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Abstract: The public's rejection of recycled water has seriously hindered the promotion of recycled water. Individual intention and decision-making behavior will be affected by group decision-making behavior. To clarify the interaction mechanism of the public's intention to reuse recycled water from the perspective of group decision-making, this study used an eye-movement experiment with a recycled water consumption scenario simulation to obtain the influencing factors and data related to purchase decisions and used the ABM (agent-based modeling) method to simulate the interaction effects of the group's intention to reuse recycled water in a combination of three influencing factor scenarios: sales volume, quality evaluation, and environmental evaluation on the Netlogo platform. The results showed that (1) quality reviews have a significant effect on the intention of the group to reuse recycled water, followed by sales, and environmental reviews have the worst effect; (2) in the two-factor interaction, the intention of the group to reuse recycled water was significantly improved, and the public's intention to reuse recycled water was highest under the influence of good quality reviews and high sales; and (3) under the combined influence of the three factors of high sales, good quality reviews, and good environmental reviews, the public's intention to reuse recycled water was the highest, but the effect was slightly different from the influence of two factors: good quality reviews and high sales. This study aimed to provide a scientific basis for the promotion policy of recycled water reuse.



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**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). **Keywords:** intention to reuse recycled water; sales; quality review; environmental review; ABM (agent-based modeling)

# 1. Introduction

Water shortages seriously threaten the survival of human beings and restrict the development of the national economy. It has become one of the strategic issues worldwide [1,2]. The United Nations Sustainable Development Goals note that water scarcity, poor water quality, and inadequate sanitation hurt food security and livelihood choices. Two-thirds of China's 600-plus cities lack water, making it one of the poorest countries in the world's for per capita water resources. Water resource shortages and water pollution are the major bottlenecks restricting China's high-quality development at present [3]. Compared with other water sources developed, such as long-distance water diversion and seawater desalination, recycled water as the "second water source" in cities has the advantages of stable water quantity, a reliable source, low cost, and not being limited by climatic conditions, and other natural conditions [4]. Thus, recycled water plays a vital role in alleviating water resource shortages and protecting the water environment and water ecology [5]. To this end, the state has issued the Guiding Opinions on Promoting the Resource Utilization of Sewage to accelerate the resource utilization of sewage and help solve the problems of regional water shortage and water ecological damage.

Currently, sewage treatment technology has become increasingly mature, and recycled water can be used in all fields of production and life [6]. Still, it is not easy to promote the

utilization of recycled water in actual output and life. The public stereotype of recycled water as sewage is one of the main reasons for this situation [7,8]. In recent years, researchers have focused on the public's participation intention and influencing factors of recycled water reuse at the micro subject level. Relevant studies mainly focus on the impact of demographic characteristics [9,10], the price [11], perception of quality and health of recycled water [12,13], residents' environmental perception, information disclosure of recycled water [14,15], and recycled water reuse policy [16] on the public's choice to reuse recycled water. However, research on the public's intention to reuse recycled water has been chiefly limited to characterizing group characteristics through the aggregation and classification of micro individual features. As a result of individual social attributes, the behavior decision is affected by the social group behavior [17]. Online reviews are becoming a decisive factor in people's decision to buy a product because they include both relatively objective information about the product itself and other people's opinions. This study, therefore, considers online reviews as the main factor influencing consumers' purchase of recycled water and, considering the factors that people are most concerned about when referring to recycled water quality and people's awareness of the environment, the study divides the types of reviews into two categories, namely, quality reviews and environmental reviews. As an environmentally friendly product, the ultimate goal of recycled water is for it to be purchased by consumers. The price of recycled water and sales can also be factors that influence consumer purchases. Therefore, this study constructed a realistic

consumer purchase through an eye-movement experiment. Most social phenomena do not occur as a result of individual decisions in isolation but as a result of the interaction of many people over time. Therefore, group decision-making is not a simple set of static individual behaviors but a complex and changeable dynamic process. To further study the real purchase behavior of consumers and explore the changes in final purchase decisions after individual-to-individual interaction of opinions, this study will analyze the influencing attributes related to the public and construct an individual decision–opinion interaction formula based on self-construction theory. Self-construction theory involves not only the demonstration of one's uniqueness in terms of one's own initiative and shared behavior (influence), which is not easily disturbed by external factors, but also the connection between the self and others using the behavior of others as a basis for one's own decision-making (being influenced) [18], and each individual may have both independent and interdependent self-construals to varying degrees [19]. Considering that both self-construals are bounded by their social scope (range of social relations) in interpersonal interactions, this study combines self-construal theory with three indicators (individual attributes), namely, being influenced, influence, and social scope, as an essential basis for establishing rules for micro-group interactions. The ABM (agent-based model) method is used to realize individual-to-individual interaction [20], and the dynamics of the public's willingness to reuse recycled water is explored from the perspective of the evolution of group decision-making behavior, which provides an adequate theoretical basis and practical guidance for the formulation of recycled water promotion policies.

online shopping environment and explored the influence of four categories of factors on

#### 2. Data and Methods

#### 2.1. Eye Movement Experiment on Intention Measurement of Recycled Water Reuse

Traditional questionnaires, interviews, and other methods often suffer from the Hawthorne effect [21], especially for recycled water, which comes from sewage and has environmental impacts. The public may make choices contrary to their fundamental ideas to cater to social norms, and this makes it difficult for traditional questionnaires or interviews to accurately test the public's implicit ideas on recycled water reuse. Eye movement experiments can capture and record the eye-tracking of the experimental participants, which is an effective method to expose the public's cognitive process and predict the general behavior decision. Attention time is an essential eye-movement index to characterize the mental function of consumers and has been widely used in consumer behavior research [22,23].

To better observe and record participants' behaviors in the decision-making process of purchasing recycled water, in this experiment, stimulation materials were designed according to the Taobao product details page to enhance the immersion and experience of the participants. The comment area was set as four interest areas: good reviews on recycled water quality, bad reviews on recycled water quality, good reviews on the recycled water environment, and bad reviews on the recycled water environment. To reduce the cognitive load of the participants in the experiment, the number of words in all of the comments was similar. After each page is displayed, it will enter the scoring screen, and the subjects must score the intention to reuse recycled water from one (very reluctant to buy) to seven (very willing to buy). After browsing all of the pages, the experiment is over.

The eye movement experiment was carried out in the Neuromanagement In Engineering Laboratory of Xi'an University of Architecture and Technology. A total of 118 participants were selected to participate in the eye movement experiment. Twelve of them participated in the pre-experiment. In the formal experiment, the participants were randomly assigned to three groups of experiments with different prices, including 32 in the low-price group, 34 in the medium-price group, and 33 in the high-price group. All of the participants had normal visual acuity or corrected visual acuity. Seven subjects were excluded due to a low rate of eye movement data collection. A total of 99 valid participants (65 males and 43 females) were collected for 296 sets of gaze duration data on quality reviews, environmental reviews, and sales [24].

#### 2.2. Self-Constructed Questionnaire Data

To obtain the data related to individual self-construction in the group decision-making process, online questionnaires were distributed, including demographic characteristics such as age and gender, as well as three individual attributes of influence, being influenced, and social scope. For individual attribute indicators a five-point Likert scale was used, e.g., influence from one to five represents influence from weak to strong. A total of 228 questionnaires were sent out in this study, and 163 valid questionnaires were recovered, with a recovery rate of 71.5%. SPSS was used in this study to analyze the reliability and validity of each indicator in the questionnaire. The analysis results showed that the Cronbach's alphas of the three variables were all >0.7, the CR (construction reliability) of the three variables was >0.7 in all cases, and the AVE (average variance extracted) of the three variables was >0.5 in all cases, indicating that the questionnaire had good reliability and validity. The results showed that the proportions of people with a social scope from one to five were 4.3%, 3.1%, 46.7%, 39.3%, and 6.6%, respectively. The proportions of people with being influenced from one to five were 2.5%, 7.4%, 76.1%, 13.5%, and 0.5%, respectively. The proportions of people with an influence between one and five were 4.8%, 25.2%, 62.0%, 8.0%, and 0%, respectively.

#### 2.3. Main Body Modeling Method of the Public's Intention to Reuse Recycled Water

Agent-based modeling (ABM) is the primary method for computer simulation of microscopic behaviors and was based on agent modeling to better simulate real-world interactions [25]. In recent years, the ABM approach and modeling using the NetLogo tool have been widely used in various micro behavioral studies [26,27]. To study the influence of price, sales, quality reviews, and environmental reviews on the group's intention to purchase recycled water, as well as to explore the changing regularity of the final purchasing decision after individual-to-individual interaction of opinions. Based on complex adaptive systems theory and the ABMS method [28], this study established the public's intention to reuse recycled water and its influencing factors, the agent's individual attribute parameters, and interaction rules in NetLogo.

To determine the correlation between price, sales, quality reviews, environmental reviews, and the purchase intention of reclaimed water and to predict and analyze it, this study constructed a BP artificial neural network to achieve its representation data fitting and it standardizes the independent variable fixation time and the dependent variable purchase intention. The loss function in Formula (1) was used to feed the error back. Eighty percent of the total data was used as the training set, and 20% was used as the test set. By continuously adjusting the learning rate and thresholds of deviation points as well as the initial range of weights among the points, the error in the training set converged and worked well (Figure 1), and the correct fitting rate of the test set was higher than 70%, and the prediction results were acceptable. To further refine the correlation analysis, a mixed OLS regression analysis using Stata revealed that the p > |t| value for price on the intention to reuse recycled water was 0.2 over 0.1, and the correlation was insignificant. Therefore, in the subsequent study, the impact of three factors on the intention to reuse recycled water, namely, sales, quality reviews and environmental reviews, was investigated.



Figure 1. Data acquisition and BP network diagram of recycled water reuse intention.

To further explore the dynamic change pattern of the final purchase intention after the interaction between individuals this study established 296 agents in NetLogo, set up the data obtained from 296 groups of eye-movement experiments one by one, and assigned the individual attribute data obtained from the questionnaire, including influence, being influenced, and social range, to the 296 agents according to the proportion of these three types of indicators. The parameters of individual attributes based on the agent were established, and a virtual and relatively realistic small world was constructed. The interaction rules in the study were the mapping of people's intention to interact a behavior in reality. In this study, the interaction formula was established based on the questionnaire data, and the intention to use the interaction results was obtained from the eye-movement experiment. According to the social scope inclusion relation, this paper sets up two sets of social rules, small world and interaction rules, as shown in Figure 2.

Social rule 1: Subject A finds Subject B within the social scope, and Subject A is also within the social scope of Subject B, leading to two-way interaction (A and B). ① A's influence \* B's being influenced < A's being influenced \* B's influence, then A is influenced by B ② A's influence \* B's being influenced > A's being influenced \* B's influence, then B is influenced by A.

Social rule 2: Subject A finds Subject B within the social scope, but Subject A does not have a one-way interaction within the social scope of Subject B (A vs. B). ① If the influence of A is less than that of B, A cannot influence B. ② If the influence of A is more significant than that of B, then A influence B.



Figure 2. Social Diagram.

Regardless of the kind of social rule, only the willingness of the affected person to reuse recycled water will change. Let the affected influence be X and the will to reuse recycled water be ID. If agent A affects agent B, the formula is as follows:

If  $ID_A > ID_B$ , then at time t + 1:

$$ID_{B} = ID_{B} + \frac{1}{6 - X_{B}}$$
<sup>(2)</sup>

If  $ID_A < ID_B$ , then at time t + 1:

$$ID_{B} = ID_{B} - \frac{1}{6 - X_{B}}$$
(3)

If  $ID_A = ID_B$ , then at time t + 1:

$$ID_B = ID_B \tag{4}$$

The single factor situation is to adjust the value of a single influencing factor in NetLogo, and the values of the other influencing factors are all 0; that is, the initial value remains unchanged. The combined situation is to adjust the two influencing factors or the three influencing factors that need to be changed. The remaining influencing factors remain the same as the initial values. Adjust the corresponding influencing factors in various situations. Due to the randomness of the agent interaction simulation process, the results of each simulation cannot be exactly the same. The behavior space tool of NetLogo was used to conduct 20 simulation simulations (to weaken the randomness) and then seek the average intention to reuse recycled water after 20 interactions.

#### 3. Results and Analysis

### 3.1. The Public's Intention to Reuse Recycled Water under a Single-Factor Situation

In this study, 800Tick was set as the simulation time to simulate the change in recycled water reuse intention under six situations: high sales, low sales, good quality reviews, bad quality reviews, good environmental reviews, and bad environmental reviews. The NetLogo setting ensures that the number of agents and the proportion of three individual attributes remains unchanged. Under the single-factor influence situation, the average reuse intention of the group after the simulation is shown in Figure 3. Over time, the intention to reuse recycled water in various situations fluctuated but still delivered an upward trend overall.



Figure 3. Output diagram of average intention results in a single-factor situation.

As seen from Figure 3a, only adjusting for the sales factor, the average intention to reuse recycled water after group interaction in the high-sales situation was 0.744, while in the low-sales situation, the average reuse intention was 0.667, and the average recycling level intention to reuse recycled water increased by 11.5% in the high-sales situation compared to the low-sales situation. The result proves that sales have a significant impact on the public's intention to purchase recycled water. As seen in Figure 3b, adjusting only for the environmental reviews factor, the average intention to reuse recycled water after group interaction in the good environmental review situation was 0.711, while the average intention to reuse recycled water in the bad environmental review situation was 0.655. The average intention to reuse recycled water in the positive environmental review situation increases by approximately 8.5% compared to the negative environmental review situation, demonstrating that there is an effect of environmental reviews on the public's intention to reuse recycled water. As seen in Figure 3c, adjusting only for the quality review factor, the average intention to reuse recycled water after the group interaction was 0.814 in the good quality situation compared to 0.565 in the bad quality situation, an increase of approximately 44.1%, thus demonstrating that the change in the good quality reviews had a significant impact on the public's intention to reuse recycled water. The effect of the change in quality rating on the public's intention to reuse recycled water is substantial.

From the three single-factor influences, the result indicates that quality reviews have the most significant impact on the public's intention to reuse recycled water compared to environmental reviews and sales, and the effect far exceeds the impact of sales and the environmental influence on it, which again proves that recycled water quality is the decisive factor influencing the public's intention to reuse recycled water. Compared to sales and environmental factors, the impact of sales on the intention to reuse recycled water was twice that of environmental reviews, indicating that the public is easily influenced by group decision-making behavior. In addition, the result also indicates that the public was less concerned with the environmental reviews of recycled water reuse at this stage, indicating that public awareness of environmental protection was relatively weak. Therefore, increasing the number of reviews of the environment alone may not produce the desired effect in terms of the intention to reuse recycled water.

### 3.2. The Public's Intention to Reuse Recycled Water under Multiple Factors

To observe the change in the group's intention to reuse recycled water under different combinations of influencing factors, high sales, good quality reviews, and good environmental reviews were combined into four combination situations of high sales—good quality reviews, high sales—good environment reviews, good quality reviews—good environment reviews and high sales—good, and quality reviews—good environment reviews to explore the changing trend of the group's intention to reuse recycled water (Figure 4).



Figure 4. Output diagram of average intention results in a multifactor situation.

As seen in Figure 4a, the group's average intention to reuse recycled water obtained from the simulation in the good quality reviews–good environmental reviews situation reached 0.868, which was approximately 22.1% and 6.6% higher than the group's average intention to reuse recycled water in the single-factor situations of good environmental reviews and good quality reviews, respectively. As seen in Figure 4b, the group's average intention to reuse recycled water obtained after simulation in the high sales—good environmental reviews situation reaches 0.822, which was approximately 15.6% and 10.5% higher than the group's average intention to reuse recycled water in the good environmental reviews and high sales one-factor situations, respectively. The result indicates that the public's intention to reuse recycled water has increased better in this two-factor situation compared to the separate single-factor situations. As seen in Figure 4c, the average group recycled water reuse intention obtained from the simulation in the good quality reviews–high sales situation was 0.893, which was an increase of approximately 9.7% and 20.0% compared to the average recycled water reuse intention of the group in the one-factor situations of good

quality and high sales. The results indicate that the public's intention to reuse recycled water increased somewhat in the good quality reviews–high sales situation compared to both single-factor situations.

In summary, all three two-factor combinations are effective in increasing the willingness to reuse recycled water, with the combination of good quality reviews and high sales having the best effect on increasing the public's willingness to reuse recycled water, and the results are not much different from the least effective combination of good environmental reviews and high sales, with the effect differing by less than 10%. The reason for this result may be that when the public makes purchase decisions on recycled water under the influence of combination factors, the positive influence of two or more factors can effectively shake the stereotype as a negative factor in the public's mind. Previous studies have also shown that the combined effects of several weak factors are not simply the sum and sometimes can even surpass the role of decisive factors. The results also showed that although a single good environmental review could not arouse the public's "favorable impression" of recycled water, combined with the influence of high sales, the group's intention to reuse recycled water would be effectively improved.

The results from Figure 4d indicate that the combination of the three factors, namely, good quality reviews—good environmental reviews—high sales, simulated the intention of the population to reuse recycled water. The results showed that under the combination of the three factors, the average output value of the population's intention to reuse water was approximately 0.916. Compared with the situation of good quality reviews—high sales and good quality reviews—good environmental reviews, the average intention to reuse recycled water only increased by 2.6% and 5.5%, and the improvement effect was not significant. Still, it increased by 11.4% compared with the situation of high sales. The results indicate that although the group's intention to reuse recycled water was the highest under the combination of three factors, the improvement effect was not noticeable compared with the two-factor combination of good quality reviews and high sales. After the two-factor combination of good quality reviews and high sales was combined with the influencing factor of good environmental reviews, the intention to reuse recycled water only increased by less than 5%. The results indicate that good environmental reviews have little influence on reuse intention when the three factors are combined. With the increase in time, the combined impact of good quality reviews and high sales can completely replace the combined effect of the three factors. The results indicate that the joint action of the three influencing factors did not achieve the best-expected result. Additionally, it was also indicated that the public's environmental attention to recycled water reuse was not strong enough, and the public's environmental awareness still needs to be continuously improved.

### 4. Discussion

The public's intention to reuse recycled water is mainly affected by quality reviews, followed by sales, while environmental reviews have the least significant effect. The above result proves that, for the public, quality is an essential factor influencing the the purchasing behavior of recycled water. Studies have also proven that although both quality and environmental awareness affect consumers' intention to reuse a product, the impact of quality is better than that of environmental awareness [29], which confirms the conclusion of this part of this study. The reason for this may be that although the average consumer may be aware of the importance of environmental knowledge to them, they may not personally feel that environmentally-friendly products bring them benefits, so the balance in the public's mind is tilted toward the quality factor.

Over time, the combined influence of multiple factors can lead to a positive change in the public's attitudes toward recycled water in a relatively short period, demonstrating that the public's 'stereotype' of recycled water quality is not easily influenced by a single factor and that a combination of influencing factors can be effective. The average intention to reuse recycled water, based on a two-factor situation simulation, proves that the combined effect of good quality reviews and high sales is most effective in promoting the public's intention to reuse recycled water. The results also indicated that while the single factor of good quality reviews has the most significant effect on increasing the average intention to reuse recycled water, the difference between the two-factor high sales—good environmental reviews situation and the two-factor situation with the good quality reviews was minimal. The results above demonstrate that the combination of both factors has a good effect on increasing the public's intention to reuse recycled water. When the factors were combined, there may be a combination effect where people's emphasis on quality was scaled. Under the influence of multiple factors, the public's intention to reuse recycled water tends to be greatest on average, but the good quality reviews—high sales combination was no less effective than the three-factor combination in increasing the public's satisfaction with recycled water, and the good quality review—high sales combination may even be a direct substitute for the three-factor combination if economic benefits are to be taken into account to quickly increase the group's intention to reuse recycled water in the short time. However, in the long term, raising the environmental awareness of the population was a crucial factor in further increasing people's intention to reuse recycled water.

This study found that the impact of environmental reviews on the public's intention to reuse recycled water was weak. In particular, in reality, people were more likely to make purchase decisions under the combined influence of multiple factors, and the proportion of environmental reviews was smaller, so environmental reviews had little impact on the public's intention to reuse recycled water. Research on the purchase behavior of environmentally-friendly electric vehicles also proves that environmental consequences do not have an impact on the public's purchase intentions [30], which is consistent with the conclusion of this study, and it is proposed that the reason for this result may be that those vehicle owners are unaware of the effects of the greenhouse effect or there is weak public awareness of environmental protection. There are also studies proving that awareness of environmental protection in the water environment is significantly positively correlated with the public's acceptance of recycled water and that public responsibility for water environmental protection will promote the public's intention to reuse recycled water [31,32]. Recycled water's quality has reached the domestic water standard. People's worries about the quality of recycled water may be more due to the lack of understanding of recycled water and their weak environmental protection awareness. Only by letting the public understand the value of recycled water can the public truly accept it from the bottom of their hearts. Although this study found that environmental reviews have little impact on the public, it also found that the public's awareness of environmental protection is weak and raising the public's awareness of environmental protection is the key factor to be overcome in the future.

### 5. Conclusions and Recommendations

### 5.1. Conclusions

This study obtained data on the public's intention to reuse recycled water and its influencing factors through eye-movement experiments and online questionnaires and constructed a relationship network between the influencing factors and intention to reuse recycled water through a BP artificial neural network built in NetLogo, establishing a set of realistic interaction rules to simulate the changing trend of the group's intention to reuse recycled water in different contexts. The research results prove that:

(1) Among the single-factor influences, quality reviews has the greatest and most significant impact on the public's intention to reuse recycled water, and the intention to reuse recycled water can be effectively increased by 44.1% compared with the positive and negative reviews. Environmental reviews had the most negligible impact on the public's intention to reuse recycled water, with only an 8.5% improvement over a negative review.

(2) On the influence of two factors, each combination achieved an excellent effect in improving the population's intention to reuse recycled water. The group's intention to reuse recycled water was the highest in the combination of good quality reviews and high

sales. Still, the difference was less than 10% from the combination of high sales and good environmental reviews with the worst effect.

(3) In the three-factor combination situation, the public's intention to reuse recycled water reached its maximum. Still, the improvement effect of the intention to reuse recycled water was not evident in the combination of good quality reviews and high sales, which only increased by less than 5%.

#### 5.2. Recommendations

The study found that the public's concerns about various factors when purchasing recycled water were, in descending order, quality reviews, sales, and environmental reviews. The above results also show that most people pay more attention to immediate interests and have a weaker perception of the long-term value generated by environmental protection. Therefore, the public's environmental protection awareness is inadequate at this stage, which is not enough to affect the public's decisions on recycled water consumption. If we want to effectively improve the public's acceptance of recycled water in the short term, in the promotion process, we should effort to make a detailed positive description of recycled water in terms of quality. Additionally, we also found that a public-driven approach to the dissemination of recycled water reuse can have a significant effect on its development. However, from the sustainable point of view of recycled water reuse promotion, public responsibility should be aroused, public awareness of environmental protection should be raised, and people's environmental protection behavior should be ultimately improved to enable the public to truly accept recycled water so that recycled water can be sustained and achieve benign development. Therefore, the government's popularization policy on recycled water and other environmental protection activities will provide the potential impetus for the sustainable development of the recycled water market.

This model was only a microcosm of the real world, with many deficiencies and improvements required. As this experiment does not take the actual time into account. Subsequent experiments can add the natural world which can be compared to the questionnaire. With the time factor of the simulated world, a perfect design of the problem makes the whole experimental design more realistic. The results have some limitations and we will optimize them in subsequent experiments. Interaction rules are fundamental to an individual's final decision. Improper formulation of interaction rules may cause a vast difference in the results. In reality, the influence of others on individual behavior decisions is a complex and changeable process. A follow-up should be carried out on a deeper level of interaction rules. In this study, only three factors were involved in the research on the public's intention to purchase recycled water. The influencing factors are far more than those mentioned above, including government intervention, regional policies, and the public's understanding of recycled water. More factors will be considered in future research.

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