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# Serving Robots: Management and Applications for Restaurant Business Sustainability

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**Abstract:** This study focuses on the attributes of serving robots, which include "anthropomorphism," "animacy," "likeability," "intelligence," and "safety," and their effect on restaurant customers. The study aims to provide a sustainable development model for the restaurant business, which is suffering from a shortage of manpower. The study identifies the relationships among serving robots' attributes, perceived benefits, perceived risks, perceived value, satisfaction, and revisit intention of customers. An online survey was conducted with customers, aged eighteen years or older, of restaurants that use serving robots. A total of 294 surveys were used for the final analysis. The results indicate that there are statistically significant relationships between "likeability" and perceived benefits, "intelligence" and perceived benefits, "safety" and perceived benefits, and "safety" and perceived risks. It also confirms that perceived benefits have a positive effect on perceived value, and perceived value has a positive effect on satisfaction and revisit intention. Moreover, satisfaction has a positive effect on revisit intention. Based on these findings, several meaningful theoretical and practical implications that can lead to the sustainability of restaurants are presented.

**Keywords:** serving robots' attributes; perceived benefits; perceived risks; perceived value; satisfaction; revisit intention; restaurant business; value-based adoption model

## 1. Introduction

Artificial intelligence (AI)-based robots are being used across the world [1]. These robots, which have been created with the combination of advanced hardware and AI technologies, are intended for human-centered innovation, recognizing people, and responding to human emotions [2]. Social robots that can function as friends for humans are considered to be an area of significant future value [2]. Currently, housekeeping robots, hospitality robots, beverage-making robots, medicine robots, table tennis coaches, and others are available [3]. In fact, not only electronics companies but also household goods companies are focusing on robot development [3]. Meanwhile, the nation's dining industry is facing trouble because of rising minimum labor costs, rent, and material costs, and it is likely that the utilization of robots in restaurants will gradually increase [4]. These rising costs have already led to an increase in the use of serving robots in the United States, Japan, China, and other countries around the world [4]. In addition, researchers predict that serving robots will contribute in many ways to the sustainability of the restaurant business in the future; this has become especially apparent in the face of the widespread use of non-contact services caused by the COVID-19 pandemic worldwide [5]. As part of this trend, serving robots are seen as leaders in convenience in the dining industry. In South Korea, serving robots are used in various restaurant franchises, and their usage is gradually increasing [6]. Particularly, serving robots that can replace employees in provincial towns' restaurants, as there is a shortage of manpower compared to Seoul and the metropolitan area, are drawing the attention of restaurant owners and also offer a unique experience for customers [7].

In the midst of this emphasis on AI technology, Tanaka and Kimura (2010) pointed out that all technologies have strengths and weaknesses, and this makes it imperative for humans to identify the best possible methods to use them [8], while Nadimpalli (2017) stated that physical performance gains are the biggest benefit of AI technology [9]. Regarding the technical aspects of AI technology, Grigore et al. (2011) pointed out that robots have been created to enhance the quality of human lives, and stated that these robots are safe and useful [10]. He stressed that in future, technological advances will be required so that robots can provide help and fulfill their duties more safely and skillfully [10]. Giuliani et al. (2013) predicted that the service robot industry will grow rapidly in the next twenty years [11]. This will entail the development of not only robots equipped to communicate through human language but also socially intelligent robots with manners and facial expressions [11]. Alenljung et al. (2019) posited that robots will help to increase the value of human life and that it is important to provide a positive usage experience for humans. For this purpose, systemic development is required [12].

A broad review of prior studies regarding the use of robots has highlighted that it is a fundamental part of this study to identify the benefits and risks that users will associate with their use [8,13–15]. This study focuses on the basic attributes of robots in situations where empirical research data is very limited and attempts to clarify the relationship between serving robots' attributes and the perceived benefits and risks. To achieve this, the value-based adoption model (VAM) is utilized. This model maximizes value by focusing on the perceived benefits and sacrifices by general users to understand customer behavior [16]. To analyze individuals' new-technology-acceptance behavior, VAM is formulated through a comparison of perceived benefits and sacrifices. The benefits include enjoyment and usefulness, and sacrifices include subconcepts such as perceived fee, technicality, risks, etc. [16]. Kleijnen et al. (2007), Wang and Wang (2010), and Chung and Ku (2015) stated that the perceived benefits that users are aware of lead to an increase in perceived value [17–19]. Sweeney et al. (1999), Snoj et al. (2004), and Kleijnen et al. (2007) confirmed that perceived risks lead to a reduction in perceived value [17,20,21]. It has been identified that these perceived values have a positive effect on customer satisfaction and behavioral intentions, including revisit intention [22,23]. The relationship between customer satisfaction and revisit intention has also been identified in many studies [23–27]. Based on the results of these preceding studies, this study analyzes the impact of the serving robots' attributes on revisit intention by mediating the customers' perceived benefits and risks. It also attempts to analyze the effect of customers' perceived value and satisfaction and to conduct research by subdividing the serving robots in the restaurant business into analysis targets.

Empirical research on robots, especially in the social sciences and the dining industry, has not been conducted widely, and most of the research so far has been focused on quality of engineering, which emphasizes the technical and systemic aspects. Serving robots offer the advantage of reducing labor cost and providing an interesting experience for customers. Ideally, through extensive empirical research, based on the unlimited growth potential of the market in the future, various theories, research models, research methods, and results regarding serving robots and consumer behavior should be prepared. This research highlights the need for empirical research regarding serving robots by taking into account the overall social trends and academic needs that encourage AI, and it is expected that it will be valuable to provide a theoretical basis for future related research and practical implications for relevant areas. After conducting this study, we intend to present detailed suggestions to enhance the revisit intention of customers by analyzing the aspects of the serving robot that are positively perceived by them and which aspects should be further complemented.

The aims of this study are to:

(1) identify the relationship between the five attributes of serving robots and restaurant customers' perceived benefits and risks, respectively;
(2) identify the relationship between perceived benefits and value and perceived risks and value; and
(3) identify the effect of the customers' perceived value on their satisfaction and revisit intention.

## 2. Research Background

### *2.1. Serving Robots' Attributes*

A serving robot is a robot that carries out useful tasks for human beings or replaces equipment [28]. These robots are used for various goals such as cleaning, cooking, healthcare, and serving as a collaborator [28]. Xue et al. (2011) studied ice cream serving robots from an engineering standpoint [29]. Neeti et al. (2016) explained the birth of a new generation of electronic waiters and analyzed them from a technical perspective [30]. Iqbal, Khan, and Khalid (2017) analyzed the system aspects of serving robots in the restaurant industry [31]. Morita et al. (2018) studied the robot system of a tea house [32]. Thanh, Vinh, and Nghi (2019) studied the development of sensors to assist robots in maintaining a stable serving speed in the dining industry [33]. From this, it is evident that most of the relevant studies are based on the engineering aspects related to the technology of serving robots.

Attributes are the features or characteristics of things and are critical antecedents of customers' behavioral intentions in various industries [34]. It is clear that empirical research on serving robots is still in the initial stages, and so this study focuses on their attributes. It also explores how customers judge serving robots on five factors—anthropomorphism, likeability, animacy, safety, and intelligence, which are based on the scales established by Bartneck et al. (2008) [35]. The reliability and validity of these scales have been confirmed through several empirical studies [35]. These attributes are defined as follows: "Anthropomorphism" involves the attribution of human characteristics, human form, and human behavior, to something that is nonhuman such as, a robot or a computer [35]. "Animacy" implies being lifelike. For example, how lifelike the characters in a computer game are affects the emotions of the player [36]. "Likeability" implies a positive first impression, which leads to a more positive evaluation by that person [37]. "Intelligence" refers to how intelligently a robot completes a task, and development of this is ongoing as robots are built on AI technology [35]. "Safety" refers to how safe users feel when interacting with a robot [35]. Very few empirical studies have been conducted on the attributes of serving robots in the restaurant business. This study is expected to be a theoretical foundation for relevant research in the future.

### *2.2. Value-Based Adoption Model*

The VAM, proposed by Kim et al. (2007), is a theory that maximizes the value of a new technology [16]. VAM considers benefits (enjoyment and usefulness) and sacrifice (perceived fee and technicality) as the main factors of perceived value and analyzes behavioral intentions [38]. Van Der Voordt et al. (2016) emphasized that sacrifice includes time, cost, and risk factors [39]. This study attempts to analyze the relationship of perceived risks, by focusing on the risk factors of sacrifice, as the research is based on serving robots, and in this context, the risk factors and the perceived benefits are both important. Technical acceptance for VAM is described based on Zeithaml's (1988) perceived value concept [40]. This reflects that the decision-making process is dependent on a comparison of the benefits and risks of uncertainty while choosing a new technology or product [41].

Till date, most research on mobile internet [16,42], smart home services [38], and accommodation applications [43] has been conducted based on VAM. This study focuses on the customers' perceived value and revisit intention, based on the perceived benefits and risks. So far, there has been very little research on serving robots in the restaurant business based on VAM. Therefore, this study is expected to provide a theoretical base for future related studies.

### *2.3. Development of Research Hypotheses*

Hypotheses to identify the relationship between serving robots' attributes, perceived benefits, perceived risks, perceived value, satisfaction, and revisit intention of costumers have been established based on the discussion above.

#### 2.3.1. Effect of Serving Robots' Attributes on Perceived Benefits for Restaurants

Hypothesis 1 relates to the relationship between the serving robots' attributes and the customers' perceived benefits. As empirical analysis has not been conducted on the relationship between these two factors in the context of the restaurant industry, the relationship between them is presumed on the basis of the results of exploratory research on robots.

In a study on robots for drug manufacturing at a British hospital, Goundrey-Smith (2008) explained that the benefits of using robots included reduction of service delivery errors, increased drug manufacturing efficiency, and increased shelf or space utilization [13]. Kim et al. (2013) analyzed how perceived benefits of their use can be linked to the perception of user's trust, enjoyment, satisfaction, and intelligence in a study on caregiving robots [15]. This research found that the role of robots has a meaningful effect on perceived benefits [15]. Moreover, it also emphasized that, the greater the perceived benefits relative to the perceived risks of robots, the more positive the perception [15].

As discussed above, empirical research on the relationship between serving robots' attributes and their perceived benefits has helped to establish the following assumptions. These aim to demonstrate the relationship between the two variables and provide a theoretical basis for future related studies. Based on these assumptions, to examine the significant effects of the five serving robots' attributes on customers' perceived benefits in the restaurant context, we propose the following five hypotheses:

**Hypothesis 1a:** *The serving robot's attribute of "anthropomorphism" will have a positive effect on the customers' perceived benefits.*

**Hypothesis 1b:** *The serving robot's attribute of "animacy" will have a positive effect on the customers' perceived benefits.*

**Hypothesis 1c:** *The serving robot's attribute of "likeability" will have a positive effect on the customers' perceived benefits.*

**Hypothesis 1d:** *The serving robot's attribute of "intelligence" will have a positive effect on the customers' perceived benefits.*

**Hypothesis 1e:** *The serving robot's attribute of "safety" will have a positive effect on the customers' perceived benefits.*

#### 2.3.2. Effect of Serving Robots' Attributes on Perceived Risks for Restaurants

Hypothesis 2 relates to the serving robot's attributes and the customers' perceived risks, and the relationship between the two variables is presumed based on the results of exploratory studies on the risk factors of robot use.

In his research on robots in the medical field, Goundrey-Smith (2008) explained the various benefits of their use as well as the risk factors [13]. Pointing out the risk of labeling errors in the course of drug manufacturing, he emphasized that human services are required while using robots [13]. He elaborated that robots cannot cope with certain unexpected events, for example, if a drug is sold out [13]. Furthermore, robots cannot accomplish tasks accurately if drugs do not have barcodes [13]. Nadimpalli (2017) pointed out in a hospital study on AI technology that in the event of a critical situation for patients, technology could lead to serious errors [9]. Additionally, it reduces human jobs and creates ethical problems as it replaces human intelligence [9].

As such, there is no empirical research on the serving robots' attributes and the customers' perceived risks, and the following assumptions have been established in this study to provide basic data applicable for relevant areas in future. Based on these assumptions, to examine the significant effects of the five serving robots' attributes on customers' perceived risks in the restaurant context, we propose the following five hypotheses:

**Hypothesis 2a:** *The serving robot's attribute of "anthropomorphism" will have a negative effect on the customers' perceived risks.*

**Hypothesis 2b:** *The serving robot's attribute of "animacy" will have a negative effect on the customers' perceived risks.*

**Hypothesis 2c:** *The serving robot's attribute of "likeability" will have a negative effect on the customers' perceived risks.*

**Hypothesis 2d:** *The serving robot's attribute of "intelligence" will have a negative effect on the customers' perceived risks.*

**Hypothesis 2e:** *The serving robot's attribute of "safety" will have a negative effect on the customers' perceived risks.*

#### 2.3.3. Effects of Perceived Benefits on Perceived Value

Hypothesis 3 relates to the relationship between the perceived benefits and perceived value for customers who have experienced being served by a robot, and empirical research regarding this has not yet been conducted. This study is based on the results of studies conducted in other fields.

Kleijnen et al. (2007) stated that as benefits of mobile channel services increase, the users' perceived value of the service increases as well [17]. Wang and Wang (2010) pointed out that the benefits of the mobile hotel reservation system have a significant impact on the customers' perceived value [18], while Han et al. (2013) stated that the benefits of smartphone use positively affect the users' perceived value [44]. In addition, Chung and Ku (2015) stated that perceived benefits of searching for travel-related information using social networking services have a significant effect on users' perceived values [19]. Kim (2016), based on a smart home service study, stated that the users' perceived benefits have a significant effect on perceived values [45].

As such, most prior studies have indicated that perceived benefits have a positive effect on perceived value. Based on these findings, it is expected that the restaurant customers' perceived benefits have a positive effect on perceived value. Therefore, we propose the following hypothesis:

**Hypothesis 3:** *The customers' perceived benefits will have a positive effect on perceived value.*

#### 2.3.4. Effects of Perceived Risks on Perceived Value

Hypothesis 4 relates to the customers' perceived risks and perceived value based on their experience with a serving robot. Empirical research has not been conducted regarding the relationship between the two variables and serving robots, and so this study is based on the relationship between the two variables as seen in the results of studies conducted in other areas.

Sweeney et al. (1999) studied the relationship between perceived risks and perceived value in the distribution environment and revealed that the perceived risk has a significant inverse effect on perceived value [20]. Snoj et al. (2004) studied the relationship between product quality, perceived risks, and perceived value for cell phone users and found that perceived risks significantly and inversely affect perceived value [21]. Based on a mobile channel service study, Kleijnen et al. (2007) stated that perceived value decreases as users' perceived risks increases [17], while in a smart home service study, Kim (2016) pointed out that privacy risks have a significant impact on perceived value [45].

As such, most prior studies have shown that perceived risks have a negative impact on perceived value. Based on these findings, it is expected that restaurant customers' perceived risks will have a negative effect on perceived value. Therefore, we propose the following hypothesis:

**Hypothesis 4:** *Restaurant customers' perceived risks will have a negative effect on perceived value.*

#### 2.3.5. Effects of Perceived Value on Satisfaction

Hypothesis 5 relates to the relationship between the customers' perceived value and satisfaction with the experience of a serving robot. Empirical research on perceived value and satisfaction relating to a serving robot has not been conducted so far, therefore the relationship between the two variables is presumed based on studies conducted in other fields.

In a study on mobile applications, Lin and Wang (2006) stated that the consumers' perceived value has a direct impact on satisfaction [22]. In a study about casual restaurants, Ryu et al. (2008) stated that the customers' perceived value has a significant effect on satisfaction [23]. Similarly, Kim et al. (2015) stated that the perceived value of tourist mobile applications has a positive effect on satisfaction [46], and Kang and Moon (2016) stated that the users' perceived value regarding social commerce has a significant effect on satisfaction [47].

Most of these studies on the relationship between perceived value and satisfaction have shown that perceived value has a positive effect on satisfaction. Based on these findings, it is expected that restaurant customers' perceived value has a positive effect on satisfaction. Therefore, we propose the following hypothesis:

**Hypothesis 5:** *Restaurant customers' perceived value will have a positive effect on satisfaction.*

#### 2.3.6. Effects of Perceived Value on Revisit Intention

Hypothesis 6 is based on the relationship between customers' perceived value and revisit intention when a serving robot is used. There is no empirical research that elaborates on the relationship between the two variables in terms of the usage of a serving robot. Therefore, the relationship between the two variables is presumed based on research conducted in other areas.

Kim et al. (2007) stated that customers intention to use a product or service is based on the perceived value, which reflects perceived benefits and perceived risks [16]. Similarly, Sirdeshmukh et al. (2002) found that if a customer has a positive perception about a product or service, it has a positive impact on revisit intention and that this intention decreases if the perception is negative. [48]. Kim et al. (2008) stated that the perceived value based on the use of products has a significant effect on customer's behavioral intentions [49]. In a study regarding a mobile application, Lin and Wang (2006) stated that the customers' perceived value directly affect behavioral intentions [22], while Ryu et al. (2008), in a casual restaurant study, also elaborated that customers' perceived value significantly affect behavioral intentions [23].

Studies on the relationship between customers' perceived value and revisit intention have been conducted extensively in all fields, and most studies have indicated that perceived value has a positive influence on revisit intention. Based on these findings, it is expected that restaurant customers' perceived value has a positive effect on revisit intention. Therefore, we propose the following hypothesis:

**Hypothesis 6:** *Restaurant customers' perceived value will have a positive effect on revisit intention.*

#### 2.3.7. Effects of Satisfaction on Revisit Intention

Hypothesis 7 is based on customers' satisfaction and revisit intention when a serving robot is used. The relationship is assumed between the two variables based on research conducted in general restaurants as there is little empirical research that reveals the relationship between the two variables based on the use of a serving robot.

In a hotel restaurant study, Han and Hyun (2017) stated that customers' satisfaction affects revisit intention [24]. In a family restaurant image study, Jeon (2017) elaborated that customers' satisfaction has a positive effect on revisit intention [25]. In a study on restaurant food, Abdullah et al. (2018) revealed that quality of service and price fairness have an impact on customers satisfaction and significantly affect restaurant reuse intention [26]. In a chicken restaurant study, Kim and Shim (2019) stated that customers' satisfaction has a positive effect on behavioral intentions [27].

Customers' satisfaction has been analyzed as a mediating variable and revisit intention as a dependent variable, and the relationship between the two has been explored in many studies. Most studies have indicated that satisfaction has a positive effect on revisit intention. Based on these findings, it is expected that restaurant customers' satisfaction has a positive effect on revisit intention. Therefore, we propose the following hypothesis (see Figure 1):

**Hypothesis 7:** *Restaurant customers' satisfaction will have a positive effect on revisit intention.*

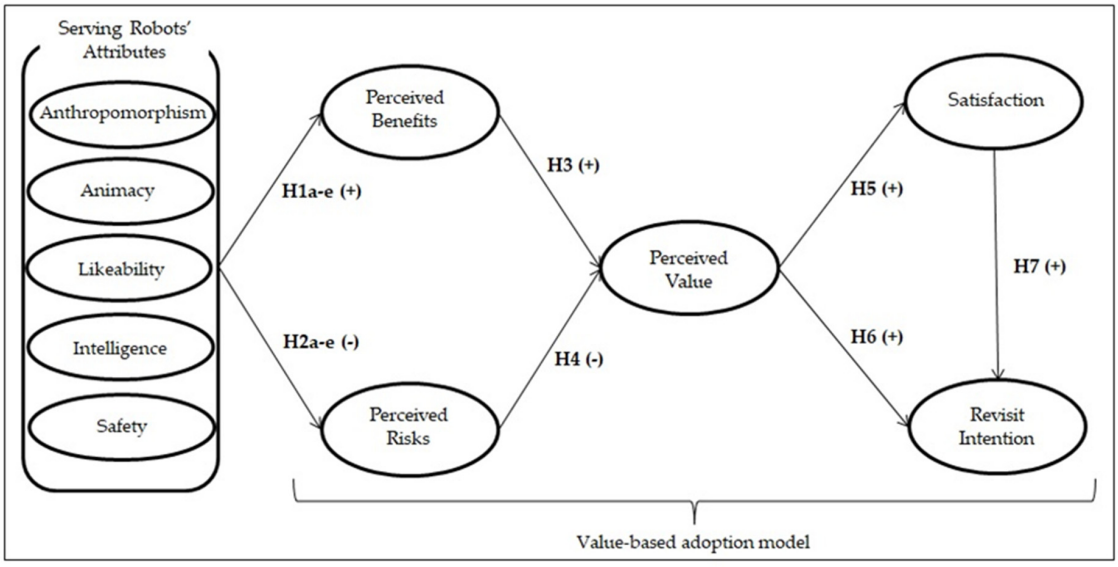


**Figure 1.** Research conceptual model.

## 3. Methods

### *3.1. Data Collection and Sampling*

The samples for this study were from restaurants that use serving robots in Korea. The subjects of this study were consumers aged eighteen and older, who visited at least one restaurant that uses serving robots within the last three months. The data were collected by an online survey company over a period of approximately one week, between 22 January and 28 January 2020. Of the 305 collected surveys, 294 were used for the analysis, as some of them were incomplete. The survey was self-administered, and convenience sampling was employed.

### *3.2. Measurements for Testing Hypotheses*

To analyze the relationship between the serving robots' attributes, perceived benefits, perceived risks, perceived value, satisfaction, and revisit intention, this study employed descriptive statistical analysis, frequency analysis, exploratory factor analysis (EFA), reliability analysis using SPSS, confirmatory factor analysis (CFA), and structural equation model (SEM) analysis using the AMOS program.

The attributes of the serving robots in restaurants has been measured based on the index by Bartneck et al. (2008) [35]. The index contains five items that are related to anthropomorphism and animacy. The index also contains four items that are related to likeability and safety, and three items related to intelligence. Customers' perceived benefits and perceived risks have been measured by adapting the measurement index given by Forsythe (2006) [50]. The index contains four items that are related to perceived benefits and perceived risks. Perceived value has been measured by the measurement index given by Petrick (2002) [51]. This index contains three items. Satisfaction has been measured by adapting the measurement index of Babin et al. (2005) [52]. This index contains four items. Revisit intention has been measured by adapting the measurement index of Youn et al.

(2019) [53]. This index contains four items. A five-point scale (ranging from 1 = Highly disagree to 5 = Highly agree) was used for all of the items.

## 4. Results

Table 1 shows the collected samples' demographic characteristics. A large proportion of the respondents were in their thirties (42.5%), and the percentage of male (49.7%) and female (50%) respondents was similar. In terms of marital status, the married respondents (56.1%) were more numerous than unmarried respondents. In terms of education, university students and graduates (68.7%) were the highest. Monthly income of the respondents was high and fell in the $2000 range (26.2%) and $3000 range (25.5%). The respondents had office jobs (66.7%), professional jobs (11.9%), self-employed (5.8%), or were homemakers (6.5%), students (6.1%), or others (3.1%).

**Table 1.** Respondent characteristics (N = 294).

| Characteristics | *n* (%) | Characteristics | *n* (%) |
|---|---|---|---|
| **Age(years)** | | **Monthly income** | |
| 10–19 | 19 (6.5%) | <$1000 | 13 (4.4%) |
| 20–29 | 50 (17.0%) | $1001–$2000 | 12 (4.1%) |
| 30–39 | 125 (42.5%) | $2001–$3000 | 77 (26.2%) |
| 40–49 | 56 (19.0%) | $3001–$4000 | 75 (25.5%) |
| 50–59 | 32 (10.9%) | $4001–$5000 | 47 (16.0%) |
| Over 60 | 12 (4.1%) | $5001≤ | 70 (23.8%) |
| **Gender** | | **Occupation** | |
| Male | 146 (49.7%) | Student | 18 (6.1%) |
| Female | 148 (50.3%) | Office job | 196 (66.7%) |
| **Marital status** | | Self-employed | 17 (5.8%) |
| Unmarried | 129 (43.9%) | Professional job | 35 (11.9%) |
| Married | 165 (56.1%) | Homemaker | 19 (6.5%) |
| **Educational level** | | Other | 9 (3.1%) |
| High school | 29 (9.9%) | | |
| Two-year college | 38 (12.9%) | | |
| University | 202 (68.7%) | | |
| Graduate school | 25 (8.5%) | | |

### *4.1. Validity and Reliability of Measurements*

Exploratory factor analysis (EFA) was performed on the serving robots' attributes, as research on these robots is still in the initial stages. The results of EFA are shown in Table 2. The serving robots' attributes were divided into five concepts, all eigen values are more than 1, Kaiser-Meyer-Olkin (KMO) = 0.899, total variance explained = 72.620, all results were shown to meet the criteria [54]. The serving robots' attributes were labeled as, "anthropomorphism," "animacy," "likeability," "intelligence," and "safety."

**Table 2.** Exploratory factor analysis results.

| Construct | | Factor Loading | Eigen Value | % of Variance |
|---|---|---|---|---|
| **Anthropomorphism** | 1 | 0.780 | 9.560 | 45.522 |
| | 2 | 0.701 | | |
| | 3 | 0.616 | | |
| | 4 | 0.728 | | |
| | 5 | 0.758 | | |
| **Animacy** | 1 | 0.576 | 1.700 | 8.094 |
| | 2 | 0.764 | | |
| | 3 | 0.777 | | |
| | 4 | 0.761 | | |
| | 5 | 0.727 | | |

**Table 2.** *Cont.*

| Construct | | Factor Loading | Eigen Value | % of Variance |
|---|---|---|---|---|
| **Likeability** | 1 | 0.834 | 1.652 | 7.869 |
| | 2 | 0.600 | | |
| | 3 | 0.831 | | |
| | 4 | 0.662 | | |
| **Intelligence** | 1 | 0.834 | 1.264 | 6.021 |
| | 2 | 0.865 | | |
| | 3 | 0.810 | | |
| **Safety** | 1 | 0.709 | 1.074 | 5.115 |
| | 2 | 0.733 | | |
| | 3 | 0.609 | | |
| | 4 | 0.744 | | |

Notes: Kaiser-Meyer-Olkin (KMO) = 0.899, $\chi^2$ = 4493.958 ($df$ = 210, $p < 0.001$), total variance explained = 72.620.

Confirmatory factor analysis (CFA) was performed to examine the validity and reliability of the measured items. After analyzing a total of forty items, Tucker–Lewis index (TLI) = 0.932; comparative fit index (CFI) = 0.940; incremental fit index (IFI) = 0.940; and root mean square error of approximation (RMSEA) = 0.053 were identified. All these results are consistent with standards [54].

The composite reliability of all construct items was 0.7 or above. As the average variance extracted (AVE) was also 0.5 or above, convergent validity was verified [54]. There was no problem regarding reliability as Cronbach's alpha ranged from 0.820 to 0.939 (see Table 3).

**Table 3.** Validity and reliability of measures.

| Construct | Standardized Loadings | t-Value | CCR [a] | AVE [b] | Cronbach's Alpha |
|---|---|---|---|---|---|
| **Anthropomorphism** | | | 0.865 | 0.563 | 0.862 |
| The appearance of a serving robot is similar to that of a human being | 0.819 | | | | |
| A serving robot looks similar to a human | 0.775 | 14.589 *** | | | |
| Serving robots seem to have the ability to perceive and judge like human beings | 0.675 | 12.226 *** | | | |
| Serving robots look natural | 0.715 | 13.135 *** | | | |
| Serving robots move gracefully like human beings | 0.758 | 14.171 *** | | | |
| **Animacy** | | | 0.851 | 0.535 | 0.868 |
| Serving robots are similar to living creatures | 0.736 | | | | |
| The serving robot looks energetic | 0.783 | 10.463 *** | | | |
| The activity of a serving robot is similar to that of a human | 0.815 | 18.775 *** | | | |
| The interaction with a serving robot is smooth | 0.663 | 11.189 *** | | | |
| Serving robots are highly responsive | 0.645 | 9.214 *** | | | |
| **Likeability** | | | 0.876 | 0.640 | 0.874 |
| Serving robots are cool | 0.850 | | | | |
| Serving robots are friendly | 0.848 | 19.528 *** | | | |
| Serving robots are kind | 0.694 | 11.705 *** | | | |
| Serving robots make me feel good | 0.799 | 11.933 *** | | | |
| **Intelligence** | | | 0.947 | 0.856 | 0.939 |
| A serving robot is good at its job | 0.938 | | | | |
| Serving robots look intelligent | 0.925 | 28.691 *** | | | |
| The use of serving robots is practical | 0.913 | 26.650 *** | | | |
| **Safety** | | | 0.822 | 0.537 | 0.820 |
| A serving robot is safe to use | 0.738 | | | | |
| Serving robots move safely | 0.721 | 12.055 *** | | | |
| The serving robot looks comfortable in its movements | 0.739 | 11.777 *** | | | |
| Serving robots look safe | 0.732 | 11.962 *** | | | |

**Table 3.** *Cont.*

| Construct | Standardized Loadings | t-Value | CCR [a] | AVE [b] | Cronbach's Alpha |
|---|---|---|---|---|---|
| **Perceived benefits** | | | 0.822 | 0.536 | 0.820 |
| A serving robot offers a new experience | 0.745 | 12.643 *** | | | |
| Using a serving robot is fun | 0.781 | 11.968 *** | | | |
| Using a serving robot is a new feeling | 0.708 | 11.637 *** | | | |
| The use of serving robot is novel | 0.690 | | | | |
| **Perceived risks** | | | 0.835 | 0.558 | 0.833 |
| A serving robot does not meet my needs | 0.712 | | | | |
| Robot serving takes longer than the staff | 0.766 | 11.361 *** | | | |
| There are many problems related to smooth interaction with serving robots | 0.723 | 11.523 *** | | | |
| Robots serve slowly | 0.785 | 12.333 *** | | | |
| **Perceived value** | | | 0.933 | 0.823 | 0.884 |
| Using a serving robot gives me pleasure | 0.926 | | | | |
| Serving robots have excellent performance | 0.906 | 25.989 *** | | | |
| The service quality of the serving robot is excellent | 0.890 | 24.487 *** | | | |
| **Satisfaction** | | | 0.922 | 0.750 | 0.916 |
| I am satisfied with the choice of a restaurant company with a serving robot | 0.858 | | | | |
| I am satisfied with the meal at a restaurant with a serving robot | 0.986 | 17.551 *** | | | |
| I am very happy to visit a restaurant with a serving robot | 0.902 | 29.287 *** | | | |
| I am very satisfied with visiting a restaurant that uses a serving robot | 0.692 | 14.733 *** | | | |
| **Revisit intention** | | | 0.907 | 0.710 | 0.895 |
| I will continue to visit the restaurant | 0.875 | | | | |
| I am inclined to visit the restaurant repeatedly | 0.793 | 17.515 *** | | | |
| I will revisit the restaurant | 0.960 | 19.684 *** | | | |
| I will recommend the restaurant to my acquaintances | 0.725 | 13.620 *** | | | |

Notes: $\chi^2/df$ = 1.812, $p < 0.001$; Tucker–Lewis index (TLI) = 0.932; comparative fit index (CFI) = 0.940; incremental fit index (IFI) = 0.940; root mean square error of approximation (RMSEA) = 0.053; [a] CCR: composite construct reliability; [b] AVE: average variance extracted; *** $p < 0.001$.

Table 4 shows correlation coefficients, the square of the correlations, and AVEs of the ten constructs used in this study [54]. The results confirmed the discriminant validity, as all the AVEs were greater than all the squares of the correlations of each pair of constructs.

**Table 4.** Correlations and discriminant validity.

| Construct | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Anthropomorphism | 0.56 [a] | 0.51 [c] | 0.47 | 0.30 | 0.33 | 0.04 | 0.00 | 0.21 | 0.26 | 0.40 | 2.99 | 0.79 |
| 2. Animacy | 0.72 [b],** | 0.53 | 0.32 | 0.31 | 0.44 | 0.12 | 0.00 | 0.26 | 0.28 | 0.38 | 3.39 | 0.65 |
| 3. Likeability | 0.69 ** | 0.57 ** | 0.64 | 0.29 | 0.50 | 0.27 | 0.01 | 0.49 | 0.42 | 0.54 | 3.48 | 0.75 |
| 4. Intelligence | 0.55 ** | 0.56 ** | 0.54 ** | 0.85 | 0.44 | 0.30 | 0.01 | 0.33 | 0.28 | 0.27 | 3.62 | 0.70 |
| 5. Safety | 0.58 ** | 0.67 ** | 0.71 ** | 0.67 ** | 0.53 | 0.43 | 0.05 | 0.46 | 0.40 | 0.46 | 3.49 | 0.66 |
| 6. Perceived benefits | 0.21 ** | 0.35 ** | 0.52 ** | 0.55 ** | 0.66 ** | 0.53 | 0.02 | 0.51 | 0.31 | 0.24 | 4.04 | 0.64 |
| 7. Perceived risks | −0.07 ** | −0.08 ** | −0.10 ** | −0.12 ** | −0.23 ** | −0.15 ** | 0.55 | 0.02 | 0.03 | 0.00 | 2.92 | 0.76 |
| 8. Perceived value | 0.46 ** | 0.51 ** | 0.70 ** | 0.58 ** | 0.68 ** | 0.72 ** | −0.15 ** | 0.82 | 0.47 | 0.46 | 3.63 | 0.66 |
| 9. Satisfaction | 0.51 ** | 0.53 ** | 0.65 ** | 0.53 ** | 0.64 ** | 0.56 ** | −0.18 ** | 0.69 ** | 0.75 | 0.56 | 3.54 | 0.72 |
| 10. Revisit intention | 0.64 ** | 0.62 ** | 0.74 ** | 0.52 ** | 0.68 ** | 0.49 ** | −0.06 ** | 0.68 ** | 0.75 ** | 0.71 | 3.45 | 0.77 |

Notes: [a] Diagonal elements (in bold) are the average variance extracted (AVE); [b] off-diagonal elements are the correlations, ** $p < 0.01$; [c] off-diagonal elements are the square of correlations.

### *4.2. Hypotheses Testing*

In this study, a structural equation model (SEM) analysis was used to verify the hypotheses. The results indicate that there was acceptable model fit, with $\chi^2/df$ = 1.934, $p < 0.001$; TLI = 0.921; CFI = 0.929; IFI = 0.930; and RMSEA = 0.056.

It is seen that "anthropomorphism" has a negative effect ($\beta = -0.381$, $p < 0.001$), "animacy" has an insignificant effect, while "likeability" ($\beta = 0.334$, $p < 0.001$), "intelligence" ($\beta = 0.234$, $p < 0.001$), and "safety" ($\beta = 0.558$, $p < 0.001$) have positive effects on perceived benefits. Thus, Hypothesis 1 has

been partially verified. "Anthropomorphism," "animacy," "likeability," and "intelligence" have an insignificant effect, while only "safety" has a significant effect ($\beta = -0.284$, $p < 0.001$) on perceived risks. Therefore, Hypothesis 2 has been partially supported. As "perceived benefits" have a positive effect on perceived value ($\beta = 0.784$, $p < 0.01$), Hypothesis 3 has been verified. As "perceived risks" have an insignificant effect on perceived value, Hypothesis 4 has not been verified. As "perceived value" has a positive effect on satisfaction ($\beta = 0.703$, $p < 0.001$) and revisit intention ($\beta = 0.152$, $p < 0.01$), Hypothesis 5 and 6 have been verified. Finally, "satisfaction" has a positive effect on revisit intention ($\beta = 0.604$, $p < 0.001$), and hence, Hypothesis 7 has been verified (see Table 5).

**Table 5.** Hypothesis testing results.

| | Relationships | β | B | S.E. | t-value | p-value | Results |
|---|---|---|---|---|---|---|---|
| H1a | Anthropomorphism→Perceived benefits | −0.381 | −0.315 | 0.071 | −4.418 | 0.000 *** | Not supported |
| H1b | Animacy→Perceived benefits | 0.034 | 0.039 | 0.102 | 0.386 | 0.699 | Not supported |
| H1c | Likeability→Perceived benefits | 0.334 | 0.283 | 0.058 | 4.839 | 0.000 *** | Supported |
| H1d | Intelligence→Perceived benefits | 0.234 | 0.189 | 0.053 | 3.556 | 0.000 *** | Supported |
| H1e | Safety→Perceived benefits | 0.558 | 0.562 | 0.095 | 5.901 | 0.000 *** | Supported |
| H2a | Anthropomorphism→Perceived risks | 0.065 | 0.061 | 0.114 | 0.530 | 0.596 | Not supported |
| H2b | Animacy→Perceived risks | 0.053 | 0.070 | 0.174 | 0.401 | 0.688 | Not supported |
| H2c | Likeability→Perceived risks | −0.025 | −0.023 | 0.092 | −0.256 | 0.798 | Not supported |
| H2d | Intelligence→Perceived risks | 0.019 | 0.017 | 0.088 | 0.194 | 0.846 | Not supported |
| H2e | Safety→Perceived risks | −0.284 | −0.322 | 0.143 | −2.250 | 0.024 * | Supported |
| H3 | Perceived benefits→Perceived value | 0.784 | 0.777 | 0.061 | 12.650 | 0.000 *** | Supported |
| H4 | Perceived risks→Perceived value | −0.045 | −0.040 | 0.040 | −0.992 | 0.321 | Not supported |
| H5 | Perceived value→Satisfaction | 0.703 | 0.864 | 0.064 | 13.594 | 0.000 *** | Supported |
| H6 | Perceived value→Revisit intention | 0.152 | 0.171 | 0.063 | 2.714 | 0.007 ** | Supported |
| H7 | Satisfaction→Revisit intention | 0.604 | 0.552 | 0.060 | 9.172 | 0.000 *** | Supported |

Notes: $\chi^2/df = 1.934$, $p < 0.001$; Tucker–Lewis index (TLI) = 0.921; comparative fit index (CFI) = 0.929; incremental fit index (IFI) = 0.930; root mean square error of approximation (RMSEA) = 0.056; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

## 5. Conclusions

Many researchers have attempted to identify successful marketing strategies to enhance customers' revisit intention, as these, coupled with consumers' satisfaction can be important sources in achieving sustainable business development [55,56]. Accordingly, scholars have focused on serving robots as their attributes are considered the basic components for evaluating customers' perceived value. These can further determine their revisit intention. This study investigated whether the attributes of serving robots can improve customers' revisit intentions through perceived benefits, perceived value, and satisfaction. The findings of this study suggest that although the restaurant industry is suffering due to labor shortages caused by an increase in the stipulated minimum wage, and now that non-contact services are in the spotlight due to the COVID-19 pandemic, using efficient serving robots could be a great strategy for more customers. Furthermore, for the sustainability of the restaurant business, customers' clear intentions to revisit restaurants could be the most important factor. This study offers several significant implications for future studies that could examine effective strategies for using serving robots to make the restaurant business sustainable. These implications are discussed in the following section.

### *5.1. Theoretical Implications*

This study investigates the relationship among the five attributes of serving robots, customers' perceived benefits, perceived risks, perceived value, satisfaction, and revisit intention. Its aim was to support in assuring the sustainability of the restaurant business in South Korea, and the results indicate the following theoretical implications.

Currently, restaurant businesses across the world, including in South Korea face increasing manpower shortages due to rising labor costs. Very little academic research has been conducted

on serving robots compared to research regarding AI as a part of our lives more generally. Most robot-related research has focused on the development and utilization of robots in engineering.

First, research focused on identifying the relative importance of the attributes of a serving robot that have an impact on the customers' perceived benefits and perceived risks is insufficient. Analysis has shown that among the five attributes of serving robots, "likeability," "intelligence," and "safety" have a positive effect on perceived benefits, and "safety" has a negative effect on perceived risks. This study confirms the reliability and validity of the five attributes, and it provides a theoretical foundation for future research.

Second, this study attempts to incorporate VAM, a theory that maximizes users' value for new technologies, to provide basic data for future studies. The research related to the restaurant business based on VAM so far, is believed to be of academic significance, although most of it has been on delivery applications, online to offline (O2O) services, and Kiosk, which are mainly categorized as a part of the information technology (IT) field. Not many studies have been conducted on serving robots. This study is expected to expand the research area on serving robots and customers' behavioral intentions by introducing new influential variables and related theories to ensure a positive dining experience.

Finally, this study analyzes various variables (perceived benefits, perceived risks, perceived value, and satisfaction), in relation to serving robots' attributes (independent variable) and the revisit intention (dependent variable) of customers and identifies causal relationships and influences. The study presents new research models and research methods related to serving robots in South Korea's restaurant business. There is no prior empirical research in this field. Additionally, the approach introduced in this study, regarding the use of serving robots in the restaurant business, is expected to be applied to research in other areas to provide new academic subjects.

### *5.2. Practical Implications*

This study was designed to examine sustainable and effective restaurant businesses. Based on the results, practical implications that can assist in establishing strategies for sustainable development in the restaurant industry are provided.

First, out of the five attributes of serving robots analyzed in this study, "likeability," "intelligence," and "safety" have positive effects on customers' perceived benefits: while, "safety" lowers perceived risks. With a focus on these results, restaurant managers need to emphasize the friendly image, positive first impression, smart serving ability, and safety of serving robots to enhance customers' perceived benefits. Furthermore, "safety" has emerged as an important attribute that has a positive and negative effect on perceived benefits and perceived risks, respectively. This implies that managers need to be aware that customers value the "safety" of the serving robot. On the other hand, the "anthropomorphism" of the serving robot seems to have a significant effect on customers' perceived benefits, but Hypothesis 1a is not supported as it indicates a negative effect. This indicates that customers do not like serving robots that resemble and mimic people.

Second, it was found that the customers' perceived benefits, through the use of serving robots, have a positive effect on perceived value. However, customers' perceived risks do not have a significant effect on perceived value. Based on the results of this study, it is necessary to focus on the relationship between perceived benefits and perceived value. Restaurant managers should develop strategies to enhance the likeability, intelligence, and safety of serving robots, and reduce anthropomorphism, so that the perceived benefits can be maximized and, in turn, increase perceived value.

Lastly, the relationships among the customers' perceived value, satisfaction, and revisit intention were found to have a positively significant effect. In particular, the focus should be on the serving robots' attributes, which is the starting point of this study, to increase the customer's revisit intention. The study found that among the serving robots' attributes, customers' perceived benefits were significantly influenced by the order of "safety," "likeability," and "intelligence," and perceived benefits were mediated by perceived value, which has a significant effect on satisfaction and revisit intention. Restaurant owners should refer to these results and eventually aim to raise the customers' revisit

intention. In other words, restaurant owners need to highlight the "safety" of the serving robot most and ensure that a friendly and highly likeable image of the robot is created. The owners need to offer robot services that can intelligently and adequately fulfill the customers' desires.

## 6. Limitations and Future Research

This study has various practical and theoretical implications. However, the study has certain limitations and there are some underexplored areas that could be studied in future.

First, this study is based on customers of restaurants that use serving robots in South Korea. For more generalized and reliable results, related research is needed for a wider variety of restaurant customers in the future. As there will be various results from serving robots' attributes, future research on serving robots should be further expanded to provide more diverse marketing strategies across different fields or industries.

Second, this study was completed on the basis of an online survey by people who are eighteen or older and live in Korea. They responded to the questionnaire based on the memory of their experience of dining in a restaurant that uses serving robots within the last three months. The fact that an onsite survey was not completed within the restaurants themselves could be a limitation of this study and should be addressed in future studies.

Finally, the fundamental significance of this research lies in the fact that human beings are fallible, whereas robots have no collective consciousness or genetic memory, and are result oriented. With further research in this field and appropriate application of the findings of such research in practical contexts, AI can be used to enhance the quality of human lives.

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