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# DETERMINING FACTORS INFLUENCING INTEREST IN USING PAPER PACKAGING AMONG INDONESIAN CUSTOMERS: A SUSTAINABLE CONSUMER BEHAVIOUR APPROACH

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*Artificial Neural Network, Customer, Food, Paper Packaging, Plastic Packaging.*



## *ABSTRACT*

***Purpose:*** *To investigate the key factors that influence Indonesian consumers' interest in choosing and using paper-based food packaging as a sustainable alternative to plastic.* ***Methodology:*** *A quantitative approach using an online questionnaire with a purposive sample of 710 respondents across Indonesia. The data were analyzed using IBM SPSS and Artificial Neural Network (ANN) models to explore complex relationships between sustainable consumer behavior (SCB) variable with attitude (AT), environmental insight (EI), environmental risk perception (ERP), governmental support & regulations (GSR), intention (IN), perceived behavioral control (PBC), and subjective norm (SN).* ***Results:*** *The survey results processed with ANN showed a high level of accuracy for all hypothesized relationships, with AT emerging as the most influential factor on SCB (98.21% accuracy), followed by PBC and IN. All seven tested hypotheses were positively accepted.* ***Findings:*** *Consumers' positive attitudes significantly influence their sustainable consumption choices in the context of preference for paper packaging over plastic packaging, indicating a shift towards environmentally responsible behavior.* ***Novelty:*** *This study uniquely integrates ANN into behavioral research on sustainability, offering a more precise modeling of consumer intentions and patterns compared to traditional statistical methods.* ***Originality:*** *This research focuses on food packaging material choices to analyze sustainable behavior in a development country, prioritizing behavioral modeling over object detection.* ***Conclusion:*** *This study underscores the need to promote positive attitudes and awareness of negative environmental impacts when using plastic packaging to encourage sustainable consumer behavior. Paper packaging can be alternative strategies to reduce plastic waste.* ***Type of Paper:*** *Empirical research paper.*

## INTRODUCTION

Plastic waste has emerged as a critical global environmental issue (Stoett, 2022), with Indonesia contributing approximately 11% of the total plastic waste generated worldwide (Jambeck et al., 2015). A significant portion of this waste originates from plastic food packaging, a material that is toxic and incompatible with the principles of a circular economy (Kan & Miller, 2022). Despite its detrimental environmental impact, plastic packaging remains the predominant choice for food wrapping due to its affordability, durability, and convenience (Apriadi et al., 2024). Nevertheless, the persistent use of plastics exacerbates pollution and waste accumulation, given their limited biodegradability (Pilapitiya & Ratnayake, 2024). Conversely, paper packaging offers a more sustainable alternative, characterized by a reduced ecological footprint and lower resource consumption, thereby presenting an attractive option for food packaging applications (Oloyede & Lignou, 2021), as illustrated in Figure 1.

**Figure 1. (a) Paper Packaging on Foods; (b) Plastic Packaging on Food**


Source: *Researcher (2024)*

Based on these considerations, the promotion of Sustainable Consumer Behavior (SCB) is important in driving the transition toward more environmentally conscious practices (Bui et al., 2022; Syed et al., 2024). Existing research indicates that the use of paper packaging can significantly influence consumers' food purchasing decisions (Temmerman et al., 2023). By selecting paper packaging over plastic, consumers can actively contribute to reducing their environmental impact. This study aims to investigate these behavioral trends within the Indonesian context, examining the factors that shape sustainable consumer behavior concerning food packaging.

This study utilizes the Statistical Package for the Social Sciences (SPSS) to analyze the data. Then, this study also utilizes Artificial Neural Network (ANN) as the primary machine learning algorithm, offering a sophisticated and effective framework for data analysis (Borhani & Wong, 2023; Kufel et al., 2023). The selection of ANN over vision-based methods is justified by the latter's predominant focus on optimizing object detection, which does not align directly with the objectives of behavioral analysis (Rodriguez-Serrano et al., 2016). Additionally, the interpretability challenges and significant computational demands associated with Automated Machine Learning (AutoML) make it less suitable for the specific requirements of this research (Siriborvornratanakul, 2022). Although vision-based methods are highly effective for tasks such as object detection and the analysis of human behavior, their applicability may be limited in contexts that require in-depth behavioral modeling, as is the case in this study (Rodriguez-Serrano et al., 2016; Siriborvornratanakul, 2022).

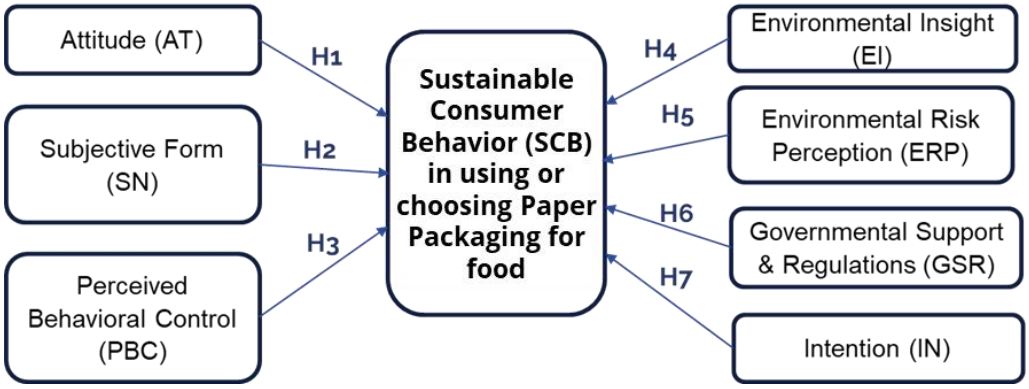
Despite widespread use of ANN in technical fields, its application in modeling sustainable consumer behavior remains limited. Most prior studies rely on traditional statistics, lacking the capacity to capture complex behavioral patterns. Few have used ANN in this context, especially in developing countries like Indonesia. This study fills that gap by applying ANN to model key behavioral factors influencing paper packaging adoption.

**Research Framework**

This study utilized a sustainable consumer behavior theory. It is behavior that seeks to meet current needs while at the same time providing benefits or limiting negative impacts on the environment (Trudel, 2018; White & Simpson, 2013). This behavior is almost the same as environmental consumer behavior and pro-environmental behavior. Environmental consumer behaviour is defined as green consumption activities that reduce possible negative effects on the environment (Korkmaz & Altan, 2024; Han et al., 2019). Similarly, pro-environmental behavior refers to actions undertaken by individuals to minimize their negative impact on the environment, aligning closely in meaning and focus (Lee & Khan, 2020).

The framework in this study focused on factors such as attitude, subjective norms, perceived behavioral control, environmental insight, environmental risk perception, governmental support & regulations, and attenton. The objective was to investigate the factors that contribute to the action to adopt paper packaging for food in Indonesia. There are seven hypotheses for this study as shown in Figure 2. ANN will be used to investigate the impact of these parameters on the action to use paper packaging for food, as predicted by the sustainable consumer behavior approach.

**Figure 2. Study Hypotheses**




Source: *Researcher (2023)*

**Exploration of Theory of Planned Behavior (TPB) including Attitude, Subjective Norm, and Perceived Behavioral Control as a Determinant Factor of Sustainable Consumer Behaviour**

The Theory of Planned Behavior (TPB) is a psychological theory developed by Icek Ajzen (1985), which proposes that individuals' intentions to engage in a behavior are influenced by three factors such as attitudes, subjective norms, and perceived behavioral control. The research conducted in Eskişehir, Turkey, by Arı & Yılmaz, (2017) delved into consumer attitudes and behavior concerning plastic usage, utilizing the TPB to comprehend the factors influencing consumers' attitudes and behaviors. Then, Zhou et al (2024) investigated consumer behavior regarding plastic use reduction in Nanjing, China, and employed the Theory of Planned Behavior (TPB) model to understand consumers' attitudes and intentions towards reducing plastic use. On the other hand, Aikowe & Mazancová, (2021) also examined the factors influencing plastic waste sorting intentions among university students in Nigeria, aiming to provide insights into improving waste management practices.

*Hypothesis 1 (H1): Attitude has a positive influence on sustainable consumer behavior by using or choosing paper packaging for food.*

*Hypothesis 2 (H2): Subjective norm has a positive influence on sustainable consumer behavior by using or choosing paper packaging for food.*

*Hypothesis 3 (H3): Perceived behavioral control has a positive influence on sustainable consumer behavior by using or choosing paper packaging for food.*

**Exploration of Environmental Insight as a Determinant Factor of Sustainable Consumer Behaviour**

Environmental insight or awareness constitutes a multidimensional construct encompassing an individual's cognizance of environmental issues, level of environmental knowledge, attitudes toward the natural environment, and perceptions regarding ecological challenges. It serves as a critical indicator of how well individuals comprehend and respond to pressing environmental concerns. Specifically, environmental awareness reflects the degree to which individuals recognize ecological problems, possess relevant environmental knowledge, and hold attitudes and viewpoints that underscore the necessity of addressing these issues (Khan et al., 2019; Zhang & Gong, 2023). Moreover, Xie et al. (2024) conducted a study that adopts a comprehensive perspective on consumer behavior related to plastic use, extending the analysis beyond immediate behavioral choices to include the broader context of consumer environmental insight and awareness.
*Hypothesis 4 (H4): Environmental insight has a positive influence on sustainable consumer behavior by using or choosing paper packaging for food.*

**Exploration of Environmental Risk Perception as a Determinant Factor of Sustainable Consumer Behaviour**

Environmental risk perception refers to an individual's subjective assessment of potential environmental threats, encompassing both the likelihood of such events and the severity of their consequences for ecosystems and human well-being (Boss et al., 2015; Janmaimool et al., 2024). This perception shapes one's awareness of environmental disturbances and their impacts. According to Janmaimool et al. (2024), individuals who possess a heightened awareness of environmental health risks are more inclined to support mitigation efforts and engage in pro-environmentally. *Hypothesis 5 (H5): Environmental risk perception has a positive influence on sustainable consumer behavior by using or choosing paper packaging for food.*

**Exploration of Governmental Support and Regulation as a Determinant Factor of Sustainable Consumer Behaviour**

The study conducted by Gulid and Yansomboon (2022) underscores the multifaceted role of government in addressing environmental challenges, particularly through the formulation and implementation of policies aimed at reducing the use of single-use plastic bags.
*Hypothesis 6 (H6): Governmental support and regulation have a positive influence on sustainable consumer behavior by using or choosing paper packaging for food.*

**Exploration of Intention as a Determinant Factor of Sustainable Consumer Behaviour**

Khan et al. (2019) conducted a study to examine the determinants of consumer behavior related to plastic bag usage, with a particular focus on three core dimensions, such as intention, environmental knowledge, and risk perception. The research specifically investigates consumers' intentions to use plastic bags, aiming to identify the underlying factors that influence their future behavioral tendencies toward plastic bag consumption.
*Hypothesis 7 (H7): Intention has a positive influence on sustainable consumer behavior by using or choosing paper packaging for food.*

## METHOD

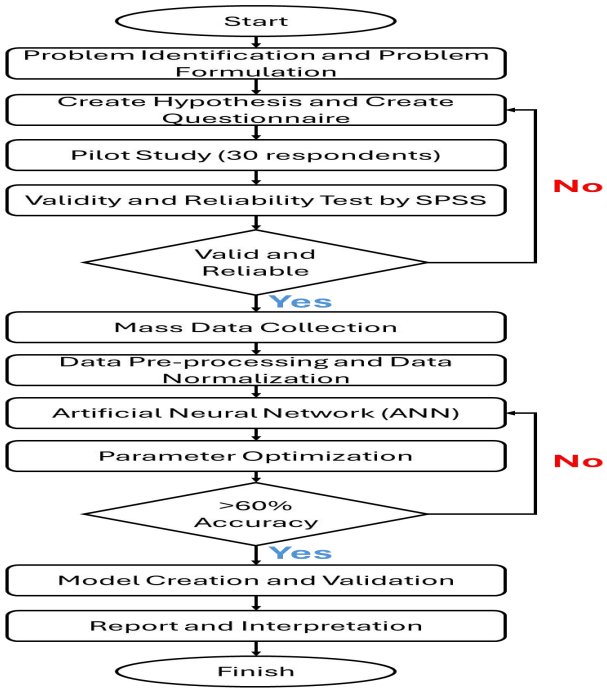
This study adopts a quantitative methodological approach to empirically examine the proposed hypotheses. Data were collected through an online survey administered via Google Forms, with respondents sourced from Indonesia. The data collection process was conducted over eleven months, from October 2023 to September 2024. Upon completion, the gathered data were systematically compiled and prepared for subsequent analytical procedures.

### Research Design and Structure

To investigate the complex statistical relationships between observed and latent variables, this study employed Machine Learning Algorithms (MLA), with particular emphasis on Artificial Neural Networks (ANN). Regression analysis within the ANN framework was utilized to detect intricate patterns and associations embedded within the dataset. The concurrent application of ANNs is anticipated to facilitate a comprehensive and nuanced understanding of the research hypotheses, thereby enriching the study's findings and offering deeper insights into its objectives. The research design flowchart is presented in Figure 3, which presents the methodological flowchart that outlines the step-by-step process undertaken in this study.

The flowchart begins with problem identification, followed by hypothesis and questionnaire creation. After that, preliminary study data collection was conducted with 30 respondents through an online survey. Then, the data underwent preprocessing using IBM SPSS, including reliability testing and correlation analysis to ensure statistical validity. Furthermore, data collection was conducted over 11 months and targeted people in Indonesia. After the data was collected, an evaluation was conducted. The cleaned and validated data were then arranged and transformed for input into an Artificial Neural Network (ANN), which serves as the main analytical model. The ANN was trained to identify complex non-linear relationships between seven input variables. The flowchart ends with model validation and performance evaluation, which ensure the robustness and generalizability of the model, these data are used for reporting and interpretation.

**Figure 3. Methodological Flowchart**




Source: *Researcher (2023)*

### Sampling and Respondent Profile

This research was conducted in Indonesia, a country in Southeast Asia regional, to investigate the factors influencing individuals' intentions to choose paper packaging over plastic for food products. To capture a broad range of perspectives, purposive sampling was employed, targeting individuals aged 18 and above from both urban and rural areas, encompassing diverse occupational backgrounds (Setiawan et al., 2024). The final sample comprised 710 respondents. Therefore, this study adhered to ethical research standards, and informed consent was obtained from all participants before data collection which was embedded on the first page of the form, ensuring anonymity and voluntary participation throughout the online survey process.

As presented in Table 1, 53.24% of the participants were male, while 46.76% were female. The age distribution indicated that the largest cohort was between 25-34 years (46.48%), followed by those aged 18-24 (38.17%), with smaller proportions aged 35-44 (13.80%) and over 44 years (1.55%). Regarding employment status, 51.83% of respondents were employed, 8.31% were self-employed, 4.37% were unemployed, and 35.49% were students. Furthermore, over 97% of participants reported familiarity with paper packaging for food, indicating a high level of awareness within the sample.

**Table 1. Sample Demographic (N=710)**

| Items | Classification | Quantity | Percentage |
|---|---|---|---|
| Gender | Female | 332 | 46.76 |
| | Male | 378 | 53.24 |
| Age | 18 – 24 | 271 | 38.17 |
| | 25 – 34 | 330 | 46.48 |
| | 35 – 44 | 98 | 13.80 |
| | Above 44 | 11 | 1.55 |
| Job | Student | 252 | 35.49 |
| | Entrepreneur | 59 | 8.31 |
| | Employed | 368 | 51.83 |
| | Unemployed | 31 | 4.37 |
| Are you familiar with paper packaging | Yes | 707 | 99.58 |
| | No | 3 | 0.42 |

*Source: Data processed (2024)*

### Variables and Questionnaire Design

This study employed an online survey as the primary data collection method, utilizing closed-ended questions to obtain responses from participants (Gratton & Jones, 2010). The questions in the survey were modified based on several references. The adoption of this methodological approach presents several distinct advantages. Firstly, online surveys offer significant convenience for respondents, enabling them to complete the questionnaire at their own pace and from any location with internet access. This flexibility enhances accessibility and has the potential to increase response rates. Secondly, online surveys contribute to the reduction of bias. The use of standardized question formats mitigates the influence of interviewer bias and diminishes the likelihood of social desirability bias. Lastly, online surveys enhance the protection of participant privacy, as they can be designed to ensure complete anonymity.

Google Forms was selected as the survey platform due to its intuitive interface and widespread accessibility. The questionnaire predominantly employed a five-point Likert scale, ranging from “strongly disagree” to “strongly agree,” to effectively capture participants' attitudes and perceptions in alignment with the study's objectives. Table 2 provides a detailed overview of the latent variables and their corresponding indicators analyzed in this research.

**Table 2. Quistionnaire Items**

| Constructs | Codes | Questionnaire Items | References |
|---|---|---|---|
| Attitude (AT) | AT1 | I believe that using paper packaging aligns with sustainability and environmental conservation values. | (Sun et al., 2017) |
| | AT2 | I am obsessed with paper food packaging because I am motivated by its environmentally positive impact. | (Sun et al., 2017) |
| | AT3 | I consider the use of paper packaging as a proactive measure for environmental protection. | (Sun et al., 2017) |
| Environmental Insight (EI) | EI1 | I am aware of the environmental impacts associated with the use of plastic packaging | (Ahmed, 2024; Musse, 2022) |
| | EI2 | I understand the detrimental effects of plastic packaging disposal on local ecosystems and wildlife. | (Ahmed, 2024; Musse, 2022) |
| | EI3 | I am knowledgeable about the advantages of using environmentally friendly alternatives, such as paper packaging. | (Ahmed, 2024; Musse, 2022) |
| Environmental Risk Perception (ERP) | ERP1 | I believe that plastic packaging presents a substantial threat to environmental health. | (Bade, 2022) |
| | ERP2 | I view plastic packaging as a serious hazard to both wildlife and marine ecosystems in our region. | (Bade, 2022) |
| | ERP3 | I feel that pollution from plastic packaging significantly impacts the quality of water resources and soil. | (Bade, 2022) |
| Governmental Support & Regulations (GSR) | GSR1 | I think regulations should be enacted to restrict the use of plastic packaging and encourage the adoption of paper alternatives. | (Knoblauch & Mederake, 2021) |
| | GSR2 | I think the government should reduce taxes on paper packaging and increase taxes on plastic packaging. | (Knoblauch & Mederake, 2021) |
| | GSR3 | I feel the government should actively engage in promoting and facilitating the transition to paper-based packaging solutions. | (Nielsen et al., 2019) |
| Intention (IN) | IN1 | I plan to actively seek out restaurants that use paper-based food packaging. | (Sun et al., 2017) |
| | IN2 | I am committed to switching from my usual restaurant, which uses plastic packaging, to one that uses paper packaging once I find right place. | (Sun et al., 2017) |
| | IN3 | I am motivated to make plastic waste reduction a key part of my sustainable lifestyle. | (Sun et al., 2017) |
| Perceived Behavioral Control (PBC) | PBC1 | I consciously feel more comfortable eating food wrapped in paper packaging. | (Setiawan et al., 2024) |
| | PBC2 | I frequently and independently choose to order from restaurants that use paper packaging. | (Setiawan et al., 2024) |
| | PBC3 | I recognize that restaurants using paper packaging are more environmentally friendly than those using plastic. | (Setiawan et al., 2024) |
| Subjective Norm (SN) | SN1 | I believe that people important to me regard the use of paper packaging as essential. | (Sun et al., 2017) |
| | SN2 | I think that the perspectives of others in my community have positively influenced my choice to select restaurants that use paper packaging. | (Sun et al., 2017) |
| | SN3 | I feel a social responsibility to follow the trend of using paper packaging among my peers. | (Sun et al., 2017) |
| Sustainable Consumer Behaviour (SCB) | SCB1 | I consciously strive to reduce my dependence on plastic packaging by opting for paper packaging as a sustainable action. | (Essl et al., 2021) |
| | SCB2 | I consistently choose restaurants that use paper packaging and bags over plastic packaging and bags. | (Minelgaitė & Liobikienė, 2021) |
| | SCB3 | I actively encourage others to adopt paper packaging as an environmentally sustainable food choice. | (Minelgaitė & Liobikienė, 2021) |

*Source: Developed for Research (2023)*

## RESULTS AND DISCUSSION

The results of this study are presented through data processing output consisting of sub-sections of construct reliability, data pre-processing, final model results & plot, result validation, and analysis of key findings.

### Construct Validity and Reliability

To evaluate the reliability and validity of the measurement model, a series of statistical analyses were conducted. Table 3 reports the descriptive statistics, including r valuie and Cronbach's alpha for each latent construct within the model.

**Table 3. Standard deviation, Factor Loading, Cronbach's Alpha, Composite Reliability, and AVE**

| Constructs | Codes | Standard Deviation | Factor Loading | Cronbach Alpha | Composite Reliability (CR) | Avarage Variance Extracted (AVE) |
|---|---|---|---|---|---|---|
| Attitude (AT) | AT1 | 0.67 | 0.819 | 0.892 | 0.92 | 0.698 |
| | AT2 | 0.681 | 0.842 | | | |
| | AT3 | 0.702 | 0.844 | | | |
| Environmental Insight (EI) | EI1 | 0.617 | 0.792 | 0.881 | 0.913 | 0.679 |
| | EI2 | 0.624 | 0.872 | | | |
| | EI3 | 0.695 | 0.827 | | | |
| Environmental Risk Perception (ERP) | ERP1 | 0.633 | 0.823 | 0.873 | 0.861 | 0.701 |
| | ERP2 | 0.714 | 0.82 | | | |
| | ERP3 | 0.677 | 0.849 | | | |
| Governmental Support & Regulations (GSR) | GSR1 | 0.692 | 0.8 | 0.891 | 0.917 | 0.647 |
| | GSR2 | 0.729 | 0.839 | | | |
| | GSR3 | 0.719 | 0.827 | | | |
| Intention (IN) | IN1 | 0.72 | 0.813 | 0.882 | 0.914 | 0.686 |
| | IN2 | 0.702 | 0.794 | | | |
| | IN3 | 0.74 | 0.85 | | | |
| Perceived Behavioral Control (PBC) | PBC1 | 0.728 | 0.811 | 0.891 | 0.92 | 0.696 |
| | PBC2 | 0.718 | 0.826 | | | |
| | PBC3 | 0.755 | 0.85 | | | |
| Subjective Norm (SN) | SN1 | 0.72 | 0.804 | 0.884 | 0.828 | 0.619 |
| | SN2 | 0.741 | 0.751 | | | |
| | SN3 | 0.755 | 0.767 | | | |
| Sustainable Consumer Behaviour (SCB) | SCB1 | 0.699 | 0.832 | 0.897 | 0.924 | 0.709 |
| | SCB2 | 0.731 | 0.859 | | | |
| | SCB3 | 0.769 | 0.865 | | | |

*Source: Data Processed (2024)*

### Data Pre-Processing

The researchers meticulously preprocessed the collected data before conducting statistical analysis and applying machine learning techniques. IBM SPSS Statistics was employed to verify that no missing values existed within the dataset, which contained 17,040 data entries. To ensure data integrity, a correlation analysis was conducted, removing variables with low correlations, where Pearson's R table was below 0.2 and p-value was below 0.05. This data-cleaning process minimized the impact of redundant information on subsequent analyses. The final Pearson correlation coefficients for all variables are presented in Table 4. Pearson's r to measure the strength and direction of the linear relationship between two variables (Berman, 2016).

**Table 4. Pearson's R Correlation**

| Variable | EI | ERP | AT | SN | PBC | IN | GSR | SCB |
|---|---|---|---|---|---|---|---|---|
| **EI** | 1 | | | | | | | |
| **ERP** | 0.808 | 1 | | | | | | |
| **AT** | 0.734 | 0.787 | 1 | | | | | |
| **SN** | 0.645 | 0.664 | 0.772 | 1 | | | | |
| **PBC** | 0.668 | 0.681 | 0.767 | 0.829 | 1 | | | |
| **IN** | 0.624 | 0.665 | 0.783 | 0.760 | 0.819 | 1 | | |
| **GSR** | 0.589 | 0.482 | 0.552 | 0.531 | 0.577 | 0.669 | 1 | |
| **SCB** | 0.472 | 0.504 | 0.524 | 0.590 | 0.650 | 0.535 | 0.540 | 1 |

*Source: Data processed (2024)*

Artificial Neural Networks (ANNs) rely on specific data points for processing. In this study, the input layer serves as the starting point, feeding the ANN with seven key factors derived from the data: Environmental Insight (EI), Environmental Risk Perception (ERP), Governmental Support & Regulations (GSR), Intention (IN), Perceived Behavioral Control (PBC), Subjective Norm (SN), and Attitude (AT). These factors were aggregated to form a consolidated representation. The ANN then processed this information to predict the factors influencing the output variable, namely Sustainable Consumer Behavior (SCB). This model to examine the relationship between the use of paper packaging and the broader tendency toward Sustainable Consumer Behavior. Additionally, as part of the ANN implementation, the data was cleaned and aggregated by calculating the mean of each construct per variable.

To prepare the data for analysis, the indicators for each variable were first averaged, resulting in a more compact representation. Data aggregation involves categorizing the sums of the means of the variables into discrete intervals, each corresponding to a specific numerical range. If the sum of a variable fell within the range of 1 to 5, it was assigned an aggregate value of 1; similarly, sums within the ranges of 4 to 6, 7 to 9, 10 to 12, and 13 to 15 were assigned aggregate values of 2, 3, 4, and 5, respectively. This grouping process transformed continuous data into discrete categories, enhancing interpretability without losing critical information. These sums were then categorized into distinct labels for easier interpretation. The labeling scheme (1–5) simplifies the data, facilitating the identification of patterns and trends in the variables. These data preprocessing steps are important for ensuring the analysis of reliability and validity, as shown in Table 5.

**Table 5. Data Aggregation**

| Indicator | | | Sum | Label | Average |
|---|---|---|---|---|---|
| EI1 | EI2 | EI3 | | | |
| 2 | 5 | 4 | 11 | 4 | 3.7 |
| ERP1 | ERP2 | ERP3 | | | |
| 2 | 4 | 4 | 10 | 3 | 2.6 |
| GSR1 | GSR2 | GSR3 | | | |
| 1 | 2 | 3 | 6 | 2 | 2 |
| AT1 | AT2 | AT3 | | | |
| 1 | 1 | 3 | 5 | 2 | 1.7 |
| SN1 | SN2 | SN3 | | | |
| 5 | 5 | 3 | 13 | 5 | 4.3 |
| SCB1 | SCB2 | SCB3 | | | |
| 5 | 4 | 1 | 10 | 4 | 3.3 |

*Source: Data Processed (2024)*

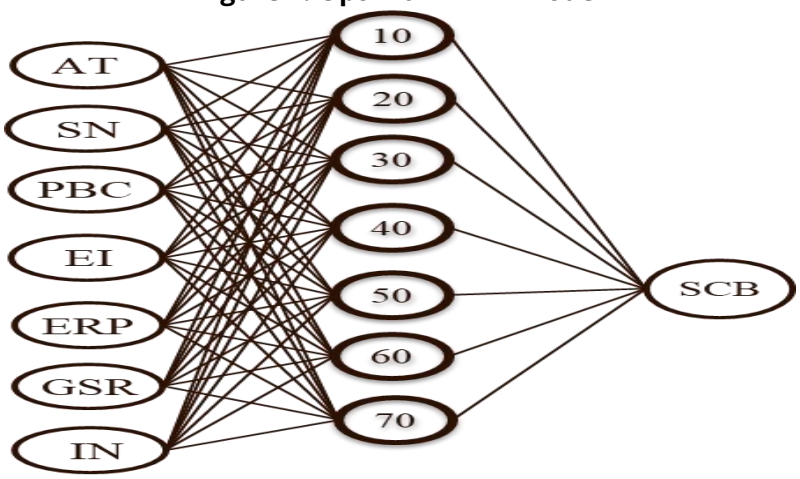
### Final Model Results and Plots

To identify the optimal architecture for the Artificial Neural Network (ANN), the training process was conducted over a sufficient number of epochs to ensure the stability of the loss

function in both the training and testing sets. This approach effectively mitigated the risk of overfitting and enabled the selection of a model that generalizes well to unseen data. Figure 4 illustrates the architecture of the optimum Artificial Neural Network (ANN) model developed in this study to predict sustainable consumer behavior (SCB) based on various psychological and contextual factors.

The model consists of an input layer with seven nodes, each representing influencing variables. These inputs were selected based on their theoretical relevance to sustainable behavior and serve as the foundational predictors for the model. The hidden layer, comprising 70 neurons, plays a critical role in capturing complex and non-linear interactions among these variables. This layer enables the model to recognize intricate behavioral patterns that might not be apparent through conventional statistical techniques. Finally, the output layer contains a single node representing SCB, which is the outcome variable the model seeks to predict. The structure shown in Figure 4 was selected after multiple iterations and training cycles to ensure optimal performance, with results demonstrating high accuracy, minimal loss, and no signs of overfitting. This figure effectively represents the core analytical engine of the study, showcasing how machine learning can be leveraged to model and understand consumer decision-making in sustainability contexts with enhanced precision.

**Figure 4. Optimum ANN Model**




*Source: Data processed (2024)*

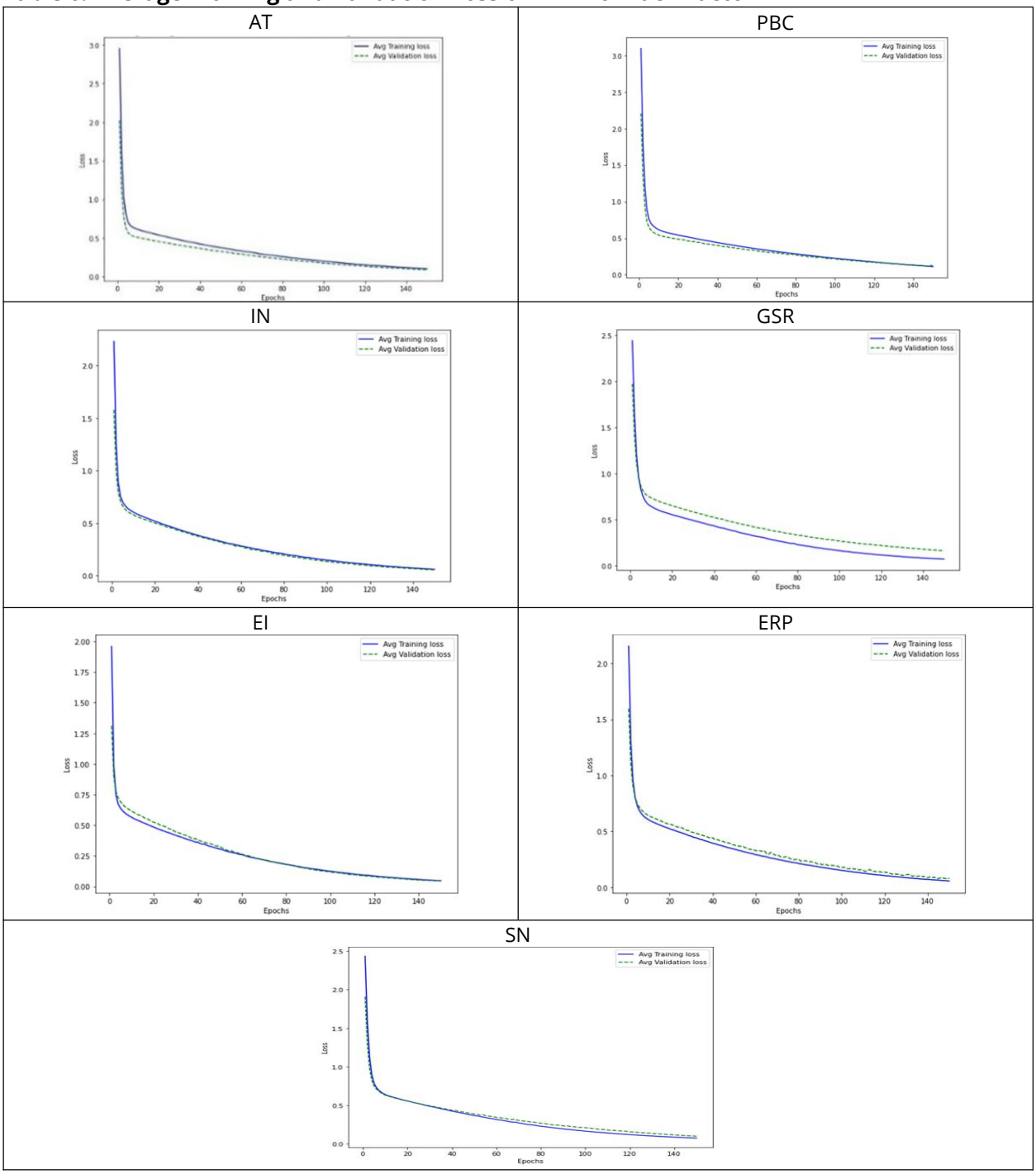
**Result Validation**

With optimized parameters, the model achieves a high accuracy of 98.21% in capturing the relationship between Attitude (AT) to Sustainable Consumer Behavior (SCB). Notably, the final model's training loss plot demonstrates an absence of overfitting or modeling issues. The training loss consistently decreases across epochs, with the validation loss following a parallel trend and showing minimal deviation, indicating a well-fitted model. This observation is further supported by Table 6, which visually corroborates the model's performance and alignment with the described statement.

Table 6 visually presents the training and validation loss curves for each key input factor used in the ANN model. Each graph tracks how the model's error (loss) decreases over multiple training epochs, allowing readers to evaluate model performance and convergence behavior. The blue lines represent average training loss, while the green dashed lines indicate average validation loss. In all cases, both curves exhibit a steep decline early in the training process and gradually flatten as they converge, which is a strong indication of effective learning and stability. Notably, the small gap between training and validation loss across all factors suggests that the ANN model did not overfit, meaning it generalized well to unseen data. For example, the AT and PBC graphs show the lowest

and most stable loss trajectories, aligning with their high predictive accuracy in the study. This table demonstrates the ANN model's robustness in capturing the relationship between behavioral determinants and sustainable consumer behavior, validating its suitability for modeling complex psychological and environmental variables.

**Table 6. Average Training and Validation Loss of ANN for Each Factor**




*Source: Data Processed (2024)*

Table 6 offers a detailed overview of the optimization runs performed for the Artificial Neural Network (ANN), highlighting the optimal parameters identified for each feature. Informed by a range of studies, these parameters were systematically evaluated and ranked based on their average

testing performance, providing insight into the relative importance of each feature with respect to the dependent variable. The ANN model demonstrating the lowest standard deviation alongside the highest accuracy was selected as the most representative of each feature's impact on the dependent variable (Kumar & Sodhi, 2023). With an accuracy of 98.21%, the factor AT emerged as the most influential among the components. Additionally, factors such as PBC, IN, and GSR were found to hold significant importance, each achieving accuracy rates above 95%, as detailed in Table 7.

**Table 7. ANN Summary of Results**

| Feature | Average Train | Train–StDev | Average Test | Test–StDev |
|---|---|---|---|---|
| AT | 0.0962 | 0.0242 | 98.21% | 0.0106 |
| PBC | 0.1025 | 0.0196 | 97.85% | 0.0089 |
| IN | 0.1278 | 0.0197 | 96.53% | 0.0115 |
| GSR | 0.1304 | 0.0177 | 95.96% | 0.0057 |
| EI | 0.1372 | 0.0203 | 93.80% | 0.0104 |
| ERP | 0.1637 | 0.0158 | 92.89% | 0.0053 |
| SN | 0.1876 | 0.0331 | 90.08% | 0.0071 |

*Source: Data Processed (2024)*

The ANN model robustly validates the hypothesized relationships between various factors and Sustainable Consumer Behavior (SCB). Table 8 presents the testing accuracy for each hypothesis, demonstrating consistently high accuracy levels with low standard deviations. These findings indicate statistically significant results, thereby substantiating each hypothesized relationship through the ANN methodology.

**Table 8. Validation of Hypothesis for ANN**

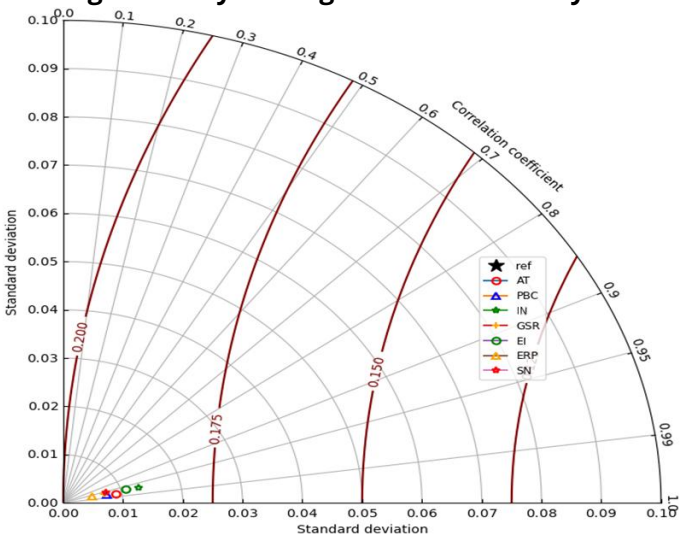
| No | Relationship | Average Test | Test–StDev | Result | Hypothesis |
|---|---|---|---|---|---|
| 1 | AT → SCB | 98.21% | 0.0106 | Positive | Accepted |
| 2 | PBC → SCB | 97.85% | 0.0089 | Positive | Accepted |
| 3 | IN → SCB | 96.53% | 0.0115 | Positive | Accepted |
| 4 | GSR → SCB | 95.96% | 0.0057 | Positive | Accepted |
| 5 | EI → SCB | 93.80% | 0.0104 | Positive | Accepted |
| 6 | ERP → SCB | 92.89% | 0.0053 | Positive | Accepted |
| 7 | SN → SCB | 90.08% | 0.0071 | Positive | Accepted |

*Source: Data Processed (2024)*

To evaluate the overall performance of the ANN model, a Taylor diagram was generated. Figure 5 presents a Taylor diagram, a statistical visualization tool used to evaluate the performance of predictive models. In this case, the ANN was used to estimate sustainable consumer behavior (SCB). Its application is particularly appropriate in the context of the present study, as it facilitates a comprehensive comparison of the ANN model's predictive accuracy. The diagram simultaneously displays three metrics, including the Correlation Coefficient to measure how closely the model predictions align with actual observed values. Values closer to 1 in the diagram indicate a high degree of correlation. Then, there is Standard Deviation (σ) to represent the spread or variability of the model predictions compared to observed data. Ideally, the model's standard deviation should match that of the observations. Furthermore, there is centered Root Mean Square Error (RMSE) to reflect the average deviation between predicted and actual values, lower RMSE values indicate better model performance. The Taylor diagram has increasingly been recognized as an effective visualization tool in machine learning, allowing for the simultaneous assessment of model performance across multiple statistical metrics (Izzaddin et al., 2024; Wickstrøm et al., 2022). The results demonstrated high model performance, with correlation coefficients exceeding 0.95 and

RMSE values remaining below 20%. These findings highlight the ANN model's robustness and predictive reliability, confirming its suitability for the task at hand (Izzaddin et al., 2024).

**Figure 5. Taylor Diagram for ANN Analysis**




*Source: Data Processed (2024)*

**Key Findings Analysis**

This study provides empirical evidence on the determinants influencing sustainable consumer behavior (SCB) in the context of paper packaging adoption in Indonesia, based on responses from 710 participants. The use of Artificial Neural Network (ANN) modeling offered precise insights into the strength of each influencing factor. Among all variables, Attitude (AT) was identified as the most significant predictor of SCB, with a predictive accuracy of 98.21%, followed closely by Perceived Behavioral Control (97.85%), Intention (96.53%), and Governmental Support & Regulations (95.96%). Environmental Insight (93.80%), Environmental Risk Perception (92.89%), and Subjective Norm (90.08%) also demonstrated statistically significant influences, though to a slightly lesser extent. These results highlight a clear hierarchy of influence, with internal cognitive and motivational factors (such as attitude and intention) exerting stronger effects on behavior than external or contextual variables.

The ANN model's overall performance was robust, as indicated by correlation coefficients exceeding 0.95 and Root Mean Square Error (RMSE) values below 20%, affirming the model's reliability in predicting behavioral patterns.

Furthermore, the demographic analysis from 710 participants revealed that the majority of respondents were aged 25–34 (46.48%), followed by those aged 18–24 (38.17%), with over 97% indicating prior awareness of paper packaging. Employment status also played a role, with 51.83% employed and 35.49% students, suggesting that sustainable preferences are prominent among young, educated, and economically active individuals.

## CONCLUSION

This study underscores the growing importance of fostering sustainable consumer behavior in Indonesia through encouraging the adoption of paper-based packaging as an alternative to plastic. The findings indicate that among the various influencing factors, consumers' attitudes play the most pivotal role in shaping environmentally responsible behavior. The high predictive accuracy achieved using Artificial Neural Network (ANN) modeling demonstrates the robustness of these relationships, with Attitude with 98.21% accuracy. Moreover, the results emphasize the necessity of raising

environmental awareness, enhancing public perception of environmental risks, and promoting supportive governmental regulations. These elements collectively create an enabling environment for sustainable behavioral change. The study's methodological approach also demonstrates the value of machine learning in behavioral research, offering new avenues for modeling consumer decision-making with precision and depth.

Thus, policymakers, marketers, and environmental advocates must collaboratively leverage these insights to craft targeted strategies that reinforce positive attitudes and reduce barriers to sustainable choices. Promoting paper-based packaging is not merely a matter of consumer preference but a strategic imperative in the broader effort to mitigate plastic pollution and support ecological resilience.

In addition, future studies could broaden the scope by incorporating cross-cultural comparisons to assess the universality of the model presented here. Investigating the moderating effects of variables such as income, education level, or geographic location (urban vs. rural) may also reveal deeper behavioral nuances. Methodologically, combining ANN with qualitative techniques such as interviews or focus groups could enrich the understanding of underlying motivations and barriers. Lastly, exploring the impactful perspective of emerging biodegradable alternatives beyond paper, such as compostable or reusable packaging, can provide a more comprehensive on sustainable choices in dynamic market conditions.

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