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Predicting Willingness to Donate Smartphones as a Reuse Option Using Decision Tree Analysis

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ABSTRACT

The increasing number of smartphone users in Indonesia, coupled with the short average usage time of smartphones, has posed a sustainability problem. Smartphone production requires natural resources including rare earth materials and energy, that need to be preserved due to their limited availability and depletion. Circular economy initiatives have become important in the last few decades, and one of them is extending product life by reusing discarded products. On the other hand, triggered by the Covid-19 pandemic, online learning has become an essential part of education. In Indonesia, marginalized communities or low-income societies have limitations in providing online learning tools such as desktop or laptop computers, including smartphones. Therefore, smartphone donation is considered a suitable initiative to help students who need a smartphone to join online learning while at the same time extending the useful life of a smartphone. Using decision tree techniques, we investigate the willingness to donate used smartphones for education in the Indonesian context. The results show that the respondents' willingness-to-donate was influenced by several considerations, which are performance, value (price), type, obsolescence of the used smartphone, and the donators' age. The resulting parameters and predictions could enhance the effectiveness of the donation mechanism.

1. Introduction

There is an increasing trend in the smartphone penetration rate in Indonesia; it was 44.44% in 2017 and increased to 67.15% in 2020 [1]. Smartphone users in Indonesia are also quite large, which reached 183.68 million users in 2020 [2]. Indonesia is the fourth-highest smartphone market after China, India, and United States. Mairizal *et al.,* [3] and Maheswari *et al.,* [4] found that the average time for a smartphone to reach its end-of-use was less than three years in Indonesia. Therefore, the smartphone demand in Indonesia is quite high and is accompanied by a fast sales turnover due to the smartphone's short usage time.

On the other hand, smartphone production requires natural resources, including rare earth materials such as cobalt, neodymium, europium, and terbium, whose availability is limited and

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increasingly depleting. In addition, it also requires energy, not all of which comes from renewable energy sources. Therefore, circular economy initiatives have become important in the last few decades. Several attempts have been made to extend the product's life, such as reusing, refurbishing, remanufacturing, or recycling. Smartphone refurbishment has been widely implemented in developed countries such as the United States, Germany, and Japan, but implementation in Indonesia is still minimal. However, consumers' interest in buying refurbished smartphones is also still low. Halim *et al.,* [5] investigated the factors influencing Indonesian customers to buy refurbished smartphones. They concluded that customers prefer to buy a flagship smartphone than the refurbished one. Gan *et al.,* [6] also found that Indonesian customers prioritize their choice of new low-end smartphones compared to refurbished or secondhand smartphones.

Smartphone has a short usage time, especially when there is a new model with more features or recent technology. Therefore, the smartphone becomes obsolete or reaches its end-of-use in a relatively short period. In an Indonesian society with mutual-cooperation culture, the most common practices in handling smartphones at their end-of-use are selling to the secondhand market, giving to family or friends, donating, reused after repairing [7]. As a result, very few smartphones were sent to waste disposals [8-10].

In the last two years, there have been enormous changes globally due to the COVID-19 pandemic. As a result, learning activities had to be conducted remotely using the internet and therefore required electronic devices. In Indonesia, marginalized communities or low-income societies have limitations in providing online learning tools such as desktop or laptop computers, including smartphones. Meanwhile, adequate devices are needed to run video conferencing applications such as Google Meet, Zoom, and Microsoft Teams. A recent study confirmed that smartphones have made it possible for people who were previously unable to access the internet to become possible with the use of smartphones. There were 96% of internet users in Indonesia use smartphones to access internet learning materials [11].

On the other hand, the Indonesian government policy during COVID-19 supported online learning by subsidizing internet data packages to access online learning materials. Still, the students had to provide the devices themselves. Therefore, there was a need for smartphone devices to support them, such as through donations. Although currently the COVID-19 condition has improved and learning activities have started to be conducted onsite in face-to-face mode, best practices from online learning can still be used to enhance and support the effectiveness of learning. For example: Sa'diyah *et al.,* [12] found that the experimental class that applied smartphone-supported learning had significantly higher critical thinking skills than the control class.

Smartphone donation is considered a suitable initiative considering the common practices in handling used smartphones and the need for smartphones for education in Indonesia. However, very few studies explored the optimal parameters of smartphone donation. Therefore, we investigate the willingness to donate used smartphones for education using decision tree techniques in the Indonesian context. The resulting parameters and predictions could enhance the effectiveness of the donation mechanism.

2. Methodology

2.1 Literature Review: Smartphone for Education

Due to the COVID-19 pandemic, learning needed to be conducted online. Batubara [13] found that the technology and infrastructure to implement online learning were inadequate in some regions of Indonesia. Three indicators used to study the success of online learning are an internet connection, information technology infrastructure, and learning materials suitable for online mode.

Jie and Ali [14] showed that three main challenges of online learning are institution's readiness, students' difficulties due to internet connection, and teachers' dilemma due to unsupportive platform design. Also, the use of AI technology in virtual and face-to-face classes can have a significant impact on students' interest in taking up the class [15]. Laksana [16] conducted a survey on the student's perceptions regarding online learning implementation in the outer area of Indonesia. They found that 34% of students did not have adequate equipment. Azhari and Fajri [17] also found that some students in remote areas could not buy the equipment needed for online learning, such as computers or smartphones. Information technology facilities are still not evenly distributed throughout Indonesia, especially in rural areas. Therefore, there is a need for smartphones to support online learning in remote areas or low-income communities.

Sole and Anggraeni [18] found that a smartphone is an effective learning instrument for online mode in such constrained conditions. Four indicators were used to measure the effectiveness: program success, target success, program satisfaction, and goals achievements. In a separate study, Hermanto and Srimulyani [19] also found that smartphones are the most used device in online learning. Zaini *et al.,* [20] found the most widely used media for online learning is social media applications such as WhatsApp, which can be easily accessed using smartphones. These studies indicate that smartphone is an effective instrument for online learning in Indonesia.

Sa'diyah *et al.,* [12] conducted a study exploring smartphone-based learning to enhance critical thinking skills. They used four indicators: understanding, application, analysis, evaluation, and generalizing. By comparing the results of the smartphone-based experimental class with the regular online class, they found that students who joined the experimental class showed a significantly higher critical thinking skill. This result indicated that smartphones could be used to increase learning effectiveness, regardless of the COVID-19 pandemic.

Despite the recent development where learning activities have returned to face-to-face mode, the benefits and best practices of online learning that have been developed during the pandemic can still be used to improve critical thinking skills, broaden students' horizons, enrich the learning materials, and increase students' learning interest through interactive modules using a smartphone.

2.2 Literature Review: Decision Tree Analysis

The decision tree technique has been widely used to solve segmentation and profiling problems. The data set is recursively split into smaller groups with different outcomes until eventually it reaches terminal outcomes. This technique would find the optimum binary branch using least squares. The implementation of this technique can be found in many areas, such as healthcare, business, and data mining. More specifically, we can see the implementation for optimizing donation in healthcare, such as organ, blood, or medicine donation. There are several other methods for decision analysis such as multi-criteria decision analysis, compromised Analytic Hierarchy Process, and artificial neural network predictive model [21-23]. To the best of our knowledge, this is the first study for optimizing smartphone donation using the decision tree technique.

The kidney-paired donation has been extended to include an altruistic living donor who donates a kidney to an incompatible candidate, believing that the donor would be paired with the second candidate, and so on. Li *et al.,* [24] proposed a novel strategy to maximize the expected utility in sequentially pairing an altruistic donor that was incompatible with the initial paired candidate to the following donor-candidate pairs using decision tree analysis. The decision tree approach was also used to review the feasibility and impact of a partnership program between Pfizer Inc. and the South African Ministry of Health called the Diflucan Partnership Program [25]. The decision tree was constructed by considering the program's goals, the responsibility of both parties, and the actions as the terminal nodes or leaves. Demir and Kumkale [26] studied the willingness to donate organs using a decision tree approach. They predicted the registration intentions using personality variables and knowledge about organ donation. They identified the facilitating attributes, i.e., empathy, elaboration of potential outcomes, conscientiousness, and knowledge. On the other hand, religiosity and neuroticism were categorized as barriers. The abovementioned studies showed that the decision tree technique is suitable to optimize donation, whether to maximize the expected utility in pairing donor and candidate, to review the feasibility and impact of a program, or to find parameters that influence the willingness to donate. Moreover, this approach can be modified for smartphone donations.

The applications of the decision tree technique were also found in blood donation problems. Boonyanusith and Jittamai [27] studied the factors that influence the decision to participate in blood donation. The factors are intention to donate, attitudes towards blood donation, perceived risks, knowledge of blood donation, and altruistic behavior. The prediction from decision tree analysis showed the potential of someone to join blood donation. Another application was predicting the health blood using data mining in the Blood Transfusion Organization, such that the performance of blood donation service was improved [28]. A study of the cost-effectiveness of blood donation screening for a particular parasite was also performed using decision tree techniques with several scenarios and model parameters [29]. Since the confirmation procedures were different for each institution, they developed a decision tree for each institution. Also, model parameters were introduced under several scenarios, such as the proportion of blood screened, the proportion of parasite positive blood sent for confirmation, specificity, sensitivity, and cost.

2.3 Model

There are two steps in the construction of the decision tree. First, we identified the parameters that influence the willingness to donate, based on a literature review and initial interviews with a small group. Second, we design the decision tree consisting of decision nodes and leaves. The relevant parameters were selected as decision nodes. Since the expected outcome from this survey is the willingness to donate, the leaves are "yes, willing to donate" and "no, unwilling to donate. The decision tree is constructed as a model to understand the factors that predict the respondents' likeliness to donate their used smartphones.

The identified parameters are

i. Performance of the used smartphone
ii. Type of the used smartphone
iii. Value (price) of the used smartphone
iv. Obsolescence stage of the used smartphone
v. Age of the smartphone owner

2.4 Methods

This study began with a literature review to determine factors influencing the decision to donate a smartphone. To improve the relevance of the factors identified from the literature review, we conducted interviews with a small group of 10 people. This approach was an attempt to involve stakeholders and real users in the process of predicting the decision to donate [30]. The results were then analyzed, and we decided on the most relevant factors as variables in the decision tree analysis. Next, we constructed a decision tree model based on the resulting factors. Furthermore, we compiled a questionnaire to collect data that will be used as the training and testing data. In addition, we also included questions about the behavior in changing old smartphones to new ones to understand the potential of smartphone donation. The data were collected through online questionnaires shared on social media, i.e., Facebook, Instagram, Line, and WhatsApp. In total there were 330 respondents participated in this survey. The data were then described statistically and tested using the chi-squared test for dependency. Finally, the classification and regression tree, which can be found in R-Software, is applied to find the pattern of willingness to donate in Indonesia [31,32].

The decision tree technique has been widely used to solve segmentation and profiling problems. The data set is recursively split into smaller groups with different outcomes until eventually it reaches.

3. Results

3.1 Respondents Data

Table 1 shows that most respondents kept the same smartphone for 3 to 4 years before deciding to get a new one. In total, the majority of respondents (81.82%) kept their smartphones for four years or less. The distribution between the Age-of-the-respondents and the Years-to-keep-the-same-smartphone is presented in Table 2. The Chi-squared test shows a dependency between Age and Years-to-keep-the-same-smartphone with a p-value of 0.02232. The marginal distribution of each Year-class indicates that 82 of 177 (46.32%) respondents at aged of less than 22 years old will keep the same smartphone for three to four years. On the other year-class, 50 out of 113 (44.24%) of the respondents aged 23-30 will keep the same smartphone for less than two years.

Table 1
Respondent's profile

Gender		Age: First time having a smartphone	
Man	51.21%	<= 12 years	50.91%
Woman	48.79%	13-18 years	36.97%
Age		>19 years	12.12%
< 22	53.64%	Years to keep the same smartphone	
23-30	32.24%	before buying the new one	
>30	12.12%	< 2 years	39.09%
Occupation		3-4 years	42.73%
Students	76.35%	>4 years	18.18%
Employee	23.64%		

Table 2
Crosstabulation of Years to keep the same smartphone to the Age of respondents

	<22 years	23-30 years	>31 years	Total
< 2 years	69	50	10	129
3-4 years	82	43	16	141
>4 years	26	20	14	60
Total	177	113	40	330

The potential of smartphone donation can also be analyzed through the practice of upgrading old smartphones to new ones as presented in Table 3. The results show that 40.30% of the respondents kept their old or used smartphones, 31.52% gave them to family or relatives, 25.15% sold them, and 3.03% donate the smartphones to other people. Hence, the most common behavior is keeping old smartphones which do not contribute significantly to a better world. This potential can be explored by finding the most suitable approach to convince people to donate their smartphones rather than keep them idle.

Table 3
The practice of upgrading old smartphones to new ones

Handling of old smartphones	
Kept it	40.30%
Gave it to family/relative	31.52%
Sold to secondhand market	25.15%
Donated	3.03%

Most respondents (83.94%) decided to get new ones even though the old ones were not obsolete. They were concerned about the performance of the smartphone. 48.18% of the respondents got new smartphones when the old ones were no longer performing as expected. Halim *et al.,* [33] showed the types of unperformed conditions that make people tend to change their smartphones, which are damaged, obsolete, and perceived as outdated. This result indicates that a significant proportion of discarded smartphones are still well-functioning, which would be a proper choice for donation.

We also found that most of the respondents (94.55%) never donated their old smartphones in the past. However, given the information that smartphone donation is needed to support online learning for students in rural areas or underprivileged students, most of them (78.48%) were willing to donate their used smartphones. The type and price of used smartphones that respondents were willing to donate are shown in Table 4.

Table 4
The type and price of smartphones that are likely to be donated

Type of Smartphone		Price (in a million Rp)	
Low-end	51.52%	1.0 – 1.4	30.30%
Mid-range	24.85%	0.5 – 0.9	24.24%
Secondhand	17.27%	1.5 – 1.9	21.82%
Refurbished	3.94%	>= 2	12.42%
High-End	2.42%	<0.5	11.21%

In donating smartphones, respondents have different preferences, as stated in Table 5. 62% of respondents choose to donate to specific institutions, namely 18.5% to social institutions, 13% to religious-based institutions, and 15.7% to educational institutions. In addition, 14.8% of respondents prefer donation institutions that operate online because it is easier and has a wider reach. The majority of the smartphone types donated were low-end types, namely 48.1%; followed by mid-range smartphones at 26.4%, and second-hand smartphones at 17.6%. Very few respondents donate refurbished and high-end smartphones. Refurbished smartphones are not often found in the Indonesian market, while high-end smartphone owners prefer to sell to the second-hand market or trade-in to get the latest model.

Table 5 shows that respondents have varying preferences when it comes to donating smartphones. 62% of respondents choose to donate to specific institutions, with 18.5% donating to social institutions, 13% donating to religious institutions, and 15.7% donating to educational institutions. Furthermore, 14.8% of respondents prefer online donation institutions because it is easier and has a wider reach. The majority of smartphones donated were low-end models (48.1%), followed by mid-range models (26.4%), and used smartphones (17.6%). Few people donate refurbished or high-end smartphones. Refurbished smartphones are not commonly found in the Indonesian market, as high-end smartphone owners prefer to sell or trade-in to get the latest model.

Table 5
Preferences in donating a smartphone

Donation institution		The donated smartphone type	
Social	18.5%	Low-end	48.1%
Religion	13.0%	Mid-range	26.4%
Education	15.7%	Second-hand	17.6%
Online	14.8%	Refurbished	5.1%
Any institution	38.0%	High-end	2.8%
The donated smartphone performance		**Type of damage in the donated smartphone**	
In good performance but the version is obsolete	53.7%	No damage	53.5%
The smartphone performance is slowing down	10.2%	Slow down	36.0%
Smartphone with minor damage	33.8%	Scratched screen	7.0%
Smartphone is not marketable	0.5%	Broken speaker	2.6%
Smartphone is no longer needed	1.9%		

The condition of the donated smartphone varies as well. The majority of those willing to donate (53.5%) have obsolete but still functional smartphones. Since obsolete smartphones have a very low selling value in the used product market, respondents would rather keep them at home or give them to family or relatives than sell them, as shown in Table 3. However, after learning how their smartphone can be donated to assist underprivileged students in joining online classes, some respondents are willing to donate their smartphones. The majority of donated smartphones are in good condition, with 53.35% having no damage and 36% functioning reasonably well but slowly.

3.2 Decision Tree Analysis

The decision tree analysis was performed using R-Software with willingness-to-donate as the dependent variable, and the independent variables are all variables shown in Figure 1 [32]. The data were split into 80:20 for training and testing using purposive sampling.

The results show that when the smartphone is well-performed, and the price is less than 0.5 million Rupiah, the respondents are willing to donate the smartphone. However, if the price exceeds 0.5 million Rupiah, only respondents younger than 22 years old are willing to donate the smartphone. Therefore, if the price of the smartphone needed to support education is more than 0.5 million Rupiah, then we should target younger donator, not more than 22 years old.

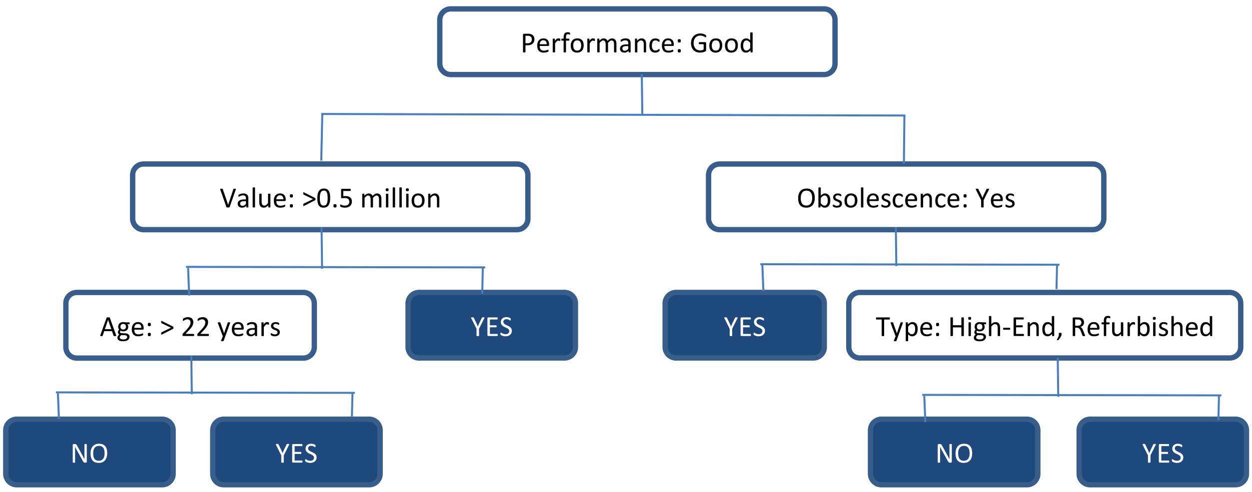

Fig. 1. The decision tree of the willingness to donate used smartphones

If the smartphone is no longer well-performed and already obsolete, then the respondents are willing to donate. However, when it is not yet obsolete, and the type of the smartphone is low-end, mid-range, or secondhand, they are willing to donate their used smartphones. Otherwise, they will not donate their used smartphones. Hence, if the smartphone needed for education is quite updated, not-yet-obsolete, then we should settle with getting low-end, mid-range, or secondhand smartphones (See Figure 1).

The confusion matrix in Table 6 shows the summary of the classification performance, explaining the classification accuracy between the data test and prediction. The results show that 8 of 13 (61.53%) test data are predicted as willing-to-donate, but in the data test, they are not-willing-to-donating the smartphone. However, only 8 of 53 (15.09%) of the respondents who are willing to donate their used smartphones are predicted as not-willing-to-donate. Overall, the error of this model is 24.24%.

Table 6
Confusion matrix of willingness-to-donate used smartphone

Willingness to Donate	Prediction No	Yes
No	5	8
Yes	8	45

The Random Forest method can be used to improve Decision Tree approach, based on the Black Box algorithm. We cannot trace which variables lead to the decisions generated by this method. It differs from the CART (Categorical Regression Tree) algorithm which was used to construct the preceding tree and is classified as a White Box algorithm. The latter allows us to trace the variables that determine how a decision is made. However, CART's weakness is that the results have a higher error rate than the black box algorithm. When applied to the data above, the Random Forest produces an error of 21.21%. Table 7 shows the confusion matrix of willingness-to-donate used smartphone using Random Forest method.

Table 7
Confusion matrix of willingness-to-donate used smartphone using Random Forest Method

Willingness to Donate	Prediction No	Yes
No	5	9
Yes	5	47

4. Conclusions

This paper studied the willingness to donate in the case of used-smartphone donations for education in Indonesian context. We applied the decision tree technique to understand the parameters for predicting the respondents' likeliness to donate their used smartphones. The resulting parameters and predictions can be used to enhance the effectiveness of the donation mechanism. The results show that the respondents' willingness-to-donate was influenced by several considerations, which are performance, value (price), type, and obsolescence of the used smartphone. We conducted a survey to get data for training and testing. The decision tree analysis revealed that younger people are willing to donate higher-valued smartphones. On the other hand, the not-yet-obsolete smartphone donated is likely to be a low-end, mid-range, or a second-hand smartphone. CART and Random Forest were unable to accurately forecast the unwillingness to donate. This is possible given that the data are unbalanced. Only 71 out of 330 respondents (21.51%) are unwilling to donate, whereas 259 out of 330 (78.49%) are eager to donate their used smartphone. Using an unbalanced technique to construct the decision tree and merging all algorithms in an unbalanced gray box decision tree may constitute future research.

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