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Consumers' and Stakeholders' Acceptance of Indoor Agritecture in Shanghai (China)

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Abstract: During recent decades, there has been increasing awareness of the development of "agritecture" ("agri"culture + archi"tecture") as a means to transform and revolutionize the food supply of future cities. The different forms of agritecture include building-integrated agricultural concepts such as vertical farms or indoor farms. In this way, urban food production could take place in proximity to consumers while employing so-called "urban waste" products (such as wastewater, waste heat, and organic waste) as valuable production inputs. Although scholars frequently highlight the potential of vertical farming and other agritecture approaches for Asian megacities, there is still a lack of academic research and completed projects related to this field in China. This study uses a mixed-methods approach, combining quantitative and qualitative research in the study location of Shanghai, to reveal the social acceptance of indoor agritecture among consumers and experts. First, to explore the perceptions of consumers, a survey of 713 potential consumers was conducted in Shanghai. Second, these surveys were complemented by 20 expert interviews with academics and practitioners from Shanghai to frame the quantitative research results. Our results revealed that the surveyed consumers' social acceptance of indoor agritecture and the expectations of the experts are high. Additionally, there is already a high level of demand and a potential market for indoor agritecture in Shanghai. This has been confirmed by the ongoing construction of the first moderate-scale vertical farm and several indoor farms, in combination with the increasing existence of edible landscape approaches and rooftop farms. This development can be viewed as the rise of urban agritecture in Shanghai. The interviews revealed that experts raise more doubts about the economic dimension, whereas its social and ecological dimensions and the contextual framework of indoor agritecture are considered to be positive.

Keywords: acceptability; perception; urban agritecture; urban farm; vertical farm; social acceptance; indoor farm; urban agriculture

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1. Introduction

1.1. General Background

Due to the depletion of the Earth's energy resources, the rapid increase in the world's population, rising demand for food, and the continuous occurrence of natural disasters, conventional agriculture is facing major difficulties feeding the world population [1–3]. Additionally, people are more aware of the problems caused by the food industry. Food

safety and nutrition are receiving increasing attention [4,5]. In this context, urban agriculture as a supplement has been playing a progressively more vital role for academia and residents [6,7].

Since the end of the last century, there has been a tendency to combine urban agriculture with buildings. In this paper, we use a new concept—urban "agritecture" ("agri"culture + archi"tecture")—to describe forms of urban agriculture that are integrated with buildings. Urban agritecture is divided into outdoor and indoor forms. Indoor forms include vertical farms, indoor farms, and building-integrated greenhouses. Outdoor forms include rooftop farms, balcony/terrace farms, and façade farms. In this paper, we focus on indoor agritecture in the research location of Shanghai. Since rooftop greenhouses are generally considered illegal additional construction according to Chinese construction standards, this study focuses mainly on indoor and vertical farms.

Indoor farms and vertical farms have many similarities in their technology, cultivation, and operation. Vertical farms can be defined as indoor farms with multiple layers [8]. The concept of vertical farming has existed since 600 BC (the ancient era of the Hanging Gardens of Babylon). In 1915, a book entitled *Vertical Farming* was written by Gilbert Ellis Bailey; during the 1980s, vertical farming was proposed by Åke Olsson as a means of producing vegetables in cities [9]. In 1999, this concept was discussed again by Dickson Despommier from Columbia University; he defined it as a sustainable indoor multistory agricultural system that produces crops, fish, poultry, eggs, etc. [10,11]. Since then, research about vertical farming has been increasing globally.

In comparison to conventional agriculture that employs heavy irrigation, intensive tillage, and excessive use of fertilizers, pesticides, or herbicides [12], vertical farms promote sustainable agricultural practices efficiently [13], advocate for food security, and preserve land resources by being greatly integrated into urban centers [10,14]. Their utilization of hydroponic technology can potentially save water resources and even help reduce CO_2 emissions [7,9,15].

Currently, the two major controversial points of vertical farms are (1) their energy consumption versus energy conservation and (2) their economic balance. On the one hand, vertical farms help to save not only resources but also food miles (food miles: the distance that a food product travels from its origin); on the other hand, their artificial lighting and closed systems require cooling and heating based on electricity. From an economic perspective, the construction of a new vertical farm requires a sizeable investment [16,17]. Gordon Graff [18] estimated that the ROI (ROI: return on investment) of a 10-story vertical farm would be approximately 8%. Considering the risk of applying new technologies, a vertical farm could probably be considered a desirable investment in the current market only if it could achieve a 15% annual ROI [12]. Another aspect that requires long-term research is the nutritional quality of the produce [14]. Since the promotion of vertical farming by Despommier [10], there have been limited completed projects. Certain recent research on, e.g., ZFarming in Berlin (Germany), has suggested that similar approaches like zero-acreage farming offer not only food production but also nonfood and nonmarket goods [16]. These methods are thought to have much potential and have attracted the attention of promoters globally [8,19].

1.2. Acceptance of Indoor Agritecture and the New Technologies in Urban Agriculture

The social acceptability of agritecture is regarded as crucial for its future development. As explored throughout innovation theory [20], the introduction of innovations is commonly accompanied by certain levels of resistance, particularly during the initial innovation phase. The literature on agricultural innovation provides many examples of how the diffusion of a technological innovation can fail if the related consumers or the key stakeholders perceive that the innovation either entails a high level of risk or delivers little societal benefit. This observation includes all kinds of innovations, ranging from the introduction of organic agriculture [21–23] to more technological innovations such as precision farming [24], and it is certainly relevant for the development of an innovation such as

vertical or indoor farming. Although the potential performance and contribution of indoor farming have been extensively assessed, real-case measurements, such as those performed by Milestad et al. [11], are still very rare. Consumers' social acceptance and preferences regarding innovations are decisive factors for the success or failure of an entrepreneurial business [25].

1.3. Research Gap and Objective

There are studies on the acceptance of different types of urban agriculture, e.g., roof gardens and public greenspaces, examining the interests of stakeholders [5,26]. There is also an increasing number of studies on vertical farms, but they have mainly focused on the technological, economic, and environmental factors and processes of vertical farming systems [27], while social studies are generally scarce. The main social studies on consumers or stakeholders use either quantitative or qualitative methods (e.g., [19,25,28,29]). However, there are few studies that employ both quantitative and qualitative research methods. Additionally, most studies mainly focus on study locations in Western countries. Although scholars frequently highlight the potential of vertical farming and other agritecture approaches for Asian megacities, the existing research rarely examines these geographical locations.

This paper tries to fill this gap by studying the acceptance of agritecture in Shanghai, China, from the perspective of both consumers and stakeholders. These two different perspectives generate a mutual complement to help us understand the social acceptance in a complex way. Based on the questionnaires, our consumer study focuses on vertical farming (as a specific type of agritecture) to simplify the study object for those surveyed. Through expert interviews, our stakeholder analysis considers the broader field of indoor agritecture to predict the development of this larger sector.

To fill the described research gap, this study addresses the following specific objectives:

- What characteristics of Shanghai residents are related to their acceptance of vertical farming?
- What are significant shopping behaviors and criteria of potential vertical farming consumers in Shanghai?
- What are the main factors that promote and hinder the acceptance of indoor agritecture among key stakeholders along the dimensions of social, economic, and ecological sustainability in the context of Shanghai?
- What are the expectations and possible routes for the development of indoor agritecture in Shanghai?

2. Materials and Methods

2.1. Case Study Description and Selection

In 1992, Shanghai was appointed as an international economic, financial, trade, and shipping center by the national government [30,31], which triggered a phase of rapid development. Since then, its population has increased from approximately 13 million to 24 million. Yet, this rapid development has led to the following problems:

1. Rapid urban area expansion: Currently, Shanghai's total area is 6340.5 km^2 (2019). Its expansion potential is geographically limited, as Shanghai is adjacent to the Yangtze River Estuary in the north and borders Jiangsu and Zhejiang Provinces in the west. The Eastern Sea lies to its east, and on its southern side is Hangzhou Bay.
2. Resource conflicts between human needs and limited land: In the new master urban plan covering the period between 2017 and 2035, the red line for constructive land is limited to 3200 km^2. However, the area of the city's constructive land has already reached 3185 km^2, meaning that Shanghai has only 15 km^2 of land left available for construction over the next 14 years.
3. Increasing land price: The increase in city value has been directly reflected in the increase in land price (Figure 1).

4. More buildings and less greening: This limited expansion potential implies an increase in the city's construction density. Green spaces in the urban center have often been repurposed for commercial buildings or other functions.
5. Increasing commuting time and distance to "nature": With the increasing urban area, population, and construction density, there is a growing demand for "nature" and activities to "get one's hands dirty."

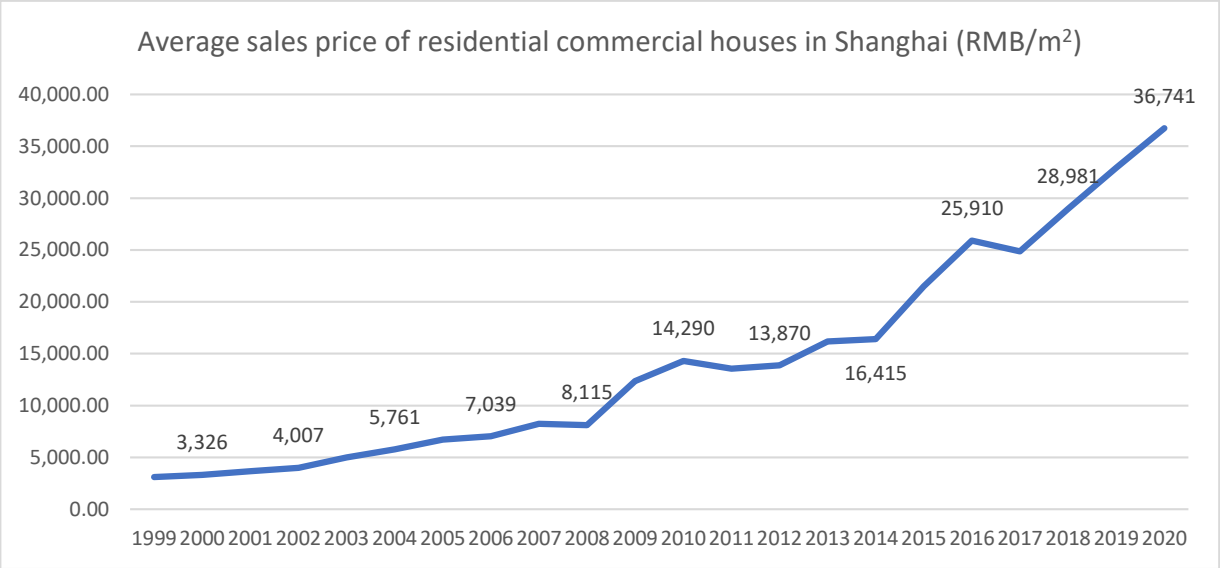

Figure 1. Average sales of residential commercial houses in Shanghai (RMB/m^2) (1999–2020) (EUR 1 ≅ RMB 8) (data based on national data: https://data.stats.gov.cn/easyquery.htm?cn=E0105&zb=A03&reg=310000&sj=2019, accessed on 25 February 2022).

At the beginning of this century, the Sunqiao Modern Agriculture Development Zone was constructed (Figure 2). Inside, agricultural parks have attracted much attention, and many advanced indoor farming technologies such as soil-based vertical farming have been implemented. Hydroponic systems have been imported and locally developed.

Figure 2. Sunqiao Modern Agriculture Development Zone (by main author in 2016).

In 2012, the first soil-based indoor farm was constructed in a newly designed shopping mall, K11, in central Shanghai (Figure 3). It supplies vegetables, herbs, and mushrooms to the restaurant next door and has been attracting considerable attention from citizens and tourists. Meanwhile, increasing rooftop farms have been emerging in the urban

area. The foregoing factors became the driving forces of the potential development of indoor agritecture.

Figure 3. K11 urban farming (by main author in 2016).

Apart from the aforementioned framework conditions, the selection of Shanghai was based on the following characteristics of the city:

- Shanghai is an international megacity, with highly mixed cultures.
- Due to its metropolitan background, the conflict between human needs and limited land resources in Shanghai is relatively prominent, which is a driving force for the development of indoor agritecture.
- Compared to other provinces or cities, Shanghai's local government pays more attention to ecological development and future research.

2.2. Methods and Empirical Basis

This empirical study was based on a case study approach [32] and applied a mixed-methods design combining a quantitative survey with qualitative expert interviews [33].

1. *Survey content*: The survey mainly focused on potential consumers' acceptance and perceptions of vertical farms. Narrowing the focus to the specific type of "vertical farms" instead of the broader concept of "agritecture" helped those surveyed better understand this relatively new concept. The survey consisted of 31 questions and was divided into five parts containing questions on (1) current food-purchasing behavior, (2) environmental perceptions of vertical farming, (3) participation willingness and marketing opportunities, (4) planning-related questions, and (5) personal data (for the English version, see Appendix B).
2. *Survey conduction and analysis*: The surveys were implemented during October and November 2013 to investigate the social acceptance of vertical farms among potential consumers. They were printed in Chinese and distributed in places with high population densities but low levels of environmental stress, such as cafes, restaurants, high schools, research institutes, and offices; additionally, they were distributed in the parks and on the streets of the urban areas in Shanghai. Potential participants were approached randomly and selected according to their willingness to partake. Therefore, this survey could be described as an exploratory, nonprobability sampling survey. It was not considered to be statistically or demographically representative of the residents. Yet, this exploratory approach offered preliminary insights into a previously unexplored topic and allowed us to collect information with which to identify trends without the use of a randomized sample.

A descriptive correlational analysis was conducted on the survey results with SPSS and Stata in accordance with the following three topics: (1) general acceptance of vertical farming technology, (2) regular shopping behaviors and preferences, and (3) willingness to participate in vertical farming and strategic development of vertical farms. Due to the binary and ordinal nature of most items, we used polychoric correlations to determine relationships between variables. Descriptive correlational analysis was chosen over a

regression or other predictive analysis due to the exploratory nature of this study and lack of overarching theoretical framework on the acceptance of agritecture.

3. *Survey participants*: In total, 941 surveys were collected. After the data-cleaning and digitalizing processes, 713 fully and correctly completed surveys could be used for further analysis.

Per the collected data, the male–female ratio of the respondents was 1:1.12, and more young people were surveyed than older people (approximately 75% of the respondents were under 40) (Table 1). The survey revealed that approximately 88% of the respondents lived within the outer ring of Shanghai (in the urban centers). The average educational level of the respondents was a bachelor's degree, which allowed for the potential understanding of new concepts. Over half of the respondents were full-time students, teachers, or technical/R&D personnel. The average income of the respondents ranged from RMB 5000 to 10,000/month (EUR 1 ≅ RMB 8) (=EUR 625–1250/month). In 2013, the average income in Shanghai was RMB 5036/month (=EUR 629.50). On average, each household consisted of three family members.

Table 1. Survey participant demographics (n = 713).

Questions	Variables	Percent
Gender	Female	52.7
	Male	47.3
Age	≤20	23.3
	21–30	34.8
	31–40	17.7
	41–50	13.9
	51–60	7.3
	>60	3.1
Highest educational degree	High school or below	27
	College	8.1
	Bachelor's	43.3
	Master's	16.5
	Doctorate	4.9
Net household income range	<RMB 5000/month	18.4
	RMB 5000–10,000/month	31.7
	RMB 10,000–15,000/month	25.9
	RMB 15,000–50,000/month	20.2
	>RMB 50,000/month	3.8
People living in the household (respondent included)	1	14.0
	2	21.6
	3	50.1
	4	9.7
	≥5	4.6

4. *Expert interviews:* A total of 20 semi-structured interviews were conducted as face-to-face interviews with experts in Shanghai in the Chinese and English languages between May and July 2016 (Table 2). The interviews consisted of five parts that focused on the broader concept of agritecture rather than vertical farming (Figure 4). The scope of the interviews was extended because (1) only one vertical farm had been constructed in Shanghai by the time of the interviews, thus requiring a broader scope for stakeholders for meaningful input; (2) the broader topic supplies a better understanding for the expertise, an easier integration of more individual experience, and a broader comparison among different forms of agritecture; and (3) the technology of the indoor forms of agritecture are similar.

Table 2. Interviewee list—researchers and practitioners from Shanghai.

Category	Field of Expertise	Interview No.
Researcher	Agriculturalist, university professor, pesticide scientist, chemist	#1
Researcher	Sociologist, professor, expert in community farms	#2
Researcher	Economist, professor, psychologist	#3
Researcher	Urban and vertical greening expert in administration	#4
Researcher	Urban ecologist, professor	#5
Researcher	Sociologist, professor	#6
Researcher/Practitioner	Urban planner, expert on urban agriculture and rooftop farming	#7
Researcher/Practitioner	Agriculturist, expert on urban and rural planning, professor, CEO of an urban design company, chief planner in a planning and design institute	#8
Researcher/Practitioner	Architect, professor, urban designer in an urban and landscape design company	#9
Researcher/Practitioner	Landscape designer, CEO of an edible landscape company	#10
Practitioner	Vice-CEO of a vertical farm in Shanghai	#11
Practitioner	Architect, CEO of an architecture company, involved in the construction of vertical farms	#12
Practitioner	CEO of a rural planning start-up, expert on rooftop farms and planting containers, landscape planner	#13
Practitioner	CEO of a planting box and container company	#14
Practitioner	CEO of an edible landscape start-up	#15
Practitioner	Landscape designer, expert in vertical greening, vertical and façade farms	#16
Practitioner	CEO of a planting machine start-up	#17
Practitioner	Landscape and urban designer in a planning and design company, expert on urban agriculture	#18
Practitioner	Urban designer, landscape planner, experienced in urban agriculture and greening	#19
Practitioner	Industrial designer, CEO of an urban design start-up, experienced in cooperating with agricultural projects	#20

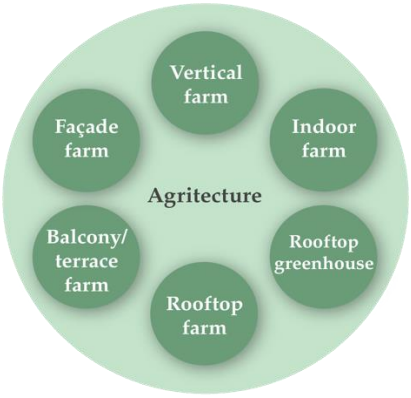

Figure 4. Positioning of vertical farming within the broader field of agritecture.

After appointments were made, the experts were visited in their professional or public environments. Each interview lasted approximately 60 to 90 min and consisted of (1) an introduction of the interviewee and their personal experiences with agritecture; (2) questions regarding the expert's opinions on the potentials and drawbacks of agritecture; (3) evaluations of the topic from ecological, economic, spatial, temporal, planning, architectural, social, and political perspectives, among others; (4) a discussion of development strategies; and (5) recommendations regarding potential interviewees or cases.

5. *Coding and data analysis:* The interviews were recorded, transcribed, coded, and analyzed by the main author via MAXQDA. We applied the principles of qualitative content analysis described by Kuckartz [34]. The interviews were coded by the main author. The analysis for this study focused on indoor agritecture. In the first round, the text fragments were assigned into homogeneous categories based on the interview guideline. In the second round, under the coding categories, the text was analyzed

with open coding analysis. In the next rounds, the open codes were consolidated and sorted into sub-categories. Finally, the codes were tabulated according to the (sub-)categories. The numbers of code segments, namely, quote numbers of the factors, were summarized. The results pertaining to these experts' perceptions are displayed in reference to the three pillars of sustainability according to the International Union for the Conservation of Nature (IUCN) [35]: the social, economic, and environmental dimensions. We apply this framework to structure our results and added the political and planning context of Shanghai as an additional pillar to the study. The quotes were translated from Chinese into English.

3. Results

3.1. Survey Results: Social Acceptance of Vertical Farms in Shanghai

3.1.1. General Acceptance of Vertical Farming Technology and Production Systems

Survey participants were asked on a binary scale (yes/no) whether they would accept the development of a vertical farm in Shanghai. Acceptance was high, with 84% of participants responding "yes." A polychoric correlation matrix shows that the demographic factors most closely associated with acceptance of vertical farms were distance to current food shopping location, younger age, lower income, and gender, with females more likely to report acceptance (Table 3). Education level, proximity of respondents' homes to the city center, and household size did not have strong relationships with acceptance levels.

Table 3. Polychoric correlation matrix of vertical farm acceptance with demographics.

Demographic Variable	Polychoric Correlation Coefficient
Income	−0.113
Gender (male)	−0.117
Age	−0.140
Education level	0.036
Proximity of home to city center	−0.026
Household size	0.012
Distance to current food shopping location	−0.133

Among participants who would not accept vertical farm development, they were about equally likely to choose the suggested responses of the system being artificial, preference for conventional agriculture, and lack of interest in vertical farming (Table 4). Other reasons included doubts regarding the farm's economic viability, potential food safety risks, the potential indirect influence of the poor megacity environment on a vertical farm, and the sufficiency of the food supply from neighboring provinces (Table 4).

Table 4. Reason for not supporting the construction of a vertical farm (n = 113).

Q7: If You Do Not Support Constructing a Vertical Farm, Why?		
Factor	**Frequency**	**Percent**
The system is artificial.	33	29.2%
Conventional agriculture still works well.	30	26.5%
This topic does not interest me.	26	23.0%
Not economical	8	7.1%
Bad air quality in Shanghai for agricultural products	2	1.8%
Doubt over food safety in vertical farms	2	1.8%
Prefer natural production process	1	0.9%
There is no need to develop vertical farming.	1	0.9%
Others	10	8.8%
Total	113	100%

Six questions about the eco-technical concepts were asked to investigate the attitudes of the participants towards different environmental practices (Figure 5).

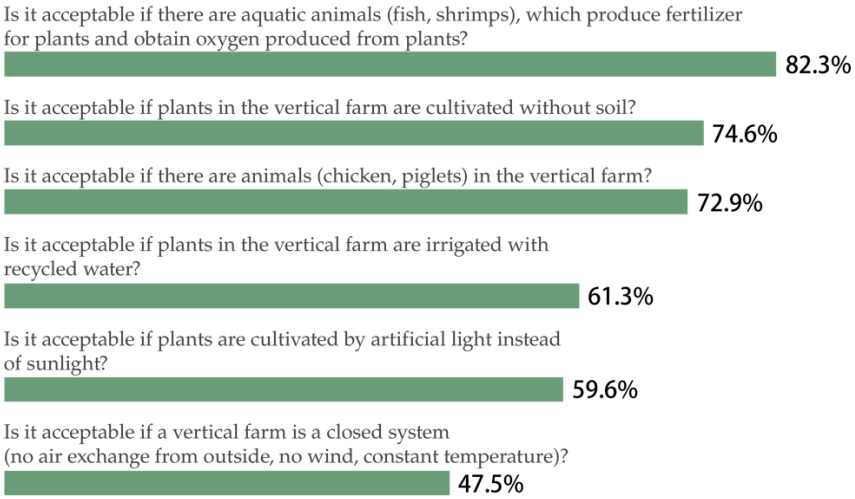

Figure 5. Survey about the acceptance of different cultivation practices in a vertical farm.

According to the survey, the most acceptable technology was the feeding of aquatic animals within a vertical farm (82.3%). A vertical farm being a closed system was the only factor with an acceptance rate below 50%. Over one-fifth of the participants accepted all the technologies and their underlying ideas. Over 81% of the respondents supported at least half of the technologies. Participants' acceptance of cultivation practices was strongly related to their overall acceptance of vertical farming, with a polychoric correlation coefficient of 0.524.

Over 58% of the respondents thought that vertical farms will contribute to finding a balance between human development and nature. This highlights the respondents' positive attitudes towards future development.

3.1.2. Regular Shopping Behaviors and Preferences for Vertical Farming Products

The research on shopping behaviors of potential consumers aims to disclose the current purchase gap of conventional agricultural products and analyze the interest of the participants in shopping at a vertical farm. Only 2.8% of them indicated unwillingness to purchase any product there. Fruits and vegetables were the most common products that participants were willing to purchase (Table 5). Most participants showed a willingness to pay higher prices for organic products as long as certain conditions were met, primarily the quality of the products.

Table 5. Survey on potential food purchases from a vertical farm (multiple choice) (n = 713).

Which Products Would You Buy from a Vertical Farm? (Multiple Choice)	No.	Percent
Vegetables (tomatoes, spinach, cucumbers, etc.)	547	76.7%
Fruit (strawberries, watermelons, etc.)	542	76.0%
Cereals (rice, flour, etc.)	394	55.3%
Beans (peas, soybeans, green beans, etc.)	364	51.1%
Aquatic products (fish, shrimp, etc.)	249	34.9%
Animal products (eggs, milk, etc.)	225	31.6%
Meat	214	30.0%
Processed food (fresh juice, roasted sweet potatoes, etc.)	93	13.0%
Nothing	20	2.8%
Other	7	<1.0%

Over 90% of the survey participants currently purchase their food in supermarkets and markets. Most respondents (97%) travel less than 5 km to purchase their food. Of those who travel more than 5 km, 71% reported being dissatisfied with this distance, and were more likely to accept a vertical farm. However, there was no strong relationship between

distance traveled for food purchase and willingness to purchase multiple types of products from vertical farms (polychoric correlation coefficient = −0.06).

The most important influencing factors for food purchases were as follows (in descending order): quality, taste, price, brand, and special offers (Table 6). Although fewer selected organic products in their top five, its average ranking was higher than the rankings for brand and special offer. This indicates that, although it is important to fewer people, it is of high importance among those who consider it when purchasing foods. Of respondents who showed preferences of improvements in their food shopping experience (97.3%), the two most desired improvements were "more organic food" (59.9%) and "more fresh food products" (62.6%). This demand suits the supposed production supply of a vertical farm.

Table 6. Most important factors in choosing food products (n = 713).

Q5. Please Select the 5 Most Important Factors for You When You Decide to Buy a Food Product		
Factor	**Number of Times Ranked in Top 5**	**Average Ranking**
Quality	678	1.7
Taste	651	2.8
Price	576	3.0
Brand	454	3.5
Special offer (e.g., on sale)	423	3.8
Organic products	398	3.0
Outer appearance	331	3.9
I decide it randomly.	42	4.5
Other	12	3.8

3.1.3. Willingness to Participate in and Strategically Develop Vertical Farms

Of the survey participants, 84.3% indicated willingness to visit a vertical farm located near a (sub-)CBD (CBD: central business district), with women more likely than men to be willing to visit (tetrachoric correlation coefficient = −0.20). Despite this high willingness, most respondents would visit it rarely (41%) or sometimes (35%). According to their polychoric correlation coefficients, higher income (0.13) and education levels (0.10) were associated with willingness to visit more often.

When considering the functions of vertical farms, respondents would most like to see these spaces combined with DIY planting and harvesting (72%) and education (49%). Fewer respondents would be interested in combining a vertical farm visit with recreation (30%) or shopping (21%). Six percent of respondents indicated the irrelevance of the combination with other functions.

Regarding entrance ticket prices (Figure 6), approximately 28% of the participants would not support paying an entrance fee for a vertical farm. Over 58% would accept ticket prices below RMB 10 (≅EUR 1.40).

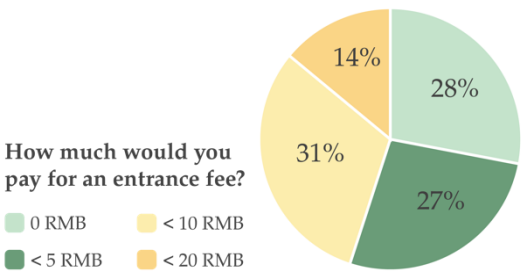

Figure 6. Survey of acceptance of an entrance fee.

Many respondents would consider renting a personal area within a vertical farm to plant their own vegetables and fruits, though only 4% said yes without further conditions. A total of 15% of the respondents would not consider it. The remaining respondents would

consider it if at least one of the following conditions were met: that they have enough time (53%), that the rent is affordable or inexpensive (39%), and that the farm is near their homes (25%). The frequency of selection for these conditions show how closely willingness is connected to time and money.

In considering which investor participants would trust to develop a vertical farm, the government had the highest approval at 59%. Foreign companies represented the second most-supported type of potential investors, with an acceptance rate of 20.5%. Few respondents trusted national companies (15%) and private investors (14%).

3.2. Results from the Expert Interviews: Factors That Promote and Hinder the Acceptance of the Development of Indoor Agritecture in Shanghai

To complement the consumer survey, the results of the expert interviews present the developmental perspectives by showing the promoting and hindering factors for the acceptance of indoor agritecture in Shanghai. The quantitative presentation of the corresponding quotes is used to illustrate the qualitative results.

3.2.1. Social Dimension

Within the social dimension, the interviewees expressed more promoting than hindering factors for the acceptance of indoor agritecture (Table 7).

Table 7. Number of quotes on promoting and hindering acceptance factors as derived from the qualitative coding scheme, social dimension.

Category	Sub-Category	Number of Quotes on Promoting Factors	Number of Quotes on Hindering Factors	Sum
Multi-functionality	Temporality	60	28	88
	Mental health	80	5	85
	Participation	29	4	33
	Recreation	22	0	22
	Education	20	0	20
	Lifestyle	15	0	15
	Community	8	2	10
	Aesthetics	5	2	7
	Decoration	4	0	4
	Physical health	3	0	3
	Sharing	1	0	1
	Job	1	0	1
Social awareness		35	37	72
Value		47	21	68
Food	Food safety	38	27	65
	Food culture	6	16	22
	Food security	7	2	9
	Taste	4	4	8
	Nutrition	2	0	2
Sum		**387**	**148**	**535**

Considering the multifunctional effects of agritecture, the most frequently discussed factor was temporal influence, with most interviewees expressing that involvement in agritecture influences spaces, surroundings, and individuals' perception of time. Some experts addressed that indoor agritecture saves consumers' time due to its locality, as "*Currently, our currency is no longer money, but time" (Economist, #3).* A universal opinion was that indoor agritecture could slow down the pace of life through participation:

> *"No matter adults, children or old people, they have curiosities for agricultural things in the cities. [. . .] Therefore, slow life is more about this state of mind. [. . .]" (Urban designer, #18)*

Opinions on hindering factors included the following: "*Low participation, too complicated for the community—all this has nothing to do with a slow life*" (*Agriculturalist, #8*).

In terms of mental health, interviewees stated that indoor agritecture positively impacts citizens with the supply of, e.g., interactivity, healing effects, sense of accomplishment, relaxation, decompression, and happiness. Hindering factors included, e.g., citizens' difficulties with enjoying indoor agritecture under high pressure in megacities.

Considering social awareness, promoting and hindering factors were almost equally quoted. The promoting factors included that citizens' awareness about the importance of food safety and urban agriculture has been growing, and that the understanding of the technology utilized in indoor agritecture has been improving social acceptance. Other interviewees emphasized hindering factors such as the depreciation of agriculture by Chinese society, the high price of the produce from indoor agritecture, and the cognitive challenges through the high technology level.

Regarding the general value estimate, the interviewees agreed that indoor agritecture could be a supplemental form of food production, a remedy for food shortages, or additional welfare for the employees or residents of buildings. As hindering factors, interviewees indicated the potential trade-offs between commercial and social uses, security risks, and a lack of trust in the innovation itself.

Under the food topic, food safety was the focus of debate. One interviewee emphasized, "*The food must be safe. If the quality of your food is harmful to people, in any case, it is harmful to urban agriculture*" (*urban ecologist, #5*). Other interviewees stressed as hindering factors that the product quality from urban agritecture could not be guaranteed, as it was not naturally grown; moreover, that there is no certification system for this sort of produce; and that based on the current food industry, people have trust issues. Food culture was the only factor with more quotes regarding hindering than promoting factors. Interviewees suggested the promoting factor that the local food culture in Shanghai (located in South China) is beneficial for the social acceptance of indoor agritecture, because the South Chinese prefer leafy greens, whereas the North Chinese enjoy prefer fruit. Doubts about the taste were raised as a hindering factor. One interviewee indicated Chinese traditions:

> *"The Chinese have a deep attachment to the land, and this is much deeper than it is for foreigners." (Expert on rooftop farms and planting containers, #13)*

It was argued that most Chinese are accustomed to conventional agriculture and low food prices in markets.

3.2.2. Economic Dimension

In the economic dimension, there were more quotes on hindering than promoting factors (Table 8).

Table 8. Number of quotes on promoting and hindering factors for social acceptance, as derived from the qualitative coding scheme, economic dimension.

Category	Sub-Category	Number of Quotes on Promoting Factors	Number of Quotes on Hindering Factors	Sum
Technology	Maturity	9	48	57
	General	23	18	41
	Hydroponics	30	9	39
	Plant species selection	14	5	19
	Lightning	3	6	9
	Aquaponics	3	3	6
	Nutrient solution	1	2	3
	Irrigation	1	1	2
Investment		19	51	70
Profitability		22	23	45
Productivity		18	18	36
Sum		**143**	**184**	**327**

Regarding technology, the number of quotes on hindering factors was high. The factor of maturity was most frequently discussed, with the main argument indicating that the technology is still in its starting phase. It was stated that it is rarely profitable for plants other than herbs and lettuce. One interviewee expressed, "*The more advanced the technology, the more vulnerable it is"* (*CEO of an edible landscape company, #10*). The promoting factors included the belief in the technological maturity in China, the supply of optimal growth conditions without seasonal limits, and the expected decreases in logistics costs. The experts familiar with hydroponics supported as promoting factors the cleanness of hydroponics and its regulation, with arguments against soil pollution resulting from conventional agriculture, soil-based pest diseases, and high soil remediation costs. The hindering factors came from, e.g., doubt over the product quality through hydroponics, health impacts, and the maintenance of the hydroponics devices:

> *"I saw that there are tools for indoor farming on foreign websites. [. . .] I have not tested it, but I think that it cannot be particularly healthy to grow things out of that. It cannot get sunlight because it is indoor. [. . .] I think it is inappropriate for eating." (CEO of an edible landscape start-up, #15)*

Investment was the second most discussed factor, with a high number of quotes on hindering factors. The experts deemed indoor agritecture as economically unsustainable, and referred to the requirement of high investments. In contrast, the promoting factors included that the high investment is affordable by setting high selling prices, that high investment helps avoid pirating of technology and devices, and that local logistics help save investment. The interviewee expressed the following: *"[. . .] the investment is about the priority of efficiency: how to produce everything efficiently to maximize profits"* (*CEO of a planting machine start-up, #17*).

The number of quotes on promoting and hindering factors regarding profitability was equal. Through the confidence in the technology and productivity, some experts foresaw its cost-effectiveness for customers. In comparison, others mentioned hindering factors regarding the potential investments and high levels of technology required (e.g., artificial lightning), holding the opinion that it would be difficult to make a profit.

Concerning productivity, promoting and hindering factors were expressed equally. Promoting factors included that indoor agritecture supplies efficiency through high-density planting in ideal growth conditions and that it provides nonseasonal produce. According to the interviewees, in terms of hindering factors, efficiency means industrial production, planting has many uncertainties that influence the yield quickly, and there have been no long-term successful cases of indoor agritecture. Decentralization of farms was regarded as low efficiency and productivity: "*It is difficult for normal people to start (agritecture). They can only make small-scale ones due to many requirements and a lack of funds, technology, and support"* (*Sociologist, #6*).

3.2.3. Ecological Dimension

From the ecological perspective (Table 9), promoting factors were more prevalent in all three categories.

Table 9. Number of quotes promoting and hindering social acceptance as derived from the qualitative coding scheme, ecological dimension.

Category	Number of Quotes on Promoting Factors	Number of Quotes on Hindering Factors	Sum
Ecology	61	13	74
Resources	26	5	31
Awareness	13	13	26
Sum	**100**	**31**	**131**

Most interviewees confirmed the positive ecological impact of indoor agritecture on urban sustainability, that it helps improve self-sufficiency within existing urban footprints, and accorded it with concepts like "eco city," "pastoral city," "sponge city," and "greening city." The experts agreed: "*It is clear that cities also need nature*" (*Architect, #12*). To create an effective growth environment, indoor agritecture needs to channel more CO_2 from urban areas for photosynthesis, which, according to the experts, helps to reduce CO_2 emissions and the urban heat island effect. Yet, there are also hindering factors: Indoor agritecture has no strong environmental impact due to its closed system, and it was until now unsustainable without solving all the problems in its system. One expert expressed:

> *"To tell the truth, this is pseudo ecology, as it is different from real ecology. It is controlled based on an artificial environment. It will have problems without maintenance, unlike a forest that becomes better if you don't take care of it [. . .]." (CEO of an urban design start-up, #20)*

Considering resource occupation, the interviewees indicated the promoting factors that indoor agritecture decreases resource consumption by developing vertically with local logistics, that hydroponics utilize recycled water systems and nutrient solution explicitly, and that the controlled closed system helps save energy. The hindering factors expressed included that some technologies like lightning are energy intensive. The land resources for the construction of new indoor agritecture was doubted, based on the negative climate impact in the construction process [36,37] and the extraordinary limitation of land resources in Shanghai [see Section 2.1]. Thus, the reconstruction and reutilization of old industrial buildings were advocated. Compared to low-tech farms using permaculture, the sustainability of high-tech farms was questioned.

The promoting factors about the ecological awareness implied improvements in environmental awareness and cognition, and the ongoing learning process about the sustainable life of citizens. A hindering factor was also noted:

> *"If a person has a few times the amount of money required to buy pollution-free products, there are two limitations. One is the disposable income limit, and the other is the knowledge limit." (Sociologist, #2)*

It was argued that there has been no ecological education in Shanghai. The society still needs time to realize the importance of ecology.

3.2.4. Contextual Framework

In terms of the contextual framework within Shanghai, the quote number of promoting factors was significantly high (Table 10).

Table 10. Number of quotes promoting and hindering acceptance as derived from the qualitative coding scheme, contextual dimension.

Category	Number of Quotes on Promoting Factors	Number of Quotes on Hindering Factors	Sum
Development strategy	240	31	271
Governmental support	49	56	105
Current situation	8	95	103
Marketing	46	56	102
Target market	67	20	87
Architecture	55	24	79
Regulation/Standards	4	65	69
Urban planning	43	16	59
Specific location of Shanghai	24	32	56
Landscape planning	19	2	21
Academic gap	11	13	24
Sum	**566**	**410**	**976**

Regarding governmental support, experts claimed hindering factors such as the government lacking awareness or interest in this area, as its current mission is to develop the economy and solve urgent survival problems. They implied that founders must have relationships with the government to receive cooperation or resources, otherwise the connection process is complicated and long. It was thought to be sufficient when the government is not against indoor agritecture, otherwise it would impact the market order. One expert gave an example that breeding poultry is forbidden in urban areas due to the bird and swine flus that occurred years ago in China. Therefore, the development of indoor agritecture is limited to supplying produce instead of meat. Currently, industrial policy support (e.g., discount for industrial electricity at night) is only for state-owned instead of foreign enterprises. Yet, the promoting factors included that the government in Shanghai has started promoting development in this area, which would bring social resources and improve social acceptance. The experts recommended a top-down development or collaboration with the companies that cooperate with the government to open the market. Possible policy support in architecture was also suggested:

> *"[. . .] The policy should support energy saving no matter how thick the wall is (built) and support the construction of internal public space by not calculating it into the plot ratio, then there will be many people trying agritecture [. . .]." (Architect, #9)*

Regarding the current situation of indoor agritecture, some experts mentioned the hindering factor that there is no need to develop indoor agritecture, as agriculture in China supplies overcapacity. Additionally, consumer awareness was not high enough for the purchase of indoor agritectural products. The promoting factors included, e.g., the increase of organic restaurants and supermarkets in Shanghai, existing commercial agritecture cases, and the fast development of indoor agritecture in countries with scarce land resources (e.g., Japan, Singapore) or high demand for salad (e.g., the USA).

Concerning marketing strategies, some of the experts confirmed the maturity of the market. The development of indoor agritecture is driven by the increasing population and, hence, increasing resource conflicts. Due to food safety problems, citizens have a high demand for a direct connection with farmers. Publicity and operation, e.g., in conjunction with courses or workshops, were proposed as primary marketing strategies. The produce, devices, and relevant support services were suggested as trade options. The experts considered indoor agritecture a good selling point for real estate companies. Its construction in community centers or (sub-)CBDs would attract tourists and residents and improve consumption in the surrounding areas. As hindering factors, the experts involved in this area frankly agreed that indoor agritecture is currently a niche market, saying that only people who are idealistic would work in this area for little profit: "*It is rather a concept, a kind of marketing that can attract more guests*" (*CEO of a planting container company, #14.*)

Regarding target markets, the number of quotes on promoting factors was higher. Experts mentioned that indoor agritecture is attractive for diverse groups, such as elderly people, young people, families with children, those who are middle-aged, female consumers, well-educated people, white-collar workers, tourists, those with free time, those interested in technology, those who worry about food safely issue, those who care about their lifestyle, those who need direct connection with farmers without middlemen, or those who need a regular vegetable supply. One expert described their target market as follows:

> *"We aim at high-end supermarkets that sell groceries to foreigners. There, our vegetables can be sold at a high price. If you want, you buy it. If you don't want it, we don't care. The partnership with hotpot restaurants is also a good choice because salads taste delicious in hotpots [. . .]." (Vice-CEO of a vertical farm, #11)*

However, some experts were concerned with the exclusiveness of some target groups.

From the architectural perspective, agritecture was considered to lend new design concepts to green architecture, help save energy, reduce emissions, and provide interaction. It was suggested to reconstruct the existing gray, negative, or public spaces for agritecture, which would enrich visual spatial effects. Agritecture could also be utilized in social welfare

spaces. Nevertheless, hindering factors showed concerns with the architectural durability of reconstructing industrial buildings.

Most experts mentioned current regulations and standards for indoor agriculture as hindering factors. Some of the experts indicated the lack of control in terms of relevant laws and regulations over food quality and the production process, as well as the lack of consolidated organic certification and its relevant control system in China. It also lacks professional management: "*From a broader perspective, agriculture looks simple, but if you would like to benefit, you need professionals to take care of it*" (*Agriculturist, #1*). The experts emphasized that the two forms of indoor agriculture—roof greenhouses and facade farms—are illegal, according to current architecture standards. One promoting statement was that the existing standards convey the positive notion that indoor agriculture can provide a process of rebuilding trust with customers, as its produce is of good quality.

From the urban planning perspective, the promoting factors indicated that indoor agriculture diversifies the urban style, highlights the characteristics of cities, and creates new urban images, which were considered compatible with concepts such as "smart cities," "garden cities," or "pastoral lives." Its food supplementation function was regarded as improving urban–rural relationships. Nevertheless, the hindering factors showed that indoor agriculture may reduce local urban characteristics and lead to homogenization. The following was advised:

> *"From an urban planning perspective, it is said that attention should be paid to domestic planning, but few have implemented this. This concept can be better accomplished from the top-down." (Vertical greening expert, #16)*

Regarding the local conditions in Shanghai for constructing indoor agriculture, the experts expressed that Shanghai has a suitable cultural background for its development, since its citizens have an advanced level of consciousness.

> *"I think the timing is indeed mature for Shanghai, because there is demand from many consumers, which is why increasing organic restaurants and boutique supermarkets exist in Shanghai. That many foreigners living here has driven some local ideology from the upper class. Then, some middle class will definitely follow up; thus, the demand is guaranteed."(Urban designer, #19)*

However, some experts identified hindering factors like the following:

> *"Shanghai is an extreme city and is one of a few mega-cities in the world, having a particularly dense population like Tokyo. The development of agritecture in these cities wastes human resources and the superior conditions of the port [. . .]." (Vertical greening expert, #4)*

They claimed that Shanghai is sufficiently supplied with fresh vegetables and fruits from the neighboring provinces.

Reflecting on the academic gaps, the experts shared that there has been little research in China. Professionals had diverse opinions and an unclear consensus on urban agriculture:

> *"After 2010, academic recognition appeared in this field. Five or six years is not enough time to form a consensus. Landscapers call it 'productive landscapes'; architects call it 'vertical farms', [. . .]; we urban planners have some imported concepts such as 'physical urbanism' and 'agricultural urbanism'. Therefore, there is no unified cognition in these fields." (Urban planner, #7)*

It was corroborated that research on, e.g., its feasibility, technical potential, and relationship between the social acceptance and purchasing power would help enhance the social acceptance. Hindering factors showed that this area lays behind the domestic problems from mainstream major ones such as housing and transportation in urban planning.

To summarize the expert opinions, the top nine most repeated development strategies included (in descending order):

1. Political support plays a crucial role on the long-term development.

2. For the starting phase, miniaturized, personalized, and customized indoor agritecture based on local culture would be a good strategy.
3. The promotion of the concept improves the awareness of the public and developers.
4. To open the market, marketing, branding strategies, and developing characteristics should be utilized to build customer retention.
5. It is essential to build trust (stores need offline interaction) with the citizens.
6. The development demands experts, expertise, and technical support.
7. The long-term development relies on economic sustainability.
8. Indoor agritecture needs corporate involvement for its development.
9. There should be clear target groups as a customer base.

The six most repeated hindering factors regarding development strategies included:

1. Indoor agritecture needs long-term continuous care.
2. Indoor agritecture would be difficult to popularize (subjective acceptance, target markets, difficult reconstruction in existing buildings with unclear property rights).
3. Indoor agritecture could not be scaled up in the short term. It would take eight to 10 years.
4. The maintenance or management for indoor agritecture would be a challenge.
5. There is doubt over general feasibility.
6. It is difficult to modify people's inherent living habits to accept indoor agritecture.

4. Discussion

4.1. Cross-Analysis of the Surveys and Interviews

To summarize, in the consumer survey, the general acceptance of vertical farms was high. In the interviews, the acceptance of indoor agritecture in the social, environmental, and contextual dimensions were high, but in the economic dimension rather low. The analysis of the survey and the interviews shows that the social acceptance of the development of indoor agritecture is still a controversial debate, which is consistent with the conclusions of Specht et al. [8] and Al-Kodmany [9]. Indoor agritecture offers a more efficient utilization of vertical height and land resources, positively impacts urban water and waste recycling [15], and helps with urban energy recycling [38]. Although most of the technologies applied are mature, indoor agritecture is still in the initial developing phase [8] because of the high investment required and the lack of completed projects. Currently, indoor agritecture production requires more energy, effort, and resources than conventional farming production [39]. Thus, the realization of this new concept is not able to financially break even [9] and needs support from policy, management, or local communities [40], especially due to the specific political system in China. If the construction of agritecture strictly follows the concept, a low customer participation possibility will result [38], and the initial cost will be high [10].

In terms of the social dimension, the general social acceptance of vertical farms in the survey was 84%. The acceptance was also considered positive, with a high sum of quotes on promoting factors (Table 7). The demand for multifunctional indoor agritecture or agritecture with recreational functions was significantly indicated in the survey (84.3%). Multi-functionality was considered a representative function promoting the acceptance of indoor agritecture by the experts. The product quality was the crucial factor considering food purchase for those surveyed, which was also emphasized by the interviewees. According to the experts, this is deeply related to current food safety problems in China, which are hereby a driving force for the future development of indoor agritecture. Many interviewees considered trust reconstruction as an essential mission. The exclusion of middlemen between farmers and consumers in the transportation and selling processes helps to reduce the end prices of products, enabling a better profit for farmers.

From the economic dimension, there were more quotes hindering social acceptance. The interviewees delivered a higher number of quotes on hindering factors about productivity. The concern was for a decrease in productivity with participation function. Both the survey participants and the experts were positive about the technology in indoor agritec-

ture (the experts had a higher number of quotes on promoting factors in all sub-categories). In the survey, the highest acceptance of the technology with the feeding of aquatic animals (82.3%) reflects the long-term aquaponic traditions of south China. A concept called the "mulberry fishpond" originated from the Pearl River delta region in China. The Dug-out soil is laid around a pond so that its depth is suitable for the planting of mulberry trees. The leaves of the trees are utilized to feed silkworms, and the feces of the silkworms are in turn utilized to feed the fish in the pond. This mulberry fishpond efficiently produces silk, mulberries, and fish, providing an ecosystem and circular economy. However, it is interesting to notice that although the acceptance of aquaponic technology was high, when it comes to shopping willingness, aquatic animals are not the priority. Because of Shanghai's advantageous geographical location, its citizens have more access to leafy greens, as well as seafood and riverfood, compared to North China. Yet, they have a high demand for vegetables in their daily food culture in comparison to seafood or riverfood. The experts also expressed that they do not deem aquaponics to be acceptable for indoor agritecture (see Section 3.2.2).

The only characteristic about technology that rated rather negatively in the survey was that vertical farming is a totally closed system (acceptance rate below 50%), which is consistent with some of the opinions from the interviewees. This could be related to the conventional agricultural traditions in China. This is also reflected through the survey result that the most common reason for rejecting a vertical farm is its artificiality. Some experts stressed that in the Chinese tradition, natural is good. According to the survey results pertaining to shopping behaviors (see Section 3.1.2) and consumers' preferences regarding products from vertical farms, vegetables and fruits account for the main products desired. As Table 5 illustrates, the third highest acceptance rate of potential purchase orientation corresponded to cereals, which shows the long-term demand for cultivating staple foods in vertical farms. The experts also debated about plant species selection, and that only a few vegetable and fruit species with a short growth period could profit well, whereas most of the rest are limited by technology or profit. They talked about the local food culture in Shanghai and that Southern Chinese prefer leafy greens and light food, which suits the potential planting species in indoor agritecture closely.

From the ecological dimension, both the survey respondents and experts confirmed positive impacts on cities if constructed systematically. The interviewees confirmed a decrease in resource consumption with the help of indoor agritecture. They also affirmed the importance of the extension of awareness through indoor agritecture (see Section 3.2.3).

Regarding the contextual framework, there were diverse discussion points in the interviews. Talking about the preferences for investors, 59% of the survey participants supported governmental investments. This implies the importance of realizing new projects with the help of political support in China. Unlike Western market mechanisms, the feasibility of new concepts in the Chinese market often relies on national and local governmental orientations. Due to its unique political system, the Chinese government has a major impact on promoting or hindering the development of agritecture. It also indicates a trust issue with Chinese citizens regarding food safety. In comparison, the result of the interviews shows that the number of quotes hindering the acceptance under the category "governmental support" was higher (see Section 3.2.4).

The survey analysis indicates that the demographic factors most closely associated with acceptance of vertical farms are younger age, lower income, and gender, with women more likely to report acceptance (Table 3). Young generations, female consumers, and other potential target markets were also referred to by the experts as target markets (see Section 3.2.4).

According to the shopping behavior analysis in the survey, supermarkets were the most popular food purchase locations among Shanghai's citizens. Although the potential for competition exists between indoor agritecture installations and supermarkets, cooperation intentions with international supermarkets as well as restaurants were recommended by the interviewees.

Some of the experts suggested a balance of participation and productivity as a development strategy. It was stated that there are different profit sorts, and that pure productivity should not be only profit. In the survey, over 58% of those surveyed accepted entry fees under RMB 10 (Figure 6) (approximately EUR 1.40), which can be a potential profit.

4.2. Limitations of the Study and Outlook on Future Research

During the research process, it was determined that the survey participants and the experts had confused the definitions of indoor agritecture (including vertical and indoor farms) with those of edible landscapes, vertical greening, urban agriculture, and urban gardening. This shows the ambiguity and the lack of academic clarity in this field and indicates the initial developmental phase of this concept in Shanghai. Hence, it is suspected that answers related to indoor agritecture may have been addressed more broadly.

Because agritecture, as a special branch of urban agriculture, has been developing rapidly during recent years, the authors are aware that the study phase is quite long and the data are not completely up to date. Moreover, this study applied a random survey method. Although not statistically or demographically representative of the 25 million residents in Shanghai, the survey results can be justified by the survey's exploratory nature. Such innovative and even futuristic concepts are challenging when attempting to find a general critical mass of people to understand and answer the questionnaires. Hereby, the fact that more than 200 surveys were filtered out also suggests the need for a clearer description of the concept for survey participants and a need for more quality assurance when motivating the respondents and gathering completed surveys regarding such specific topics.

The selection of the interviewees for the qualitative interviews may have entailed a certain bias. When approaching interview partners on such a new topic, those who were generally more interested in the topic may have agreed to participate in the expert interview. Thereby, the interviews may cover the innovative milieu in Shanghai well; however, the more traditional or even conservative power—the administration and planning/design institutions—are likely to be less covered. Overall, this combination of quantitative and qualitative data provides the first general insight into the development of agritecture in Shanghai. Further studies are required to inspect the more recent developments.

On the one hand, the lack of successful completed projects leads to scarce research on the technology and sustainability of indoor agritecture. On the other hand, the technology has been improved continually during recent years, also through utilization in other branches. Both factors require long-term continual research. Despite the controversial debate about indoor agritecture, the first vertical farm was constructed in 2016 in Shanghai. It is a two-story farm located in the sub-urban area and focuses on production without allowing participation by the consumers. This indicates, however, the great potential and market attractiveness of indoor agritecture.

Economic sustainability is key to the long-term development of indoor agritecture. Taking vertical farms as an example, although there have been many attractive designs that have received great feedback and awards in different design competitions, there are not enough completed projects to provide enough data for economic development or ROI analysis. This can be researched in depth along with the realization of more commercial agritectural projects.

Small-scale indoor agritecture is the initial development. It still lacks data sharing in different areas, such as in seed selection and marketing strategies, which not only hinders the development process of companies or start-ups but also leads to communication gaps in commercial and academic fields. Therefore, it is necessary to create data-sharing platforms and to research the long-term economic sustainability by comparing different cases in the future.

5. Conclusions

In comparison to the diversity of research in the Western world, the development of indoor agritecture has been weakly researched and reported on in the East Asian urban

context. This paper focused on the social acceptance of indoor agritecture in conjunction with social, ecological, economic dimensions and the contextual framework in the research location of Shanghai. The mixed approaches of survey and interviews helped to research the social acceptance from the perspective of both potential consumers and stakeholders into the extent and depth. Although the analysis of the interviews illustrated both promoting and hindering factors about indoor agritecture, the results of the questionnaires indicate a more supportive attitude toward the development of vertical farms.

The quantitative study demonstrates that the social acceptance of indoor agritecture among the surveyed respondents is high, and there is already a demand and potential market for indoor agritecture. This was validated through the construction of the first moderate-scaled vertical farm and several indoor farms in Shanghai after the quantitative research phase, in combination with the increasing existence of edible landscapes, plant factories, and rooftop farms.

In terms of the qualitative research conducted, the social and ecological dimensions of indoor agritecture were shown to be positive, but the experts doubted the economic sustainability of indoor agritecture. The contextual frame was considered generally positive, and further development strategies were suggested by the experts.

Despite the lack of academic research and completed projects, more installations of indoor agritecture have been constructed in metropolises in Asia, indicating the success of the first step. This phase establishes a milestone that lays the groundwork for the intensive and productive phase of indoor agritecture in the foreseeable future. With the development of the necessary technology and a relevant decrease in the investment, the expansion mode of indoor agritecture will shift from small-scale and low-profit forms to large-scale and highly profitable forms [40]. By harnessing its impact on the urban ecosystem, urban energy recycling, and circular economy, as well as its ability to permanently and macroscopically reduce the food miles incurred by society, urban agritecture should be developed systematically with other forms of urban agriculture together to support local food security in the future.

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Institutional Review Board Statement: Ethical review and approval were waived for this study due to there being no institutional review board at CMS, TU Berlin, at the time of the study. This study would be exempt from review for current institutional review boards, because it does not involve any medical or invasive procedures and collected data that was non-identifiable and not sensitive in nature.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon request.

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Appendix A. Questionnaire (Original Chinese Version)

一. 食品购买状况调研

1. 您平时在哪里购买大多数食品？

- ○ 超市
- ○ 市场
- ○ 露天或路旁小摊
- ○ 其他_____

2. 您购物的地方离家多远？

- ○ <1 千米 （步行 <15 分钟，自行车 <5 分钟）
- ○ 1–2 千米（步行 <30 分钟，自行车 <10 分钟）
- ○ 2–5 千米（步行 <1 小时，自行车 <20 分钟）
- ○ >5 千米（步行 >1 小时，自行车 >20 分钟）

3. 您对这个距离满意吗？

- ○ 满意
- ○ 不满意

4. 你希望有何改进措施？（可多选）

- ○ 更多店铺
  - ☐ 更多超市
  - ☐ 更多市场
  - ☐ 更多果蔬商店
  - ☐ 更多小摊
  - ☐ 可以自己体验摘新鲜蔬果的地方
- ○ 更多产品
  - ☐ 更多新鲜食物
  - ☐ 更多绿色食品
- ○ 不需要改进
- ○ 其他_____

5. 请选择 5 个最重要的影响您购买食品的因素并排序（请在方框内输入 1,2,3,4,5；1 为最重要）

- ☐ A. 价格
- ☐ B. 口感
- ☐ C. 品牌
- ☐ D. 质量
- ☐ E. 优惠活动（大减价）
- ☐ F. 外观
- ☐ G. 有机食品（绿色食品）
- ☐ H. 随机决定
- ☐ I. 其他_____

6. 在您读了上述介绍之后，您能够接受在上海试点建设垂直农场吗？

- ○ 能（至题 9）
- ○ 不能

7. 如不能，为什么？

- ○ 因为它是人工系统
- ○ 传统农业现在还运行良好
- ○ 这个问题我不感兴趣
- ○ 其他_____

8. 如不能，哪个生产原因是您不能接受的？（可多选）

- ○ 无土栽培
- ○ 废水净化再浇灌
- ○ 没有自然光照
- ○ 封闭系统
- ○ 其他_____

二. 生态调研

9. 如果在垂直农场中用人工照明取代太阳光照来种植作物，您能接受吗？

- ○ 能
- ○ 不能

10. 如果垂直农场中的植物是无土栽培的，您能接受吗？

- ○ 能
- ○ 不能

12. 如果垂直农场中的植物用经过污水循环过滤后的水浇灌，您能接受吗？

- ○ 能
- ○ 不能

13. 如果在垂直农场中饲养动物（如禽类，小香猪），您能接受吗？

- ○ 能
- ○ 不能

11. 如果垂直农场是一个封闭系统（和外界没有空气交换，内部无风，恒温），您能接受吗？

- ○ 能
- ○ 不能

14. 如果在垂直农场中养殖水生动物（如鱼，虾）用来生产粪肥同时它们也能通过植物获得更多氧气，您能接受这种植物和鱼共同饲养的节能方法吗？

- ○ 能
- ○ 不能

三. 市场调研

15. 如果垂直农场只生产绿色食品（无化肥无农药），但是价格较一般产品贵些，您能接受吗？（可多选）

- ○ 能
- ○ 也许
  - ☐ 取决于产品口感
  - ☐ 取决于产品质量
  - ☐ 取决于价格差距
  - ☐ 其他_____
- ○ 不能

16. 您可能会购买垂直农场中的何种产品？（可多选）

- ☐ A. 粮食（大米，白面等）
- ☐ B. 豆类（大豆，豌豆等）
- ☐ C. 蔬菜（番茄，菠菜等）
- ☐ D. 水果（草莓，西瓜等）
- ☐ E. 动物产品（鸡蛋，牛奶等）
- ☐ F. 肉类
- ☐ G. 水产（鱼，虾等）
- ☐ H. 加工食品（烤番薯，鲜榨果汁等）
- ☐ I. 不会购买任何产品
- ☐ J. 其他_____

17. 您最能接受哪方投资开发垂直农场？（可多选）

- ○ 政府
- ○ 国企
- ○ 外企
- ○ 民营企业/个人
- ○ 其他_____

四. 规划调研

18. 如果垂直农场坐落于城市中心(如人民广场)或副中心(如五角场)，而您恰巧在那附近，会顺便去参观吗？

- ○ 会
- ○ 不会

21. 如果垂直农场坐落于您家附近，您会经常光顾吗？

- ○ 偶尔
- ○ 有时候
- ○ 经常
- ○ 频繁

19. 您认为垂直农场中应该有其他功能吗？如果是，哪些功能对您来说很重要？（可多选）

- ○ **是**
  - ☐ 教育功能（关于植物种植的介绍，展览，书店）
  - ☐ 体验功能（可自己种植收获植物）
  - ☐ 娱乐功能（电影院，饭店，咖啡馆）
  - ☐ 购物功能（服装，纪念品）
  - ☐ 其他_____
- ○ **否**

22. 如果您可以在垂直农场中付较少的租金租一块属于您的“地”并且可以种植自己喜欢的瓜果，您会这么做吗？（可多选）

- ☐ 会
  - ☐ 如果我有时间的话
  - ☐ 如果我不需要付很多租金的话
  - ☐ 如果有专家可以指导我如何种植的话
  - ☐ 如果离家很近的话
  - ☐ 其他_____
- ☐ 不会

20. 如果进入垂直农场需购买门票，什么价位的门票您能接受？

- ○ 0 元
- ○ <5 元
- ○ <10 元
- ○ <20 元

23. 您支持在上海建设全世界第一个垂直农场的想法吗？

- ☐ **是**
- ☐ **否**

24. 相较于传统农业，您认为垂直农场能够成为人类发展与保护自然之间的平衡点吗？

- ○ 能

	○ 不能
五. 个人信息	
25. 您的性别： ○ 男 ○ 女	**29. 您目前的职业：** ○ A. 全日制学生 ○ B. 生产人员 ○ C. 销售人员 ○ D. 服务人员 ○ E. 市场/公关人员 ○ F. 行政/后勤人员 ○ G. 人力资源 ○ H. 财务/审计人员 ○ I. 文职/办事人员 ○ J. 技术/研究/发展人员 ○ K. 管理人员 ○ L. 教师 ○ M. 医生 ○ N. 顾问/咨询 ○ O. 专业人士（如会计师，律师，建筑师） ○ P. 艺术家 ○ Q. 退休人员 ○ R. 其他_____
26. 您的年龄： ○ ≤20 岁 ○ 21–30 岁 ○ 31–40 岁 ○ 41–50 岁 ○ 51–60 岁 ○ >60 岁	**30. 您的家庭收入情况（税后）：** ○ <5000 元/月 ○ 5000–10,000 元/月 ○ 10000–15,000 元/月 ○ 15,000–50,000 元/月 ○ >50,000 元/月
27. 在哪个区域居住？ ○ 内环以内 ○ 内环–中环 ○ 中环–外环 ○ 外环以外 ○ 其他_____	**31. 您家有几位和您一起使用家庭收入的成员？（包括您自己）** ○ 1 ○ 2 ○ 3 ○ 4 ○ ≥5
28. 您已获得或正在攻读的最高学历： ○ A. 小学及以下 ○ B. 中学 ○ C. 中专/职校 ○ D. 高中 ○ E. 大专 ○ F. 本科 ○ G. 硕士 ○ H. 博士 ○ I. 其他_____	

非常感谢您的耐心回答！祝安康!

Appendix B. Questionnaire (Translated into English)

A. Actual Food Purchase Situation

1. Where do you purchase most food products?

- ○ In supermarkets
- ○ In markets
- ○ From stands on the street
- ○ Other_____

2. How far away are the places where you normally buy your food products?

- ○ <1 km (by foot <15 min, by bike <5 min)
- ○ 1–2 km (by foot <30 min, by bike <10 min)
- ○ 2–5 km (by foot <1 h, by bike <20 min)
- ○ >5 km (by foot > 1 h, by bike >20 min)

3. Are you satisfied with this distance?

- ○ Yes
- ○ No

4. What kind of improvements do you wish for? (Multiple choice)

- ○ More stores
  - ☐ More supermarkets
  - ☐ More markets
  - ☐ More shops
  - ☐ More stands
  - ☐ Places to harvest fresh food on my own
- ○ More products
  - ☐ More fresh products
  - ☐ More organic products
- ○ No improvements are needed.
- ○ Other_____

5. Please select the 5 most important factors for you when you decide buying a food product (sort with 1, 2, 3, 4, 5).

- ☐ Price
- ☐ Taste
- ☐ Brand
- ☐ Quality
- ☐ Special offer (e.g., on sale)
- ☐ Outer appearance
- ☐ Organic products
- ☐ I decide it randomly.
- ☐ Other_____

6. After reading the introduction above, can you accept developing a vertical farm in Shanghai?

- ○ Yes (to Q9)
- ○ No

7. If not, why?

- ○ The system is artificial.
- ○ The conventional agriculture still works well.
- ○ This topic does not interest me.
- ○ Other_____

8. If not, which production factor is not acceptable for you? (multiple choice)

- ○ No soil
- ○ Recycling and reuse of wastewater
- ○ No natural sunlight
- ○ Closed system
- ○ Other_____

B. Ecological Survey

9. Is it acceptable for plants in a vertical farm to be cultivated by artificial light instead of sunlight?

- ○ Yes
- ○ No

10. Is it acceptable for plants in a vertical farm to be cultivated without soil?

- ○ Yes
- ○ No

12. Is it acceptable for plants in a vertical farm to be irrigated by recycling water?

- ○ Yes
- ○ No

13. Is it acceptable for there to be animals (e.g., chickens, piglets) in a vertical farm?

- ○ Yes
- ○ No

11. Is it acceptable for vertical farm to be a closed system (no air exchange from outside, no wind, constant temperature)?

- ○ Yes
- ○ No

14. Is it acceptable for there to also be aquatic animals (e.g., fish, shrimps) in a vertical farm, which produce fertilizer for the plants and obtain oxygen produced from plants?

- ○ Yes
- ○ No

C. Marketing Survey

15. If the vertical farm only produces organic products (without pesticides) but the price is higher than normal products, is it acceptable? (Multiple choice)

- ○ Yes
- ○ Perhaps
  - ☐ Based on the taste of the products
  - ☐ Based on the quality of the products
  - ☐ Based on the price difference
  - ☐ Other_____
- ○ No

16. What kinds of products would you buy from a vertical farm? (Multiple choice)

- ☐ Cereals (rice, flour, etc.)
- ☐ Beans (peas, soybeans, green beans, etc.)
- ☐ Vegetables (tomatoes, spinach, cucumbers)
- ☐ Fruit (strawberries, watermelons)
- ☐ Animal products (eggs, milk, etc.)
- ☐ Meat
- ☐ Aquatic products (fish, shrimps, etc.)
- ☐ Processed food (fresh juice, roasted sweet potatoes)
- ☐ Nothing
- ☐ Other_____

17. Which investor has your confidence for managing a vertical farm? (Multiple choice)

- ○ Government
- ○ National company
- ○ Foreign company
- ○ Private investor
- ○ Other_____

D. Planning Survey

18. If the vertical farm were located in a CBD (central business district: People's Square) or sub-CBD (e.g., Wu Jiao Chang) in Shanghai, would you visit it on occasion when you are nearby?

- ○ Yes
- ○ No

21. If a vertical farm were located near your home, how often would you visit it?

- ○ Rarely
- ○ Sometimes
- ○ Regularly
- ○ Very often

19, Is the combination of a vertical farm with other functions important? If yes, which one do you think is important for you? (Multiple choice)

- ○ Yes
  - ☐ Education (introduction for children, exhibition, bookstore)
  - ☐ DIY (do it yourself: plant and harvest on your own)
  - ☐ Recreation (cinema, restaurant, cafe)
  - ☐ Shopping (clothes, souvenirs)
  - ☐ Other_____
- ○ No

22. If you could rent an area in a vertical farm and plant vegetables and fruits as you wish, would you do it? (Multiple choice)

- ○ Yes
  - ☐ If I have time
  - ☐ If I don't have to pay a lot
  - ☐ If there are experts guiding me on how to take care of the plants
  - ☐ If it is not far away from my home
  - ☐ Other_____
- ○ No

20. If there is entrance, how much would you pay?

- ○ RMB 0
- ○ <RMB 5
- ○ <RMB 10
- ○ <RMB 20

23. Would you like to support the idea of building the world's first vertical farm in Shanghai?

- ○ Yes
- ○ No

24. Comparing with conventional agriculture, do you think vertical farms could make a contribution to find the balance between human development and nature in the future?

- ○ Yes
- ○ No

E. Personal Data

25. Your gender:

- ○ Male
- ○ Female

26. Your age:

- ○ ≤20
- ○ 21–30
- ○ 31–40
- ○ 41–50
- ○ 51–60
- ○ >60

27. In which area do you live?

- ○ Inside the inner ring
- ○ Inner ring–middle ring
- ○ Middle ring–outer ring
- ○ Outside the outer ring
- ○ Other_____

28. The highest degree that you are studying or have obtained:

- ○ Elementary school
- ○ Middle school
- ○ Technical secondary school
- ○ High school
- ○ College
- ○ Bachelor's
- ○ Master's

29. Your current career:

- ○ Full-time student
- ○ Production staff
- ○ Sales staff
- ○ Service staff
- ○ Marketing/PR
- ○ Administrative/support staff
- ○ Human resources
- ○ Finance/audit staff
- ○ Clerical staff
- ○ Technical/R & D personnel
- ○ Manager
- ○ Teacher
- ○ Doctor
- ○ Consultant/Consulting
- ○ Professional (accountant, lawyer, architect, urban planner, etc.)
- ○ Artist
- ○ Retiree
- ○ Other_____

30. Your household income range (net):

- ○ <RMB 5000/month
- ○ RMB 5000–10,000/month
- ○ RMB 10,000–15,000/month
- ○ RMB 15,000–50,000/month
- ○ >RMB 50,000/month

31. How many people live in your household? (You included)

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ ≥5

○ Doctorate

○ Other_____

Thank you very much for your patience to complete the questionnaire! We wish you all the best!

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