

論文の内容の要旨

論文題目 Environmental consequences of e-book reader:
implications of changing consumption pattern and consumer satisfaction
(電子書籍端末がもたらす環境波及効果-消費行動と消費者満足度の変化)

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The digitalization of media transfer through the use of information and communication technology (ICT), such as an electronic book reader (thereafter, e-book reader) has been promoted for environmental sustainability, because it has a potential to reduce environmental impact when substituted with traditional medium, such as paper. However, such claim is based on the assumption that the digital media entirely substitute paper media during consumption stage, where the product functions and conditions of use remain unchanged. In reality, ICT devices possess novel functions that they are not used in the same way as conventional media. Additionally, a change in consumer satisfaction with different medium is often neglected, even though it is a vital factor that determines retention and adoption of technology. In order to capture the environmental effectiveness of ICT for sustainable society in an extensive manner, such dynamic changes in the consumption pattern and consumer satisfaction induced by technology should be considered in the environmental impact assessment. The research objective of this doctorate research is to develop and examine environmental assessment methodology that quantifies the attributional (i.e. the lifecycle impact of the medium), consequential (i.e. changes in consumption pattern), and perceptual (i.e. changes in consumer satisfaction) effect of an e-book reader. As a final output, this research aims to map extensively considered environmental impact of an e-book reader as a quintessence of an ICT, which can be used to examine the current state and forecast future consequences.

This research integrated three major components as a mean to achieve the objective: life cycle assessment (LCA) of emerging technology, consumption pattern analysis, and analysis of consumer

satisfaction and experience. In the following paragraphs, methodology, results, and discussions of each study is discussed. The final paragraph describes the result of integrated discussion, which combined results of all three components to derive a sustainability implication of e-book readers. The study subject, an e-book reader, in this research considers a portable electronic device mounting e-ink display, which of its major function is to display digitally published books (i.e. e-books). This research focused on the consumers of the United States, where the e-book market is more matured than any other parts of the world.

Firstly, LCA of an organic light emitting diode (OLED) display for smartphones was conducted to formulate a methodology to estimate environmental impact of emerging technology. Currently, the lifecycle inventory (LCI) data of an e-book reader is nonexistent in a commercial LCI databases, and published literatures use limited data from lab-scale fabrication to estimate the environmental impact. As a mean to compose a method to collect and construct LCI of emerging technology, case study with OLED display for smartphones was conducted. The approaches for constructing inventories of chemicals and fabrication process involved manipulation of existing inventory with patents and stoichiometry, and application observed correlation between display area and production cost in the display industry. As a result, the environmental impact assessment outcomes communicate that integration of detailed material flow improves data representation of the production of complex chemicals. Additionally, environmental impact per one OLED display exhibited superiority in global warming potential (GWP), when compared with a previous study on a comparative size of liquid crystal display. The developed methodology is applicable for LCI data collection of an e-book reader.

Secondly, consumption pattern was analyzed to identify book reading activity that leads to environmental impact, to segment consumers based on reported patterns, and to examine the environmental impact from reading activity of the segmented groups. Literature review and interviews to e-book reader owners and paper book readers identified that major activities leading to environmental impact are the number of books acquired and the time spent on reading. A web survey was followed to collect data on the activities in the US, where 395 effective responses were acquired. Statistical analysis led to determine average consumption pattern of consumer groups segmented based on the ownership of an e-book reader. There was a general trend that e-book consumption is larger than paper book consumption, where consumers that read e-books buy and spend more time reading overall, and e-books and paper books were used in combination. The GWP of average annual reading demonstrated that ownership of tablet and e-book reader led to increased GWP relative to those without electronic devices,

owing to the embodied GWP of electronic devices and proliferated consumption of paper books. GWP of annual book reading activity per person-book shows that e-books can be more environmentally beneficial than paper books, but current trend suggests that e-book reader is backfiring on the environmental impact through aggravating overall book reading activity.

Thirdly, consumer experience in book reading was examined to identify functions of product influencing consumer satisfaction in book reading experience, and to quantify consumer satisfaction gained by different reading media. Voice of Customer (VOC) interviews to readers identified 11 functions in book reading activity, where e-book readers and paper books possess 10 and 6 of the functions respectively, and 5 functions are shared between them. Two methods were employed to compute consumer satisfaction from the products: Kano model and Likert scale. One advantage of Kano model is its capability to evaluate consumer satisfaction of consumers without the use experience of a product. As a result, comparison of original intent and favorable features on an e-book reader from VOC interview and quantified level of importance before and after Kindle Experiment revealed that use of e-book reader indeed change consumer perspective on general book reading, as well as temporal change associated with learning of the technology. Other than experience with an e-book reader, reading location was also found to influence satisfaction and importance. The product satisfaction of e-book reader and flexible e-book reader was greater than that of paper book, though inclusion of small yet important aspects of paper books that lead to satisfaction may be one reason behind the difference.

Lastly, integrated discussions were formulated through employing conceptual model of eco-efficiency. Environmental impact (i.e. GWP) from book reading activity was plotted against satisfaction gained from book reading activity. Two indicators of satisfaction from book reading were analyzed: the number of books bought and the number of hours spent on reading. As a result, because adoption of e-book reader is yet to result in full substitution of paper book consumption, both satisfaction and GWP increase positively with respect to consumers who are yet to adopt e-book reader. Consumption pattern of K_{out} (i.e. Kindle Users who read at home and outside) is hopeful for future outlook, as e-book consumption exceeds paper books, which results in reduced GWP and increased satisfaction. On the other hand, qualitative data from Kindle Experiment suggests that e-book reader does not act as an addition of book consumption, but rather as a substitution. Kindle Experiment result suggests that reducing GWP while increasing satisfaction is indeed plausible.

In summary, this research aims to examine environmental consequences of an e-book reader with a consideration of dynamically changing consumption pattern and consumer satisfaction. LCA, web

survey, and social experiment were carried out for data collection, and current results exhibit that an e-book reader may be backfiring the environmental impact through proliferating intensity of reading activity. Integrating environmental impact and consumer satisfaction revealed that adoption of e-book reader results in increased environmental impact and increased satisfaction, which is a rather unfavorable pattern relative to the current consumption pattern of paper books.