

Predicting Foodbank e-Marketplace Adoption Intention using Machine Learning Approaches: the case of NCR, Philippines

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Abstract—eMarketplace for food banks is essential to provide accessible and trustworthy food supply for individuals seeking food assistance and support. However, this relatively new idea of foodbank eMarketplace, needs for investigation of its adoption intention, especially in developing economies. This paper aims to predict adoption intention based on behavioral factors. Data were collected through online surveys from 400 Filipinos, situated in National Capital Region, Philippines. Six machine learning techniques, such as Decision Trees, Random Forests, Gradient Boosting, XGBoost, K-Nearest Neighbors, and Support Vector Machines were used to develop the predictive models of adoption intention. Results show that all of the models achieved above 80% classification performance, with Random Forest and Support Vector identified as the models with good predictive performance, achieving accuracy of 0.94. Furthermore, the study revealed that perceived behavioral control, usefulness, and social norms were the most significant factors of e-Marketplace of food bank adoption intention. Overall, this study indicates the potential of e-Marketplace of Foodbank adoption, as technology that could assist in improving food insecurity and accessibility challenges in the NCR, Philippines, addressing sustainable development goal (SDG 2 – Zero Hunger). Research and practical implications are presented.

Keywords: machine learning, artificial intelligence, analytics modelling, e-Marketplace, adoption intention, food banks, technology acceptance, zero hunger.

I. INTRODUCTION

The Philippines is still grappling with the issue of food hunger and insecurity. Despite massive efforts to curb this problem, a significant percentage of the population is still affected. The survey conducted by the Department of Science and Technology in 2021 shows that nearly 34% of rural households suffer from moderate to severe food issues. People use credit to buy goods or borrow money from neighbors or relatives to simply survive. Some people have tried to solve this problem by growing vegetables and fruit or raising animals for personal use [1]. The COVID 19 pandemic made it even harder to obtain food, and uprooted entire food systems, worsening the problem of food scarcity within the

marginalized sections of urban society. The lockdowns caused by the pandemic came with a set of restrictions that greatly reduced people's movement and resulted in lost income, thus reducing the quality and accessibility of food in places like Manila [2].

Meanwhile, the reduction of food surplus and the prevention of food waste is indeed a critical feature of the law which the Philippine government had aptly drafted, the Food Surplus Reduction Act. Such law seeks to encourage donations along with the recycling of food into compost to mitigate food waste and targets various agricultural commodities like rice, bananas, cabbage, calamansi, eggplant, mangoes, and sweet potatoes which do have considerable postharvest losses. Meanwhile, business practitioners in the Philippines are starting to take initiatives in the battle against food wastage. For example, some enterprises like FAST Logistics Group have applied modern cold chain technology to improve the distribution, storage, and transportation of perishables. With this technology, food products are kept in the desired precooked state throughout the supply system, helping to mitigate spoilage and waste [3].

On the other hand, food banks, a local initiative to collect and distribute food, have also developed which gathers excess (good quality) food from different sources and redistribute it to people who need it. While these initiatives have long existed, they became more prominent during the COVID-19 pandemic as job losses surged. With that said, these food supply banks have developed into an important solution to combat food insecurity and food waste in the Philippines. Food banks essentially obtain surplus food from retailers, food producers, and individuals who would have otherwise discarded the food. These organizations are important to reducing hunger while reducing food waste, providing food to people in need. This is especially important in the Philippines when food waste is a key challenge due to post-harvest inefficiencies, distribution issues, and spoilage [4, 5].

Despite the increasing global interest in food banks as a solution to both food insecurity and food waste, little is known about the implementation and efficacy of e-Market place of food banking programs in the Philippines. While some food bank-related studies exist, most address larger issues of food

insecurity or food waste. Very little research exists addressing the implementation, logistics, and sustainability of food banks in the Philippines [6]. Empirical studies that examine e-Marketplace of food banks' direct impact on food security, food waste, and socioeconomic outcomes are limited. Filling in these gaps could be particularly vital to develop a model for food banks that meets all the needs unique to the Philippine settings, a developing country.

This paper develops machine learning models to predict the adoption intention of Filipinos in a e-Marketplace of food bank, specifically in the National Capital Region (NCR), Philippines, through a survey of respondents on behavioral factors, analyzed using machine learning models, namely, Decision Trees (DT), Random Forests (RF), Gradient Boosting (GRB), XGBoost (XGB), Support Vector Machines (SVM), and K-Nearest Neighbor (KNN).

II. LITERATURE REVIEW

A. e-Marketplace for Food Bank and Supply

Food insecurity is limited to availability of safe foods that are acquired in acceptable ways. Research shows that food insecurity often starts being anxious for limited food supply decreasing food intake. According to a study, 78.2% of the population in North America are secure food. However, 4.9% are considered suffering from severe food insecurity. Number of food banks has increased over the last fifteen years in Germany. People aim to examine the prevalence of food insecurity among large food bank users and to study the association of food insecurity's socio demographic and health variables [7]. As a result, high-income countries that provide good social welfare systems prevent low-income people from becoming food insecure.

In the Philippines, e-marketplace for food bank is underexplored. Several organizations are still using traditional methods of information dissemination and access to foodbanks maintained by non-government organizations [8, 9]. This situation results in under supply of food packs and essential goods in food banks [10]. Individuals were also not aware of how to get into the food bank as beneficiary or partner to sustain the operations [11]. Meantime, there are also challenges impeding the development of e-marketplace food banks such as lacking policies, partnerships were fragmented or weak, and mobile apps for service delivery have been limited or underutilized [12, 13]. Overall, there are opportunities to improve food banks situation, through e-marketplaces that provides coordinated system among stakeholders, which offers transparency and fair access to these food supply, especially to those under privilege members of urban communities.

B. Conceptual Framework

Adoption intention has been investigated in information systems and emerging technologies. Several theoretical models and frameworks were used, such as the theory of planned behavior, technology acceptance model, and the unified theory of acceptance and use of technology [14, 15]. Recent studies apply these theories to understand adoption intention, acceptance, and actual usage behavior, which provides a comprehensive understanding of technology adoption processes among end users [16]. Moreover, these theories were modified to extend their conceptual scope and contribution [17, 18].

While this study defines the factors that may influence e-marketplace of foodbank adoption intention such as: Food Quality (FQ) refers to users' perception of the safety, freshness, nutritional value, and overall acceptability of food offered through the e-Marketplace of Foodbank platform. Perceived usefulness of food banks (PU), on the other hand, refers to how respondents find food bank e-commerce as beneficial in terms of providing quality, ethical, and supportive food options. As regards perceived behavioral control (BC), this refers to how much control respondents have over their ability to participate in food bank e-commerce. In reference to social norms (SN), it refers to the influence of social expectations on food bank participation. Lastly, the awareness of consequences (AC) is about the understanding of the potential positive or negative impact of supporting food bank e-marketplace. Thus, this study proposes a baseline conceptual framework of behavioral factors of e-Marketplace of Foodbank adoption intention, as presented in Fig. 1.

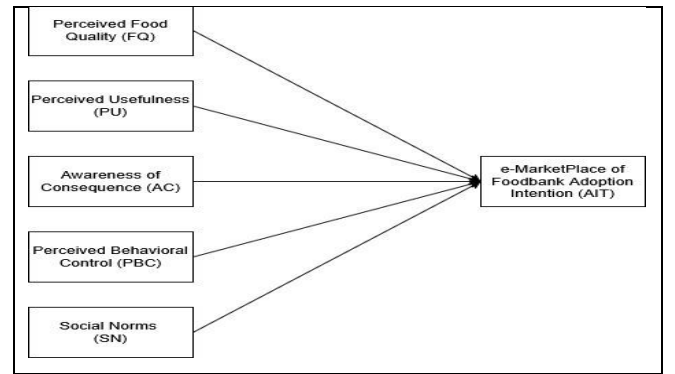


Fig. 1. Conceptual Framework

III. MATERIALS AND METHODS

A. Survey Development

The online survey was structured into two parts. A data privacy consent and informed consent was provided before the actual survey to ensure compliance with ethical standards in research practice. The first part of the survey collects the demographic data of the respondents. The second part of the survey contains the factors influencing adoption intention of e-marketplace for food bank using a 7-point Likert scale, indicating agreement or disagreement for each item from Strongly Disagree (1) to Strongly Agree (7). The survey was pilot tested to at least 30 participants, comments and suggestions were obtained as well from technology adoption researchers and professors to improve the survey instrument. A final version of the survey containing a total of 35 items was used for data gathering.

B. Participants and Data Gathering

This study employed a non-probability sampling approach to achieve the goal of the study, specifically a convenience sampling, wherein surveyed respondents are only located in the National Capital Region, Philippines. Non-probability sampling is applicable as the study focuses on an emerging and underexplored e-marketplace context, as there is no reliable population frame or sampling list related to the study. The survey was distributed to the respondents' emails or social media accounts provided before the start of the survey. The survey data was collected from February 2024 to April 2024. Follow-up sessions were performed to

increase response rate and completion. After the specified data collection period, there were 400 responses collected and subjected to data analysis.

TABLE I. DEMOGRAPHICS OF THE RESPONDENTS

	Attribute	Frequency (%)
Age	21-23	25 (6.25%)
	24-26 years old	107 (26.75%)
	27-35 years old	221 (55.25%)
	36 years above	47 (11.75%)
Gender	Male	222 (55.78%)
	Female	175 (43.97%)
	Other	1 (0.25%)
Education	High School	142 (35.5%)
	Bachelor's	184 (46.0%)
	Master's / Doctorate	74 (18.5%)
Employment Status	Employed	142 (35.5%)
	Unemployed	258 (64.5%)

Table I shows the demographics of the respondents. In terms of age group, most of the respondents are from the age group 27–35 years old ($n = 221$, 55.25%), while the least belongs to the 21–23 years old group ($n = 25$, 6.25%), followed by 24–26 years old ($n = 107$, 26.75%) and 36 years and above ($n = 47$, 11.75%). As for gender, predominantly are male ($n = 222$), with a percentage of 55.78%. Followed by female ($n = 175$), with a percentage of 43.97%, and other ($n = 1$, 0.25%). Education of respondents varies from high school ($n = 142$, 35.5%), bachelor's ($n = 184$, 46%), and master's / doctorate programs ($n = 74$, 18.5%). Also, respondents reported employment status as employed ($n = 142$, 35.5%) or unemployed ($n = 258$, 64.5%).

C. Data Preprocessing

Missing values were checked using Microsoft Excel to ensure that the data is complete and usable for modeling. Also, the inconsistencies of answers were rechecked and reviewed by the respondents before inclusion in the clean data set for modelling and analysis. The column name standardization was done by renaming each variable into upcased two-letter symbolizing specific adoption intention factor. For example, the Social Norms column was renamed as "SN." All attributes names were labelled, and checked for consistency. The final data set in excel was prepared for use in Python Google Colab.

D. Modelling

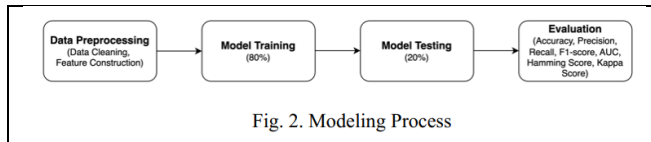


Fig. 2. Modeling Process

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Fig 2. shows the modeling process which consists of four parts: 1) Data Processing; 2) Model Training; 3) Model Testing; and 4) Evaluation. The study utilized training and testing various machine learning models such as DT, RF, GRB, XGB, KNN, and SVM. In which, the dataset was split 80%-20% training-test ratio. The independent variables (FQ, PU, BC, SN, and AC) are used to predict the dependent variable (PI). This study configured the machine learning algorithms as predictors to enable the development of the six models in Python, using scikit-learn, and visualized using matplotlib, and other related libraries. The six models were

developed in Google Colab where Python is used, as the main programming language.

TABLE II. HYPERPARAMETER SETTINGS

Algorithm	Parameters	Value
DT	max dept	10
	min samples split	5
RF	max depth	10
	n estimators	50
KNN	C	10
	Gamma	auto
XGB	n estimators	50
	learning rate	0.01
GRB	n estimators	50
	learning rate	0.01

Table II shows the hyperparameters used for every machine learning model. The settings of each model are finely tuned to optimize the accuracy and improve generalization. These parameters were experimented to determine the most suitable values, which leads to acceptance performance, were used across the six machine learning algorithms.

IV. RESULTS AND DISCUSSION

A. Performance of Machine Learning Models

The metrics considered to assess the performance of the models are accuracy, precision, recall, F1-score, Hamming score, kappa score, and AUC-ROC.

TABLE III. PERFORMANCE OF MACHINE LEARNING MODELS

	Accuracy	Precision	Recall	F1-Score	Hamming Score	Kappa Score	AUC-ROC
DT	0.84	0.87	0.88	0.88	0.16	0.64	0.84
RF	0.94	0.91	1.00	0.95	0.06	0.86	0.95
KNN	0.91	0.89	0.98	0.94	0.09	0.80	0.93
SVM	0.94	0.91	1.00	0.95	0.06	0.86	0.95
XGB	0.89	0.85	1.00	0.92	0.11	0.73	0.95
GRB	0.93	0.91	0.98	0.94	0.08	0.83	0.95

Table III shows the comparison of the model's performance. It can be determined that both SVM and RF have the highest accuracy value of 0.94, precision of 0.91, recall of 1.00, F1-score of 0.95, Kappa score of 0.86, and AUC-ROC of 0.95, and lowest Hamming score of 0.06. This simply means that these models are best in predicting the adoption intention. Followed by GRB, which has also an accuracy of 0.93, precision of 0.91, recall of 0.98, F1-score of 0.94, and the highest AUC-ROC of 0.95. KNN and XGB also perform well but have slightly lower accuracy (0.91 and 0.89), precision (0.89 and 0.85), F1-score (0.94 and 0.91), and Kappa score (0.80 and 0.73). On the other hand, DT had the lowest accuracy (0.84), F1-score (0.88), and Kappa score (0.64), with the highest hamming score (0.16).

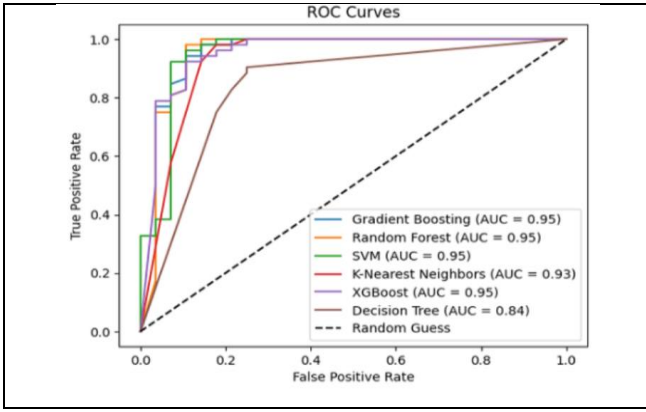


Fig. 3. ROC Curves of Machine Learning Models

Fig. 3 shows the ROC Curves of the machine learning models. In general, all of the models have performed better than random guess, having an AUC score of 0.80 and above. However, four of these: GRB, RF, SVM, and XGB are among the best performing models. On the other hand, DT is the least performing model. Further validation was performed to determine whether the models overfit or underfit, results show that the predictive models were able to achieve closely similar predictive performance of adoption intention, both from training and testing activities.

B. Feature Importance Plots of Machine Learner Models

Fig. 4 illustrates the feature importance of the six different machine learning models. Wherein, features are ranked descending to its importance in predicting the adoption intention of e-Marketplace of foodbanks. Results show that social norms, and behavioral controls, and perceived usefulness were the top features (factors), significantly contributes to the adoption intention, among the predictive models.

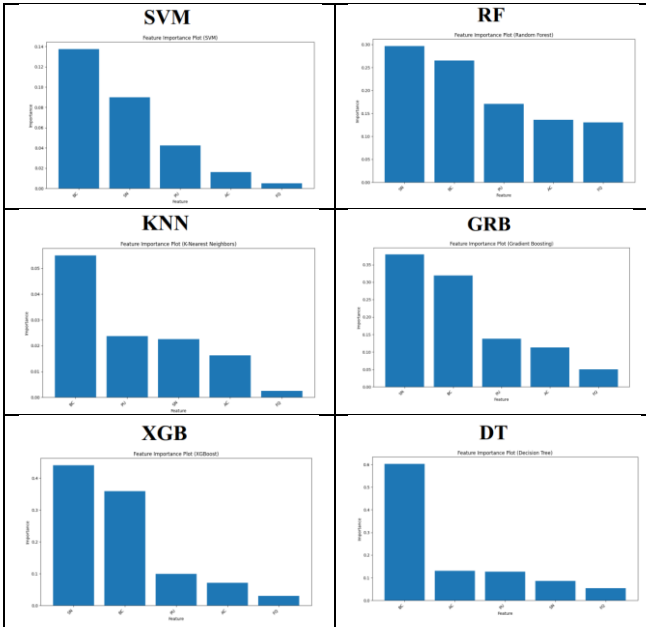


Fig. 4. Feature Importance Plots of Machine Learning Models

Fig 5. shows the heatmap of the feature importance across the machine learning models. It can be identified that BC is the most impactful feature, achieving 0.573 in DT, 0.359 in XGB, and 0.319 in GB. Followed by SN, with 0.440 in XGB, 0.379 in GB, and 0.273. Then, PU with 0.213 in RF, 0.319 in

GB, and 0.127 in DT. Meanwhile, FQ is the least impactful, which is very low across models, 0.002 in KNN, 0.005 in SVM, and 0.030 in XGBoost. These features reflect its contribution to predict adoption intention of social e-marketplace of foodbank.

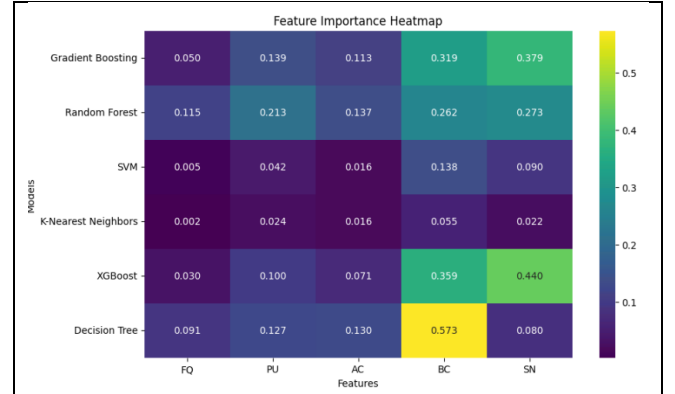


Fig. 5. Feature Importance Rankings across Machine Learning Models

C. Discussion

The results of the feature importance highlight the key factors influencing e-marketplace of food bank adoption intention. From the factors considered, perceived behavioral control emerged as the most significant predictor, which means that individuals who feel a greater sense of control over their ability to engage in food banks are more likely to adopt it. This aligns well with Theory of Planned Behavior suggesting that behavioral control plays a crucial role in shaping consumer decision-making in online and ethical purchasing contexts. Followed by social norms, this implies that the perceived expectations of peers and society can significantly impact the chances of engagement with food bank platforms. Another is the perceived usefulness, this further reinforces the notion that individuals are more encouraged to participate when there are recognizable benefits, such as accessibility, ethical sourcing, and quality assurance in food bank transactions. On the other hand, perceived food quality was found to have minimal impact, which suggests that even though there might be prior engagement, it does not necessarily translate into the adoption intention. Results of this study on social norms and perceived usefulness are consistent with prior studies on agricultural e-commerce [19], social e-commerce [20], and ordering platforms during COVID 19 pandemic [21].

This study contributes to research and practice of e-marketplaces of food supply related systems and emerging technologies. In research, this work is the first evidence of understanding e-marketplace of food bank from the Philippines, a developing country. Also, this study provides baseline machine learning based prediction models of adoption intention, which were empirically validated using real user data and can serve as reference models for future technology adoption studies in similar contexts. Furthermore, this work extends existing technology adoption literature by integrating machine learning techniques with e-marketplace and food bank management research. In practical sense, this work identified some factors that may influence the design of food banks e-marketplace, which could encourage further use

and continuous adoption. Moreover, this study could assist policy makers to introduce change in the existing food bank processes to govern, expand and standardize operations to improve efficiency, transparency, and equitable food distribution. Finally, this research offers practical insights for developers and stakeholders in designing sustainable, technology-driven food bank platforms that address food insecurity challenges.

V. CONCLUSION

Foodbank e-marketplace is essential to aid food insecurity challenges. This study conducted a survey to predict foodbank e-marketplace adoption intention, analyzed using machine learning. Results indicate that among the predictive models, Support Vector Machine and Random Forest, have the highest predictive performance, achieving higher 90% accuracy and not overfitting. These results implied that SVM and RF are reliable models for predicting e-marketplace of food bank adoption intention. Moreover, this study reveals that perceived behavioral control is the most influential factor in predicting adoption intention, followed by social norms and perceived usefulness. This suggests that individuals who feel more in control of their ability to adopt food bank platforms, who perceive social encouragement, and who recognize the benefits of using the platform are more likely to engage in purchasing behavior. On the other hand, perceived food quality was identified to have the least impact, which means that prior usage alone does not strongly influence future adoption intention decisions. Overall, this study indicates the potential of foodbank e-marketplace for adoption, among both employed and unemployed in emerging markets.

Despite contributions of this study, there are some limitations needing further investigation. First, this study did not consider socio-cultural and economic factors to determine adoption intention of foodbank e-market place. Second, this study did not consider underprivilege or marginalized sectors as target respondents. Finally, this study did consider experiences of takers of foodbank in NCR, Philippines, which could provide insights on the issues, challenges, and nuances of its implementation.

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