

Remediating the Existing E-waste Problem through Incorporation of Consumer Behavior in Design for Multiple Life Cycles and Design for Ease-of-Return

University at Buffalo and PC Rebuilders & Recyclers

Electronic Waste Problem

41.8 million tones of e-waste was generated in 2014 .

What is E-waste?

E-waste is a term used to cover all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of re-use (Step Initiative 2014).

- E-Waste is one of the fastest growing pollution problems in the US and worldwide .
- More than 60% of electronic waste consists of precious metals.
- A huge amount of used electronics is exported to Africa, Asia and Eastern Europe that results in an economic loss for the country as well as severe environmental pollution and human health issues.
- Other issues:* cost of collection, old age of e-waste, uncertain quality, quantity and timing of returns.

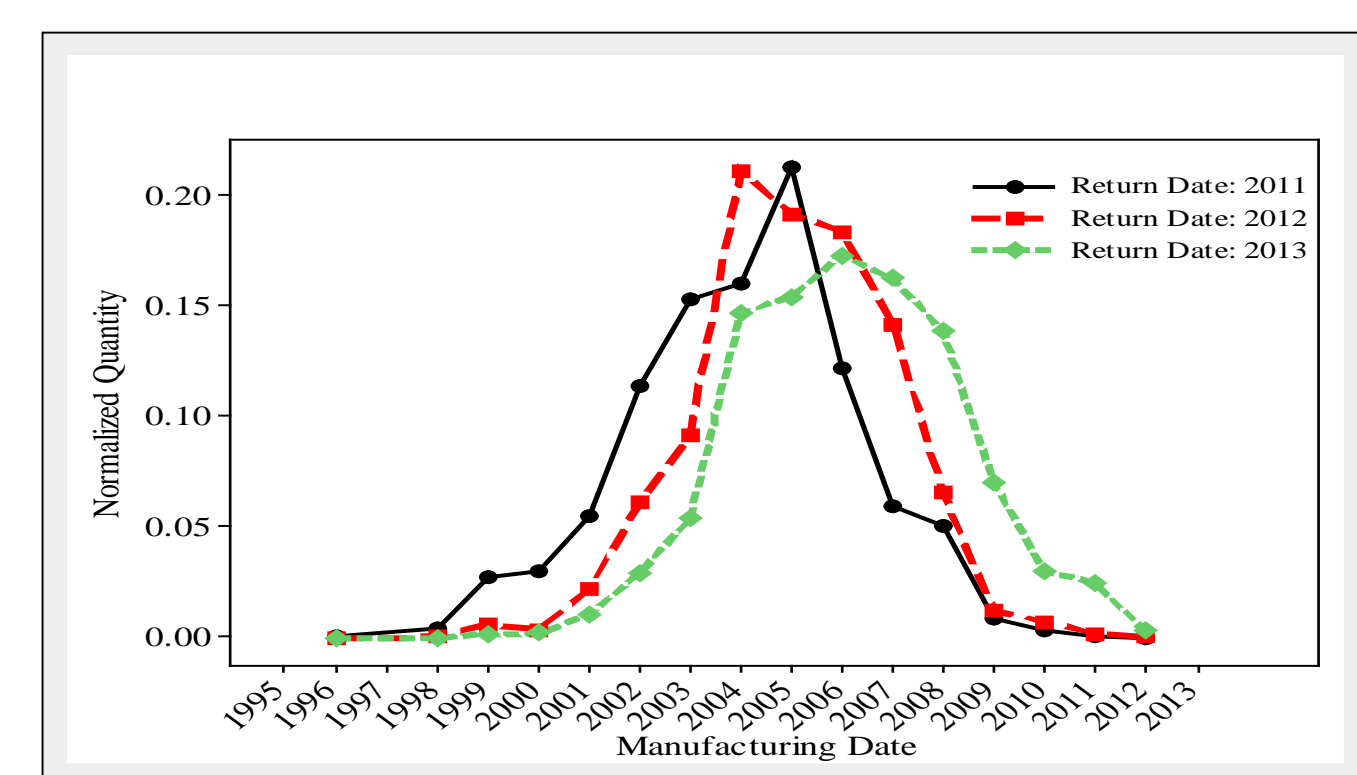


How long do people store their used electronics? How do they use their electronics?

- Q1:** What are the design factors underlying the consumer's product-storing behavior of end of use electronic devices?
- Method:** A dataset of 44,600 Hard Disk Drives (HDDs) gathered by our industry partner, PCRR, has been analyzed to study the effects of design characteristics, brand and consumer type on the electronics usage time and end of use time-in-storage.
- Q2:** What is the impact of customers' tendency to keep used items in storage on increasing the uncertainties in the waste stream?
- Method:** An agent based simulation model has been developed to predict customer choice decisions on returning used products (e.g. storage, resell, throw away, and return to the waste stream).
- Q3:** How to control the timing of end-of-use product return?
- Method:** A game theory model has been developed to define the level of monetary incentive that should be offered to consumers for a given design to reduce the product storing behavior.
- Q4:** What is the impact of design features and consumer usage behavior on the future reusability of a product?
- Method:** A dataset of 500 same-brand Lithium-ion laptop batteries collected from an all-girl high school located in Burbank, IL has been analyzed to study the impact of battery's technical characteristic and consumer's battery charging behavior on the future reusability of old Li-ion batteries.

What did we find from the industry datasets?

Consumers' Product-Storing Behavior

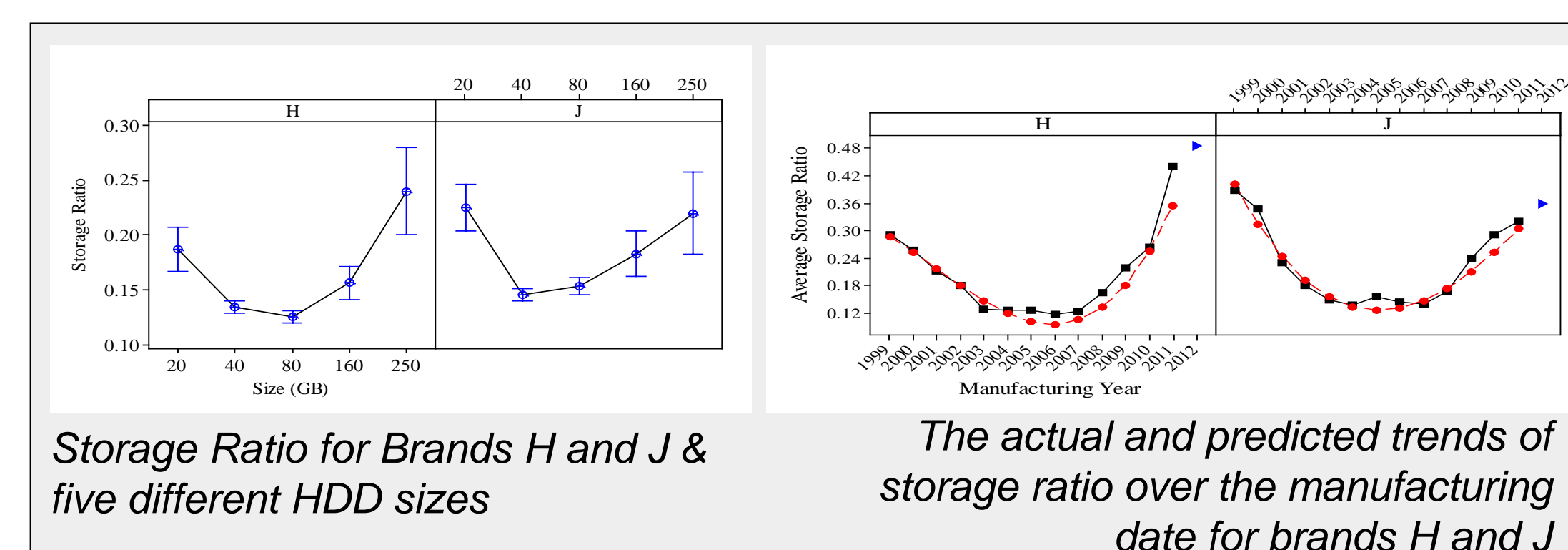
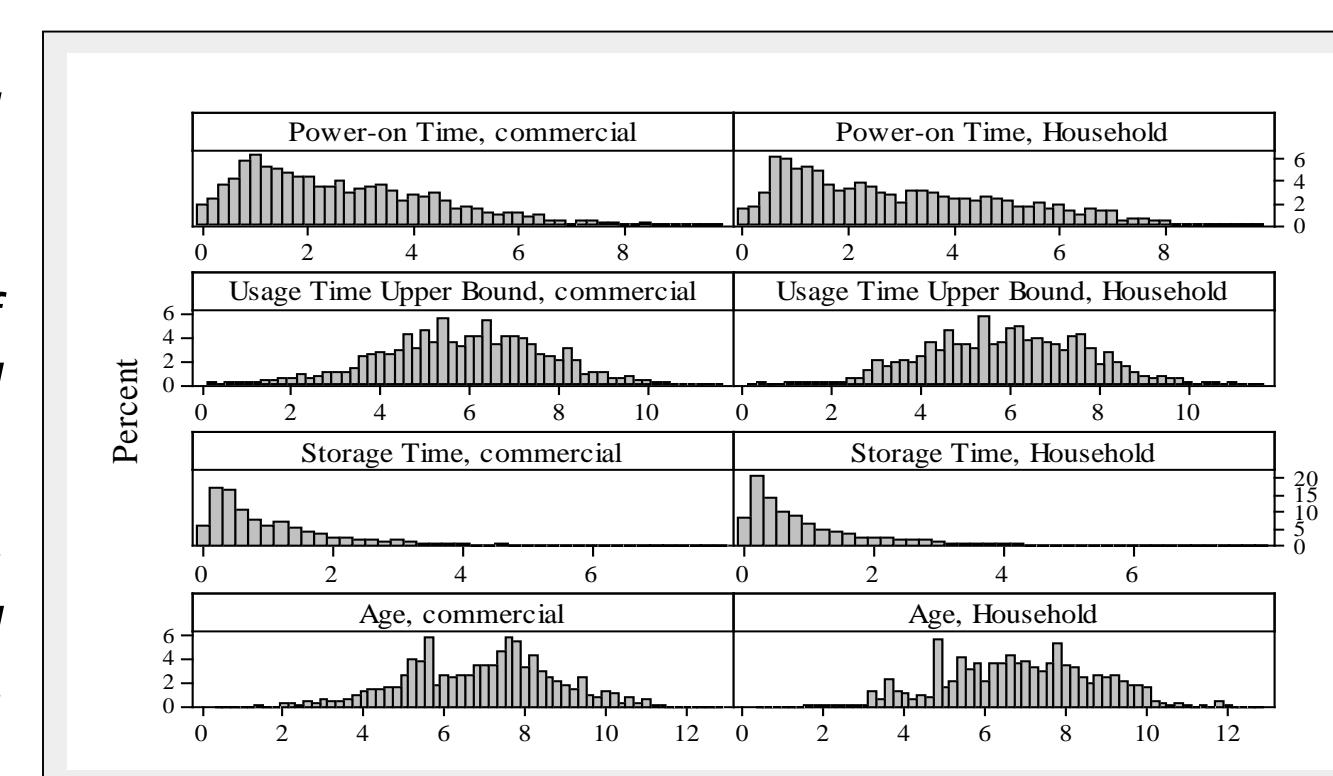


A dynamic behavior has been observed in the number of Hard Disk Drives (HDDs) manufactured in different years and donated to e-waste collection site in each return year (2011-2013).

The average Age of HDDs has decreased by %5.4 in three years from 7.2 years in 2011 to 6.8 years in 2013.

Distributions of HDDs lifespan characteristics including product age, storage time, usage time, and power-on hours for two groups of consumers, households and commercial consumers.

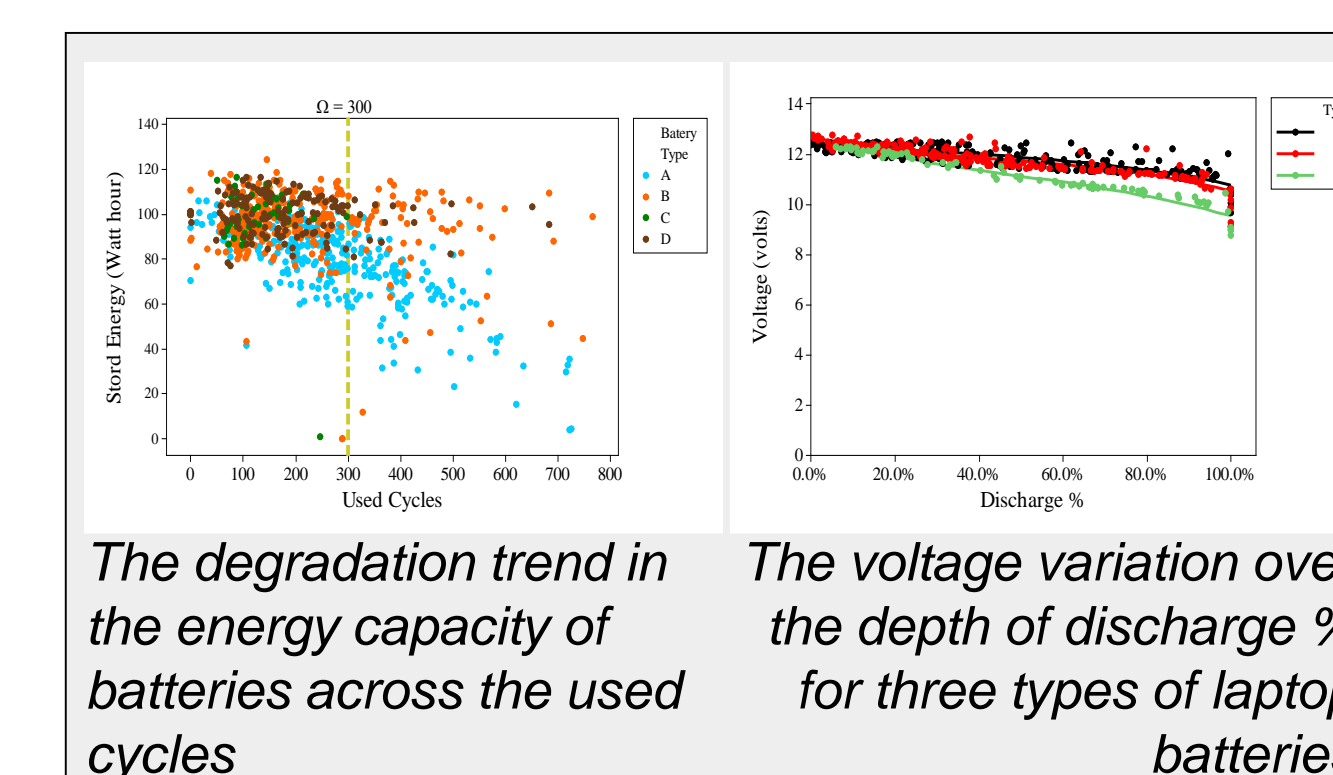
The average Age of HDDs is 6.9 years and consumers tend to store the unwanted HDDs for 1.1 years on average



Storage Ratio = Storage Time / Product Age

Commercial consumers have stored computers more than household consumers regardless of brand and size factors. Moreover, a homogenous storage behavior is observed for different brands of HDDs regardless of size and consumer type.

Consumers' Product-Usage Behavior

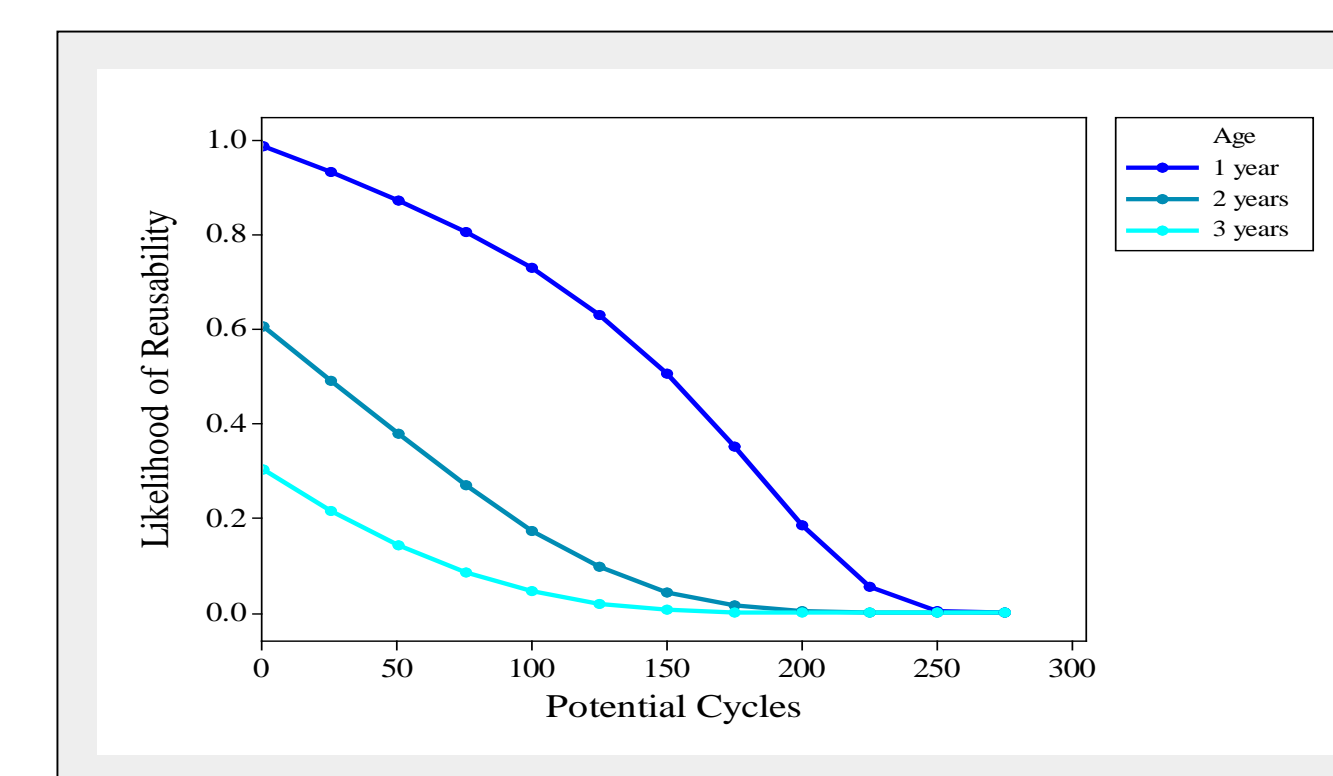


The degradation trend in the energy capacity of batteries across the used cycles

The voltage variation over the depth of discharge % for three types of laptop batteries

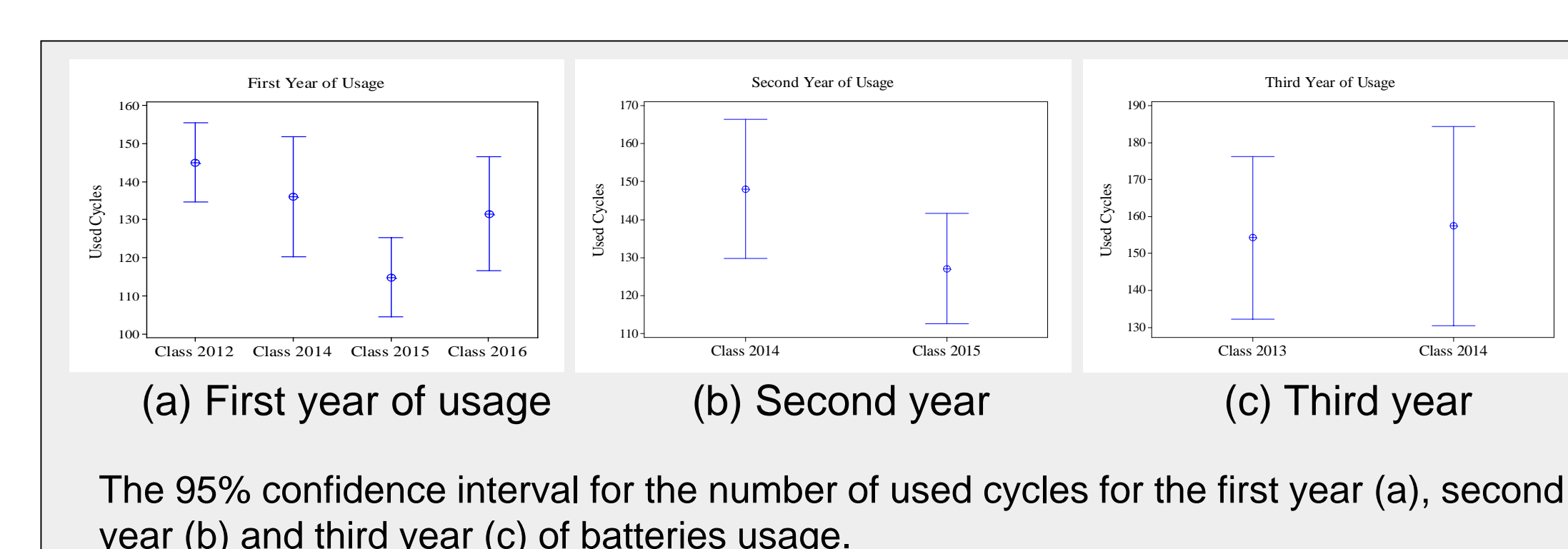
The laptop batteries' first 300 used cycles can be regarded as the stable lifetime before the performance drops significantly.

A decreasing trend in voltage has been observed for each type of batteries.



The reusability likelihood is computed for a 1-year, 2-year and 3-year old laptop battery.

For the 1st year of usage, the decreasing rate of reusability is not so high before 100 cycles (about 20%), so there is a high potential for reusing batteries.



How do students utilize their laptop batteries?

The number of battery's used cycles is analyzed for different classes of students (Class of 2011, 2012, 2013, 2014, 2015, and 2016) over three years of usage.

What do we recommend?

Consumers Product-Storing Behavior

- Consumers often have a tendency to store their used, old or unwanted electronics for a period of time before they discard them.
- The storage time can be predicted using machine learning methods. Consumer Type, Brand, Product Design Features (e.g. hard drive capacity), Actual Usage Time, Power-on Time and Manufacturing Date are predictors.
- Household consumers tend to keep electronic waste longer in storage when they use them less than the normal time. If the product Usage Time increases by 5%, then Storage Time is expected to decrease by 22%.

Consumers Product Usage Behavior

- The future reusability of a used battery depends on how the previous users have charged and discharged the battery.
- The reusability of a product is affected by the functional life of their components. The average usage time of computers (e.g. PCs and laptops) is reported as 5.85 years. With a normal lifetime of 3 years for batteries, it is evident that the chance of reusing laptops will be limited.

Role of Design and Consumer Behavior

Our contribution lies in understanding the role of product design and consumer behavior (e.g. product-storing behavior, utilization behavior) in generating e-waste.

Our Objectives

- Understand the role of consumer behavior and product design features on the uncertainties (e.g. quantity, quality, timing) in e-waste stream.
- Create a novel class of design evaluation techniques with the aim of creating designs that ensure long term solutions to control waste.

Acknowledgment

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GOAL: Remediating E-waste Problems by Considering Consumer Behavior in Design for Multiple Life Cycles and Design for Ease of Return



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References:

Sabbaghi, M., Esmaeilian, B., Raihanian, A., Behdad, S., Cade, W., 2014, An investigation of used electronics return flows: A data-driven approach to capture and predict consumers storage and utilization behavior, J. of Waste Management, doi:10.1016/j.wasman.2014.11.024.

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Feedback? Questions?

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