the intention to participate varies with past behavior, gender, and age.

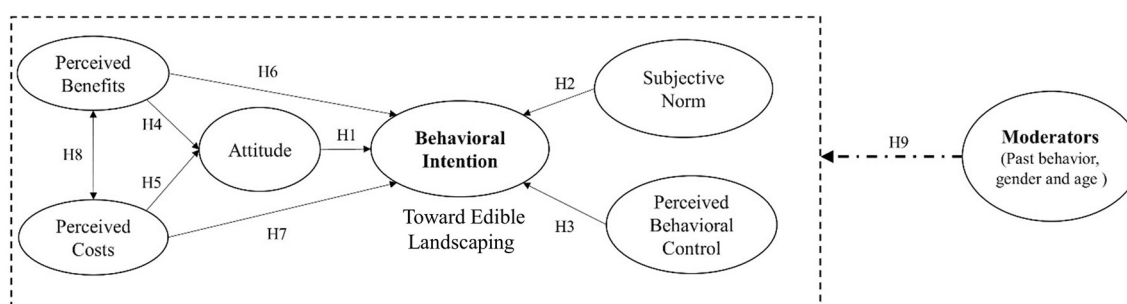


Figure 2. The proposed model.

3. Methods

3.1. Participants and data collection

This study collected data in the city of Hefei, Anhui Province. Hefei is in the Yangtze River delta area, with a population of 9.634 million and a built-up area of 11,445 km². The study area focuses on the main city area of Hefei. Since 2016, the Hefei government has issued many laws and regulations related to urban agriculture. The Hefei government has provided policy support for the construction of EL, and there is a

movement called Shared Community Garden that organizes residents to adopt vacant land and plant EL. This study chose Hefei as the study area because the development of EL here is in the initial stage in China and has achieved a supportive government environment.

An online survey was conducted from February to May 2023 in Hefei. The survey contents, including variables and item descriptions, were designed by the authors, and the questionnaires were distributed through a professional online survey service provider, Chengdu Beiyantong Information Technology Co., Ltd. The company's strict confidentiality regulations for personal information and incentive measures for participation help to reduce potential bias. In this survey, this questionnaire has been translated into Chinese and targets citizens residing in Hefei. When selecting interviewees, we strive to ensure a balanced distribution of groups based on gender, age, etc. The questionnaires were distributed through online platforms such as WeChat applications within community groups in the study area. A total of 410 questionnaires were collected, and after excluding the incomplete and erroneous ones, 375 valid questionnaires were obtained, yielding a response rate of 91.46%.

The respondents' characteristics are shown in **Table 1**. The sample profile of the respondents includes their gender, age, education level, and past behavior. The interviewees consisted of 194 males (51.7%) and 181 females (48.3%), with a relatively balanced gender ratio. Among them, 66 were under 20 years old (17.6%), 107 were between 20 and 39 years old (28.5%), 140 were between 40 and 59 years old (37.3%), and 62 were over 60 years old (16.5%). 21 interviewees had a master's degree or above (5.6%), and 142 had a bachelor's degree (37.9%). There were 158 people with a high school education (42.1%), and 54 completed junior high school education or below (14.4%). Of these respondents, 183 (51.2%) had experience with or hobbies related to gardening and agriculture. There are 192 people without related experience, accounting for 48.8%.

Table 1. Sample profile.

Characteristics	Items	Frequency	Percent
Gender	Male	194	51.7%
	Female	181	48.3%
Age	<20	66	17.6%
	20–39	107	28.5%
	40–59	140	37.3%
	>60	62	16.5%
Educational level	Junior high school and below	54	14.4%
	High school	158	42.1%
	College or undergraduate	142	37.9%
	Graduate	21	5.6%
Past behavior	With past behavior	183	51.2%
	Without past behavior	192	48.8%

3.2. Measures

According to the existing literature, this study made modifications to measurement scales to adapt to the research context. Each construct in the questionnaire consisted of a set of items presented in a five-point Likert format to assess the degree to which respondents agreed or disagreed with the statements stated on each item (1 = “strongly disagree” and 5 = “strongly agree”), higher scores indicate a stronger intention. Behavioral intention was measured by three items adapted from Lin et al.^[46]. Attitudes were measured by three items suggested by Lee and Matarrita-Cascante^[47]. According to Wu et al.^[28], subjective norm was measured by

three items from it, perceived behavioral control adapted one item from it, and another two items were adapted by Ding et al.^[48]. Perceived benefits included four items, including the recognized main benefit of food security and the other three items reflecting the new nexus elements. These items included bringing visual aesthetics and enhancing mental health, adapted from Lin et al.^[46]. Two items were adapted from Wu et al.^[28] to fulfill the needs of exchange and enhance food self-sufficiency. Through the literature^[26,49], we have identified three items that measured perceived costs, considering the research background. We collected data on the participants' gender, age, education level, and past behaviors related to gardening and planting.

3.3. Data analysis

This study utilized structural equation modeling (SEM) and followed a two-stage approach to analyze data by Anderson and Gerbing^[50]. Firstly, confirmatory factor analysis (CFA) is used in the initial stage to test the quality of the measurement model to confirm its reliability, convergent validity, and discriminant validity. Secondly, to verify the hypothesized relationships and model fit, SEM was performed. In this study, we adopted SEM to verify the relationships between latent variables and latent constructs. CMIN/DF (ratio of chi-square statistics over degrees of freedom), the comparative fit index (CFI), the Tucker-Lewis index (TLI), the incremental fit index (IFI), and the root mean square of approximation (RMSEA) are the indices of model estimation that we used to assess model fit in this study.

A norm of less than 2.0 is regarded as excellent, and less than 5.0 is an acceptable fit^[51]. According to MacCallum et al., a value of RMSEA less than 0.05 is considered a better fit, and up to 0.08 is a reasonable fit^[52]. In general, CFI, TLI, and IFI values should be higher than 0.90, with 0.95 indicating a better fit^[53]. This study used the approach of multi-group SEM analysis to determine if structural differences between respondents' demographic variables were significant. All statistical analyses in this study were conducted using SPSS 27 and SPSS Amos 28.

4. Results

4.1. Descriptive statistics

Table 2 shows the descriptive statistics, including the item means and standard deviation of each construct in the hypothesized model.

Table 2. Descriptive statistics of survey items.

Constructs and items		Mean	S.D.
Attitudes (ATT, mean = 3.324, SD = 1.043)			
ATT1	I know about EL.	2.883	1.196
ATT2	I support community EL.	3.429	1.281
ATT3	I am willing to eat food provided by EL.	3.659	1.248
Perceived behavior control (PBC, mean = 3.290, SD = 1.086)			
PBC1	Accessibility affects my behavioral control capabilities.	3.397	1.318
PBC2	The availability of fully equipped infrastructure affects my behavioral control capabilities.	3.296	1.248
PBC3	My gardening experience and skills affect my behavioral control capabilities.	3.176	1.280
Social norm (SN, mean = 3.070, SD = 0.937)			
SN1	The views of family and friends are important.	2.859	1.082
SN2	The views of neighbors are important.	2.928	1.151
SN3	The views of community staff are important.	3.424	1.201

Table 2. (Continued).

Constructs and items		Mean	S.D.
Perceived benefits (PB, mean = 3.282, SD = 1.101)			
PB1	The function of leisure, stress relief, and mood adjustment.	3.392	1.257
PB2	The function of increasing community food self-sufficiency.	3.003	1.305
PB3	The function of bringing visual aesthetics to the community.	3.275	1.288
PB4	The function of Enhancing Communication and community cohesion.	3.459	1.280
Perceived costs (PC, mean = 3.282, SD = 1.101)			
PC1	EL will cause ecological impacts and damage.	2.819	1.320
PC2	EL will cause encroachment of public lands.	2.976	1.233
PC3	EL will cause interfere with management and bring conflicts.	3.275	1.307
Behavioral intention (BI, mean = 3.131, SD = 1.042)			
BI1	I will participate in the planting and gardening of EL.	3.195	1.248
BI2	I will promote EL on social media and praise it.	2.965	1.202
BI3	I will participate in recreational and communication activities in EL.	3.232	1.280

4.2. Measurement model

A preliminary confirmatory factor analysis on each of the measurement model's latent constructs was then conducted to evaluate convergent validity. The collected data and estimated model showed good fit indices according to $X^2/df = 1.609$, CFI = 0.972, IFI = 0.972, TLI = 0.964 and RMSEA = 0.040.

Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) were used to evaluate the internal consistency and convergent validity of the scales. The result is shown in **Table 3**. All the standardized factor loadings are greater than the required level of 0.50 (range: 0.591–0.858). All Cronbach's α was greater than the recommended level of 0.70 (range: 0.754–0.828), demonstrating good internal consistency and reliability of the questionnaire items. All CR estimates achieved the recommended level of 0.70 (range: 0.758–0.881). The AVE values (range: 0.514–0.650), fulfilling the suggested value of 0.50, indicate that each dimension has good convergent validity and composite reliability.

Discriminant validity was investigated using the AVE of a single construct in comparison to the squared shared variances between constructs. As shown in **Table 4**, the square root of each construct's AVE was greater than the inter-construct correlation of that same construct and all other measured constructs, thus having discriminant validity^[54].

Table 3. CFA results of the measurement model.

Construct	Item	Standard factor loading	Standard error	Cronbach's α	CR	AVE
Attitudes	ATT1	0.713	0.062	0.790	0.795	0.567
	ATT2	0.858	0.066	-	-	-
	ATT3	0.675	0.064	-	-	-
Perceived benefits	PB1	0.835	0.065	0.881	0.881	0.650
	PB2	0.794	0.067	-	-	-
	PB3	0.797	0.067	-	-	-
	PB4	0.797	0.066	-	-	-

Table 3. (Continued).

Construct	Item	Standard factor loading	Standard error	Cronbach's α	CR	AVE
Perceived costs	PC1	0.662	0.065	0.828	0.835	0.630
	PC2	0.849	0.061	-	-	-
	PC3	0.807	0.066	-	-	-
Subjective norm	SN1	0.656	0.056	0.754	0.758	0.514
	SN2	0.649	0.059	-	-	-
	SN3	0.831	0.062	-	-	-
Perceived behavioral control	PBC1	0.802	0.068	0.803	0.803	0.577
	PBC2	0.771	0.064	-	-	-
	PBC3	0.704	0.066	-	-	-
Behavioral intention	BI1	0.796	0.064	0.788	0.785	0.554
	BI2	0.591	0.061	-	-	-
	BI3	0.824	0.064	-	-	-

Table 4. Results of discriminant validity.

Construct	(1)	(2)	(3)	(4)	(5)	(6)
(1) Attitudes	0.756	-	-	-	-	-
(2) Perceived behavioral control	0.221***	0.760	-	-	-	-
(3) Subjective norm	0.184**	0.279***	0.717	-	-	-
(4) Perceived benefits	0.316***	0.339***	0.284***	0.806	-	-
(6) Perceived costs	-0.226***	-0.400***	-0.297***	-0.313***	0.794	-
(6) Behavioral intention	0.373***	0.409***	0.326***	0.448***	-0.575***	0.755

Note: 1. Values on the diagonal of correlation matrices represent the square root of the AVEs.

Note: 2. *** $p < 0.001$; ** $p < 0.01$.

4.3. Structural model and hypotheses test

In this study, the hypothesized structural model was subsequently estimated to examine the causal relationships between constructs. The hypothesized model showed good goodness-of-fit measures (GOFs) for the sample data indices: CMIN = 326.349, $df = 144$, CMIN/ $df = 2.266$, CFI = 0.938, IFI = 0.938, TLI = 0.926, and RMSEA = 0.058. **Figure 3A** presents the standardized path coefficients and significant levels for the estimated model. All eight hypotheses for the estimated model were empirically supported: Both attitudes ($\beta = 0.189$, $p < 0.01$), subjective norm ($\beta = 0.110$, $p < 0.05$), and perceived behavioral control ($\beta = 0.155$, $p < 0.01$) had significant positive effects on behavioral intention, thus supporting H1, H2, and H3. Perceived benefits had significant positive effects on participants' attitudes ($\beta = 0.273$, $p < 0.001$) and behavioral intention ($\beta = 0.213$, $p < 0.001$), supporting H4 and H6. Perceived costs had significant negative effects on participants' attitudes ($\beta = -0.138$, $p < 0.05$) and behavioral intention ($\beta = -0.417$, $p < 0.001$), hence supporting H5 and H7. Perceived benefits and costs ($\beta = -0.340$, $p < 0.001$) are negatively associated with each other, thus supporting H8.

The results from **Figure 3B** provide further evidence of the impacts of perceived benefits and costs on behavioral intention. The results proved to be consistent with TPB theory. However, the impacts of perceived benefits and costs on behavioral intention are not fully explained through the mediating effect of attitudes, indicating that the three variables of the TPB model cannot fully explain the relationship between perceived and residents' behavioral intention.

Figure 4 highlights the importance of three perceived benefits associated with urban edible landscaping, beyond food self-sufficiency and aligning with the new nexus shown in **Figure 1**. These benefits encompass enhancing experiences and enabling emotional expression, implying a cultural role; infusing visual aesthetics to fulfill art pursuits; and fostering community cohesion through enhanced communication and exchange among members. Factor loadings for each factor exceeded 0.80, confirming their reliability as indicators of the perceived benefits of EL. In addition to a direct effect on behavior intention, perceived benefits had an indirect effect by mediating residents' attitudes to encourage EL through obtaining better understanding and social support among the community.

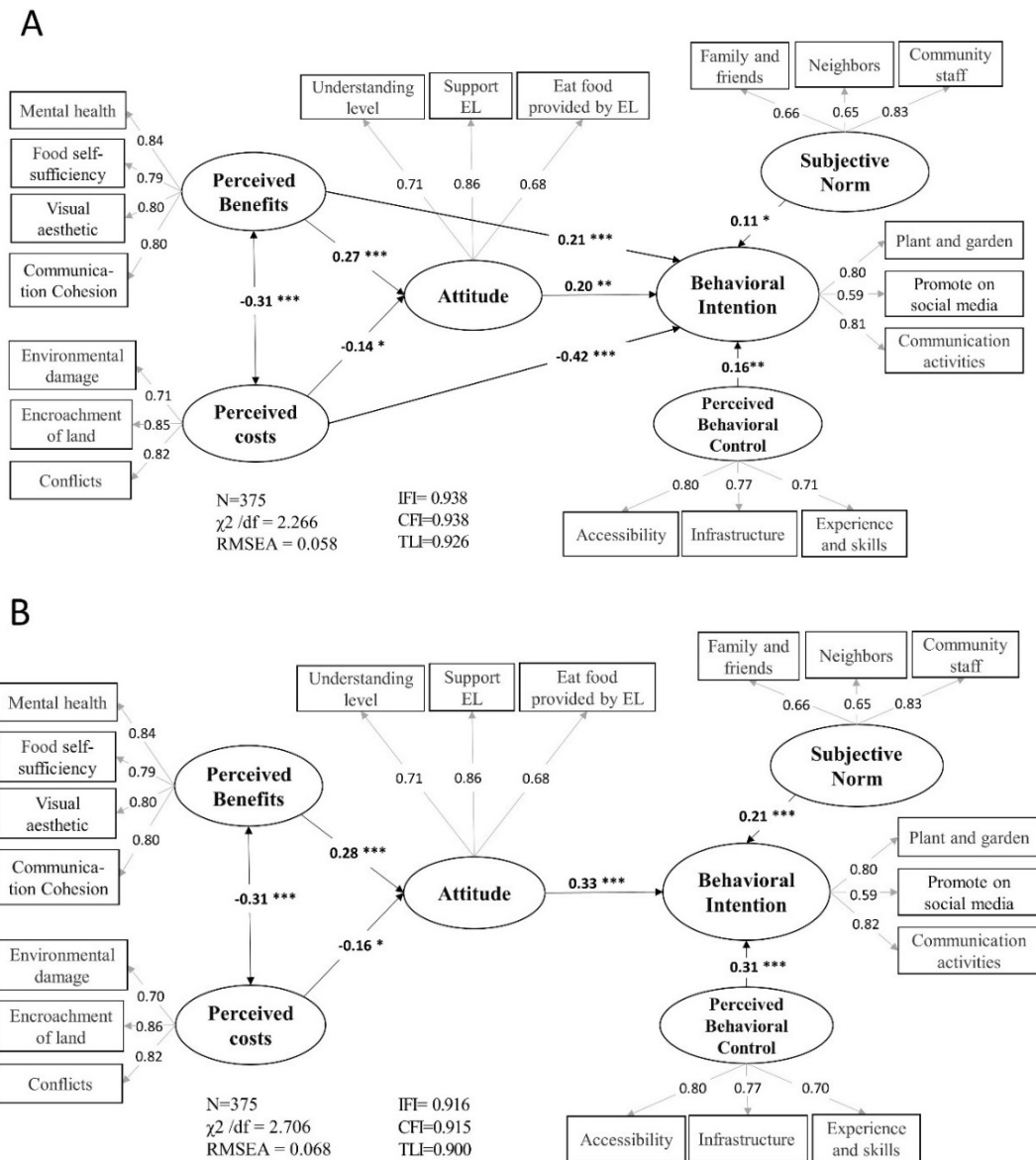


Figure 3. The estimated model. **(A)** emphasizes the direct effects of perceived benefits and costs on behavioral intention; **(B)** highlighting that the three factors in TPB may not be a sufficient factor to comprehensively explain a behavior.

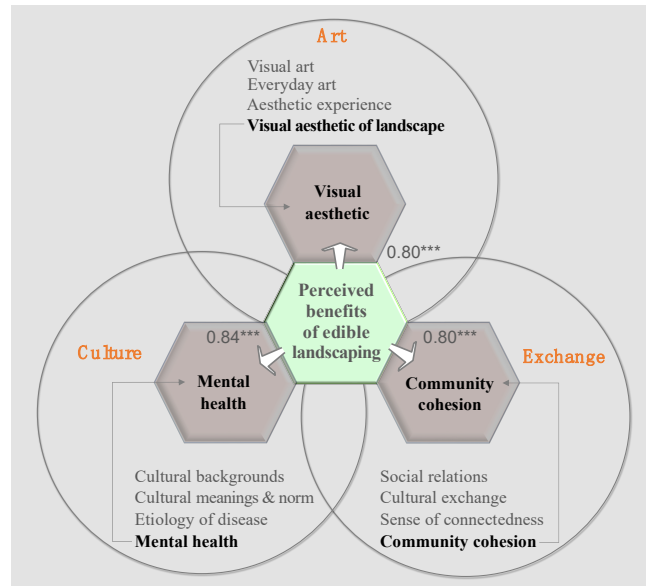


Figure 4. Three perceived benefits of urban EL corresponding to the new nexus (in Figure 1).

4.4. Multi-group analysis

To assess the moderating effects of the structural model that was hypothesized, a multi-group study was conducted. Through the implementation of multi-group analyses, this study examines the moderating impact of past behavior, age, and gender on the proposed model. According to Sudman, each major group or subgroup in the sample requires a minimum of 100 elements^[55]. As shown in **Table 1**, the age is divided into four groups, with samples under 20 years old and over 60 years old both being less than 100. Therefore, for ease of calculation and analysis, this study divided the age into two groups: below 40 and above 41.

The unconstrained models of the moderating variable groups were compared to their measurement weight models and structural weight models. If such moderating effects occur, they should result in statistically significant variations in the empirical relationship (path coefficient) between the same two model variables within each subgroup. To investigate the differences between these models, the chi-square difference test is performed^[56,57].

Moderating effects of past behavior

The result of chi-square difference tests between the unconstrained model ($X^2 = 451.07$, $df = 288$) and structural weight model ($X^2 = 627.67$, $df = 327$) conducted $\Delta X^2(39) = 176.60$, p -value < 0.001 , indicating that there is a significant difference between with past behavior and without past behavior. As shown in **Table 5**, we found significant differences existed in three paths between with past behavior and without past behavior, i.e., H1: attitudes \rightarrow behavioral intention (z -score = 2.990), H4: perceived benefits \rightarrow attitudes (z -score = 1.997), and H6: perceived benefits \rightarrow behavioral intention (z -score = 2.727).

Moderating effects of gender

The results of the test on the unconstrained model revealed a Chi-square value of 476.73 with 288 degrees of freedom and structural weight model unveiled a Chi-square value of 607.02 with 327 degrees of freedom. The result of chi-square difference ($X^2(39) = 130.29$, p -value < 0.001) structural expressed that there is a significant difference between with male and female. According to **Table 6**, significant differences were found in two paths between males and females, i.e., H5: perceived costs \rightarrow attitudes (z -score = -2.632) and H6: perceived benefits \rightarrow behavioral intention (z -score = 1.837).

Moderating effects of age

The unconstrained model with $X^2 = 485.80$, $df = 288$, and the structural weight model ($X^2 = 588.48$, $df = 327$), showed $\Delta X^2(39) = 102.68$, p -value < 0.001 , indicated that there is a significant difference between age below 40 male and age over 41. Significant differences in four paths, i.e., H1: attitudes \rightarrow behavioral intention (z -score = 2.281), H3: perceived behavioral control \rightarrow behavioral intention (z -score = 1.861), H4: perceived benefits \rightarrow attitudes (z -score = 1.670), and H7: perceived costs \rightarrow behavioral intention (z -score = 1.691), are found between age below 40 and over 41 in **Table 7**.

Table 5. Results of multi-group analysis for the moderating effects of past behavior.

Path	Fully constrained		Unconstrained				z-score
	Estimate	P	With past behavior		Without past behavior		
			Estimate	P	Estimate	P	
H1: ATT \rightarrow BI	0.205	**	-0.048	ns	0.342	***	2.990***
H2: SN \rightarrow BI	0.099	ns	-0.011	ns	0.050	ns	0.621
H3: PBC \rightarrow BI	0.169	**	0.114	ns	0.193	*	0.742
H4: PB \rightarrow ATT	0.234	***	0.095	ns	0.293	***	1.997**
H5: PC \rightarrow ATT	-0.104	*	-0.088	ns	-0.073	ns	0.160
H6: PB \rightarrow BI	0.198	***	0.023	ns	0.299	***	2.727***
H7: PC \rightarrow BI	-0.371	***	-0.358	***	-0.321	***	0.358

Note: ns: non-significant; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 6. Results of multi-group analysis for the moderating effects of gender.

Path	Fully constrained		Unconstrained				z-score
	Estimate	P	Male		Female		
			Estimate	P	Estimate	P	
H1: ATT \rightarrow BI	0.204	**	0.125	ns	0.212	*	0.664
H2: SN \rightarrow BI	0.097	ns	0.006	ns	0.143	ns	1.345
H3: PBC \rightarrow BI	0.162	**	0.113	ns	0.203	*	0.797
H4: PB \rightarrow ATT	0.226	***	0.178	**	0.186	*	0.072
H5: PC \rightarrow ATT	-0.123	*	0.032	ns	-0.232	***	-2.632***
H6: PB \rightarrow BI	0.205	***	0.043	ns	0.240	**	1.837*
H7: PC \rightarrow BI	-0.392	***	-0.325	***	-0.381	***	-0.495

Note: ns: non-significant; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 7. Results of multi-group analysis for the moderating effects of age.

Path	Fully constrained		Unconstrained				z-score
	Estimate	P	Below 40		Over 41		
			Estimate	P	Estimate	P	
H1: ATT \rightarrow BI	0.212	**	0.043	ns	0.337	***	2.281**
H2: SN \rightarrow BI	0.107	*	0.127	ns	0.062	ns	-0.643
H3: PBC \rightarrow BI	0.155	**	0.044	ns	0.253	**	1.861*
H4: PB \rightarrow ATT	0.222	***	0.126	ns	0.298	***	1.670*
H5: PC \rightarrow ATT	-0.112	*	-0.068	ns	-0.144	*	-0.764
H6: PB \rightarrow BI	0.198	***	0.122	ns	0.197	**	0.707
H7: PC \rightarrow BI	-0.378	***	-0.470	***	-0.278	***	1.691*

Note: ns: non-significant; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

5. Discussion and conclusions

This study presents an integrated model regarding residents' intention to participate in EL. The model assumes that the intention is influenced by TPB factors, perceived benefits, and costs, and we also examine the impact of residents' personal attributes to moderate the hypothetical relationships. The findings indicate that perceived benefits and costs have a significant positive or negative impact on behavioral intention, while attitudes, perceived behavioral control, and subjective norms partially explain these effects. Furthermore, we also found differences among individuals with and without past behavior, males and females, as well as those aged below 40 and above 41.

The results of the model in **Figure 3B** are consistent with the TPB. Among the three factors of TPB, attitude is a strong predictor of behavioral intention, which aligns with previous findings^[28]. This means that residents with a more positive attitude towards EL are more likely to participate in EL. However, compared to the model in **Figure 3A**, the influence of perceived benefits and costs on behavioral intention cannot be fully explained by attitudes, and the impact of perceived benefits and costs is stronger than attitudes. This indicates that perceived benefits and costs not only indirectly affect behavioral intention through attitudes but also have direct positive or negative effects on behavioral intention. The perception of EL by residents can serve as an influential factor in explaining and predicting residents' behavior and attitudes, thus playing a crucial role in influencing residents' participation. In addition, the effect of subjective norms on behavioral intention is slightly less than that of perceived behavioral control. The results of perceived behavioral control indicate that green infrastructure and accessibility can effectively promote social interaction. Research suggests that green infrastructure attracts more foot traffic, while community gardens within a five-minute living circle have increased resident participation^[48]. The impact of subjective norms on residents' behavioral intentions is mostly reflected in community stuff, consistent with previous research findings: local authorities can change people's beliefs about subjective norms by adjusting policies, thus promoting participation in gardening behavior^[58]. These findings support the effectiveness of extending the TPB model for predictive purposes.

The multi-group analysis results among past behavior groups, gender groups, and age groups have further implications. The impact of attitudes and perceived benefits on behavioral intention, as well as the influence of perceived benefits on attitudes, is only positively significant in individuals without past behavior. This suggests that individuals without past behavior are more likely to perceive the benefits of EL for human well-being and develop more positive attitudes and cognitions towards EL, resulting in higher motivation. The impact of perceived costs on attitudes and the influence of perceived benefits on behavioral intention are significantly negative or positive only among women. This suggests that women are more susceptible to the influence of perception, which in turn affects their behavior and practices. Individuals under 40 are more concerned with the perception of benefits when shaping their behavioral intentions than those over the age of 41. The influence of attitudes and perceived behavioral control on behavioral intention, as well as the impact of perceived benefits on attitudes, are only significantly positive among the participants over 41. The older population, due to differences in motivation, is more concerned with the difficulty of performing actions such as planting and gardening. At the same time, they are more concerned about their perception of benefits, which leads to more positive attitudes and a greater intention to act.

The findings of the study can be utilized to guide the future design, implementation, management, and evaluation of EL in China. The findings of this research project can provide strategic assistance to future planners in attracting more residents. It is important to promote the benefits of EL to increase residents' awareness. Enhancing horticultural techniques, educating the public, and implementing effective community management can maximize the benefits of EL and minimize the negative costs at the same time. Improving the conditions of EL implementation and providing education and outreach on horticulture and agriculture-

related techniques will make it easier for residents to participate. Authority figures, such as community managers, can play a crucial role in encouraging and supporting residents' involvement, leading to more positive participation. When designing EL programs, it is essential to consider the needs of potential participants, especially those of older adults and women. We hope that these findings will be helpful for decision-makers to further develop EL in China.

This study also has some limitations. First, the measurement items for perceived benefits and costs, attitudes, subjective norms, and perceived behavioral control in this study were derived from previous research and relevant literature. However, due to limited research on residents' behavioral intentions toward EL, there is a lack of a widely tested measurement scale, which may lead to potential inaccuracies. Second, we assume that behavioral intention leads to actual behavior adoption. However, behavioral intention is one direct factor that affects actual behavior^[59]. Future research should fill the gap between expectations and actual participation behavior. In addition, during our field research in Japan, we found differences in the participation of Japanese residents compared to our research findings. This may be influenced by cultural backgrounds and the current development of EL. Further studies in various cultural or national contexts worldwide can be conducted to explore this further.

Author contributions

Conceptualization, KD; methodology, YX and CCC; software, YX; validation, CCC and KY; formal analysis, YX; investigation, YX; data curation, YX; writing—original draft preparation, YX; writing—review and editing, CCC and KD; visualization, KD; supervision, KD and KY. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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