Estimation Lifespan of Home Electronic Appliances in Indonesia: The Case Study of Java Island

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Abstract. In this study, the lifespan distribution of home electronic appliances (televisions, refrigerators, and washing machines) in Indonesia are investigated. The data to estimate lifespan distribution based on the questionnaire survey conducted on Java Island. The better fit distribution model is examined with comparing Log-likelihood, AIC, and BIC for each product. Weibull distribution is the better fit for lifespan distribution of televisions and Normal distribution is the better fit for lifespan distribution of refrigerators and washing machines based on result of model selection. The possession span is 8.67 years, 9.76 years, and 11.69 years for televisions, refrigerators, and washing machines, respectively. This study also investigates storage time that potential to be a barrier to increase the collection rate. The results show that there is an influence on the duration of storage time of home electronic appliances in Indonesia. To avoid that impact, the duration of storage time should be lowered by creating a collection center for e-waste.

1. Introduction

Electronic products are common goods owned by humans in the present era. Ownership of electronic products in the world continues to increase each year accompanied by the development of advanced technology, both in the developed and developing countries [1]. In a positive note, electronic products certainly help the daily activities of all people in the world. But with the rapid development of technology and the high variation of electronic products, this will accelerate the technology used to be obsolete and will certainly reduce the lifetime of electronic products. As a result of the massive flow of electronic products that are not used anymore, the amount of electronic waste (e-waste) continues to increase and is expected to rise 3 - 4% per year in the world [1].

The annual increase in e-waste in the world is not only due to the growth of the electronics industry and the consistency of innovations in technology. Increased e-waste is also due to changes in behavior of consumers, ignoring the dynamic lifespan of electronic products [2] and the market conditions that always starving. In Indonesia, e-waste is potentially increasing because of the high level of consumption of EEE, and no lifespan estimation of electronic products and e-waste generated.

Research on lifespan in electronic products has been done by studies from the developed countries and some of the developing countries in recent years. Some researches on lifespan in developed countries include Kim et al. [3] in South Korea, Wang et al. [4] in the Netherlands, Babbitt et al. [2] in USA and so on. Research in the developed countries is generally easier because the average developed countries already have a good e-waste management system and the availability of sufficient data.
In the developing countries, research on the lifespan of electronic products has also begun to be in demand as most of the developing countries have plans to build e-waste management systems to reduce the impact of e-waste on the environment. Research on the lifespan of electronic products in developing countries conducted by Yamasue et al. [5] in Vietnam. Besides, there are other problems such as dead storage or storage time that is directly related to the lifespan of electronic products. The storage time here is defined as the time between the end of active use and the time its final disposal or transfer to the next owner. The active use is defined as the time of a device between the first time received and the time of the transfer. The summation of the ‘active use’ and the ‘storage time’ is called ‘possession span’ [6]. The problem of storage time is when end-of-life or unused electronic products do not return to the circular loop and cause a lack of supply for raw materials for recycling. A longer storage time will further disrupt sustainability, and many resources are lost. For that reason, storage time should be minimized.

Based on The Global E-waste Monitor 2017 [1], the largest e-waste growth rate is electronic products that have changes in temperature as refrigerators and large appliances as washing machines. Indonesia is a country that has a very large population and is a large e-product consumer and does not yet have a good e-waste management system. The products chosen for this study are refrigerators and washing machines representing the most massive e-waste growth rate and television as a potential product as the most substantial e-waste in Indonesia. So the objective of this study is the lifespan estimation of the household electronics product by using model selection to assess the distribution fit for lifespan electronic products in Indonesia and see the impact of storage time.

2. Literature Review
In general, there are four methodologies that were used for estimating lifespan of electronic products. First, estimation from the number of discarded electronic products for each lifespan. Second, estimation from the number of electronic products for each products age. Third, estimation from the number of electronic products in use for each products age at beginning and the end of certain period. And the last, estimation from the total number of electronic products in use by using mass balance principle [6, 7].

According to the literature, there are two approaches that can be made in estimating lifespan in electronic products. First is a non-parametric approach that does not assume a statistical distribution for lifespan estimation in electronic products. Second is the parametric approach that assumes the observational data follows a statistical distribution function such as Normal distribution, Lognormal Distribution, Weibull distribution, and Exponential distribution [6, 7]. Weibull distribution is widely used by researchers in previous research. Weibull distribution has been used in Australia [8], Netherlands [4], South Korea [3] and Vietnam [5] in determining an estimation of the lifespan of electronic products. Not only Weibull distribution but estimation of lifespan electronic products with lognormal distribution has also been used in USA [2].

From the previous study, Weibull distribution is the most widely used method of lifespan estimation of EEE. In Babbitt et al. [2] and Petridis et al. [9], some statistical distributions were examined to obtain the best fitting distribution model for lifespan data. Lifespan data from distribution models were compared by calculating Log-likelihood, the Akaike Information Criterion (AIC), and the Bayesian Information Criterion (BIC) to select the distribution with the best fitting.

3. Methods
Television (TV), refrigerator (RF), and washing machine (WM) are selected as product targets. This study used an estimation method from the number of discarded electronic products for each lifespan. The method used to obtain data is an online questionnaire survey to the owners of home electronic appliances that they have disposed of in the past. The questionnaire asks for the year of each appliances bought or received, the year when respondent stopped using the appliances, the year when the respondent disposed of the appliances, the reason of keeping end-of-life or unused, and disposal pathway for appliances that already disposed of.
The data is obtained from an online questionnaire survey conducted mainly on Java Island in 2018 from a previous study [10]. In the previous study, selected products were small electronic devices (mobile phones and laptops). Java Island considered to represent Indonesia as the total population of Java island about 145 million people or about 56% of the total population of Indonesia and Java Island is the center of government and economy in Indonesia. In this study, the data collected from randomly selected 400 households for each product.

For processing data, this study uses midpoint value from the survey result. Midpoint value is required because the information from the respondents in the survey is cumulative number for 1-year periods. Midpoint value is taken per year as an average data point of computation for lifespan [3, 4, 8]. For instance, between 0-year and 1-year, number 0.5 was taken and so on. MATLAB® was used for obtaining Log-likelihood, AIC, and BIC to compare Normal distribution, Lognormal distribution, Weibull distribution, and Exponential distribution to get best fitting distribution model for electronic products in Indonesia.

4. Result and Discussion
The result of survey for the reason for keeping end-of-life or unused home electronic appliances and disposal pathways can be seen on Figure 1. From disposal pathways in home electronic appliances, there are more than 65% of respondents who dispose of home electronic appliances that have been end-of-life or unused to scavengers. For the reason of keeping home electronic appliances, more than 55% of respondents said they did not know a legal place to dispose of electronic waste.

![Figure 1](image)

(a) Reason for Keeping  (b) Disposal Pathways

The selection of the better fit distribution was performed by testing the data from survey against the selected continuous distribution (Normal, Lognormal, Weibull, and Exponential) [2, 9]. In this study, three goodness of fit criteria were taken in order to select and compare the distribution to obtain the better fit distribution for home electronic appliances in Indonesia. The distribution is considered to fit better to the lifespan distribution for maximum Log-likelihood and minimum AIC and BIC values, as shown in Tables 1-3 and the better fit distribution are denoted with bold letters.

| Table 1. The better fit distribution for lifespan of televisions in Indonesia |
|-------------------------------------------------|-------------|-------------------|-------------------|-------------|-------------|-------------------|-------------------|
| Distribution        | Active Use | Possession Span |
|---------------------|------------|------------------|------------------|------------|-------------|-----------------|------------------|
|                     | BIC        | AIC              | Log-likelihood   | BIC        | AIC         | Log-likelihood   |
| Normal              | 2009.707   | 2001.724         | -998.862         | 2150.603   | 2142.620    | -1069.310        |
| Lognormal           | 2053.703   | 2045.720         | -1020.860        | 2171.343   | 2163.360    | -1079.680        |
| Weibull             | 1983.923   | 1975.940         | -985.970         | 2136.363   | 2128.380    | -1062.190        |
| Exponential         | 2297.566   | 2293.574         | -1145.787        | 2534.578   | 2530.587    | -1264.293        |
Table 2. The better fit distribution for lifespan of refrigerators in Indonesia

| Distribution | Active Use | Possession Span |
|--------------|------------|-----------------|
|              | BIC        | AIC             | Log-likelihood | BIC   | AIC       | Log-likelihood |
| Normal       | 2056.463   | 2048.480        | -1022.240      | 2211.483 | 2203.500 | -1099.750       |
| Lognormal    | 2256.143   | 2248.160        | -1122.080      | 2368.003 | 2360.020 | -1178.010       |
| Weibull      | 2070.763   | 2062.780        | -1029.390      | 2219.203 | 2211.220 | -1103.610       |
| Exponential  | 2420.842   | 2416.850        | -1207.425      | 2628.420 | 2624.429 | -1311.214       |

Table 3. The better fit distribution for lifespan of washing machines in Indonesia

| Distribution | Active Use | Possession Span |
|--------------|------------|-----------------|
|              | BIC        | AIC             | Log-likelihood | BIC   | AIC       | Log-likelihood |
| Normal       | 2129.983   | 2122.000        | -1059.000      | 2227.103 | 2219.120 | -1107.560       |
| Lognormal    | 2289.543   | 2281.560        | -1138.780      | 2387.523 | 2379.540 | -1187.770       |
| Weibull      | 2136.263   | 2128.280        | -1062.140      | 2228.243 | 2220.260 | -1108.130       |
| Exponential  | 2604.917   | 2600.925        | -1299.463      | 2772.978 | 2768.987 | -1383.494       |

In Tables 1-3 shows that the better fit distribution for televisions is Weibull distribution and for refrigerators and washing machines are Normal distribution. Parameter values for each distribution were derived using Maximum Likelihood Estimation (MLE) method with MATLAB®. Figure 2-4. shows the Probability Density Function of active use and possession span for each of the distributions of the lifespan for each product. The estimated parameters of each better fit distribution and average lifespan for each product are presented in Table 4.

Possession span is summation of the ‘active use’ and the ‘storage time’ [6]. From Tabel 4. It is shown that the duration of storage time for televisions, refrigerators, and washing machines are 2.24 years, 2.23 years, and 2.21 years, respectively. Table 5. shows disposal ratio per year for each product and influence storage time in disposal. From the result of disposal ratio, there is an influence of storage time to all product under study. Although the storage time of home electronics appliances tend to be low, this will have an impact on the environment and supply to industry recycling if this happens continuously. To avoid these impacts then it takes an effort to reduce the duration of storage time in home electronic appliances in Indonesia.
Table 4. Parameters of the fitted distribution for each product

|        | Distribution parameters |          |          |          |
|--------|-------------------------|----------|----------|----------|
|        |                         | Scale ($\eta$) | Shape ($\beta$) | Average Lifespan (years) |
| TV     |                         |          |          |          |
| Active Use | 7.26                   | 2.25   |          | 6.43     |
| Possession Span | 9.76              | 2.60   |          | 8.67     |
| RF     | Mean ($\mu$) | Std. Dev ($\sigma$) | Average Lifespan (years) |
| Active Use | 7.53                 | 3.13   |          | 7.53     |
| Possession Span | 9.76             | 3.79   |          | 9.76     |
| WM     | Mean ($\mu$) | Std. Dev ($\sigma$) | Average Lifespan (years) |
| Active Use | 9.48                 | 3.43   |          | 9.48     |
| Possession Span | 11.69            | 3.86   |          | 11.69    |

Figure 3. Distribution fitting for the lifespan of refrigerators (c) Active Use, (d) Possession Span

Figure 4. Distribution fitting for the lifespan of washing machines (e) Active Use, (f) Possession Span
5. Conclusions
The result show the better fit distribution model for the lifespan distribution of televisions in Indonesia follow Weibull distribution and the lifespan distribution of refrigerators and washing machines follow Normal distribution. Distribution for active use and possession span is same for each home electronic appliances in Indonesia. Average lifespan of possession span for televisions, refrigerators, and washing machines is 8.67 years, 9.76 years, and 11.69 years, respectively.

Based on result of the disposal ratio, there is an influence duration of storage time to be able to maintain sustainability both environmental and economical in terms of supply to industrial recycling needed for raw material. To avoid these impacts then it takes an effort to reduce the duration of storage time. Based on result of survey, there are more than 65% of respondents who dispose of home electronic appliances that have been end-of-life or unused to scavengers. For the reason of keeping home electronic appliances, more than 55% of respondents said they did not know a legal place to dispose of electronic waste. The results of survey on the reason for keeping and disposal pathways are interconnected which is due to ignorance of the public about the legal place to dispose of electronic waste causes them to throw into the scavenger. So the effort to reduce the duration of storage time that can be done is to make the collection center as a legal place to dispose of e-waste.

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References
[1] Baldé C P, Forti V, Gray V, Kuehr R and Stegmann P 2017 The global e-waste monitor – 2017 (UNU, ITU & ISWA, Bonn/Geneva/Vienna)
[2] Babbitt C W, Kahhat R, Williams E and Babbitt G A 2009 Environmental Science & Technology 43 5106–5112
[3] Kim S, Oguchi M, Yoshida A and Terazono A 2013 Waste Management 33 474–483
[4] Wang F, Huisman J, Stevels A and Baldé C P 2013 Waste Management 33 2397–2407
[5] Yamaseue E, Cravioto J, Nguyen D Q, Oguchi M and Daigo I 2017 Procedia CIRP 61 152–154
[6] Murakami S, Oguchi M, Tasaki T, Daigo I and Hashimoto S 2010 Journal of Industrial Ecology 14 598–612
[7] Polá k M and Drá palová L 2012 Waste Management 32 1583–1591
[8] Golev A, Werner T T, Zhu X and Matsubae K 2016 Journal of Cleaner Production 133 262–271
[9] Petridis N E, Stiakakis E, Petridis K and Dey P 2016 Journal of Cleaner Production 112 3072–3085
[10] Sumasto F, Ardi R and Zulkarnain 2018 Proceedings of APCoRISE ISSN: 2621-4555