Causal Relationship between Smartphone Usage Behavior and Carbon Emission

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Abstract

The main purpose of this research was to study the causal relationship between smartphone usage behavior and carbon emission. The sample consisted of 400 students of Mahasarakham Rajabhat University during the second semester of the 2016 academic year. By means of structural equation modeling, it was revealed that behavioral usage of smartphones (BIS) was significantly influenced by factors of acquiring smartphones (FAS) and attitudes toward carbon emission of smartphone usage (ATE) for 45 percent. Moreover, both usage patterns of smartphones (UPS) and FAS influenced ATE significantly for 52 percent.

Key words: Receptive vocabulary size, vocabulary learning strategies, Thai business English students

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Introduction

Communication is important to human beings. Humans utilize communication in transmitting information and in order to be aware of current situations and changes in the world. Nowadays, communication technology is constantly evolving with the application of a number of communication devices, making communication borderless and highly effective. This is particularly the case with smartphones, which have become an integral part of everyday life, and the use of smartphones greatly affects the lifestyle of users. According to a survey in India, conducted by Ericsson (Ericsson, 2012), it was found that more than 80 percent of smartphone users were immersed with the information they gained from their smartphones to the extent that they spent less time with their families and acquaintances. In addition, more than a third of them admitted that they often forgot that there were people around when they were using their smartphones. This has caused widespread concern that if smartphones are developed to be more capable and more convenient to use, they may cause problems with regard to interpersonal interaction as well as keeping people excluded from their surroundings. This survey also dealt with differences in the way information was consumed by male and female smartphone users. It was revealed that males used map applications more frequently than females while considerably more females relied on chat applications and messaging services. In particular, female users spent 50 percent more hours playing games than male users (Mongkhonvanit, 2013).

The development of computer technology, electronic appliances, and devices, especially smartphones, has been a cause for concern in waste management as well as in recycling, in terms of the need to reduce environmental impact (Cleanriversstl, 2015) and the need to develop environmentally-friendly information technology products of "Green IT" (Khampachua, 2009).

Research Objectives

This research investigated the extent to which the use of smartphones could affect the environment, especially by producing carbon particles. More specifically, it aimed to build a causal model involving the factors of acquiring smartphones (PAS), usage patterns of smartphones (UPS), attitudes toward carbon emissions of smartphone usage (ATE), and behavioral usage of smartphones (BIS).

Literature Review

1. Carbon Footprint

Carbon footprint refers to the amount of greenhouse gases emitted by any product throughout the Life Cycle Assessment (LCA). This is calculated in the form of a carbon dioxide equivalent to the carbon footprint label that will be placed on products. This is to inform consumers that the Life Cycle Assessment of products will cause an impact on the environment. An LCA for carbon footprint, or CF, can be calculated to show the amount of carbon dioxide that occurs from the start to the end of the life of products or services. Any products which are low in carbon, compared to similar products, will be considered to be more effective and cause less impact related to greenhouse gases. In Thailand, the MTEC (the National Metal and Materials Technology Center), under the NSTDA (the Ministry of Science and Technology), has attempted to create a National Life Cycle Inventory Database which can be used for many products. There is also usage of Carbon Footprint Pilot Products in order to inform the public about the quantity of greenhouse gas emissions throughout the life cycle of those products. It is expected that carbon footprinting will help consumers in making purchase decisions and encourage entrepreneurs to make more eco-friendly technologies as well as increase competitiveness in the world market. There is a demand for imported products marked with a carbon footprint (Mungkung, et al., 2010).

Thailand's Greenhouse Gas Management Organization (Public Organization, 2016) defines the "carbon footprint of an organization" as the amount of greenhouse gases emitted by an organization's activities, such as combustion, fuel consumption, and electrical consumption.

2. Impacts of Information Technology

The impacts of information technology could be broken down into positive impacts and negative impacts (Information Technology Management, 2014).

2.1 Positive Impacts

1) Information technology improves the quality of human life and urban society with the development of telecommunication systems as well as convenient appliances for home use.

2) Information technology promotes social equality and opportunity distribution as it is spreading everywhere, even in rural areas.

3) There is use of information technology in teaching and learning in schools.

4) Much natural resource management, such as forest maintenance, needs the use of information technology.

5) Military operations also use information technology. Modern weapons as well as protection and surveillance systems rely on computers and control systems.

6) Information technology is used in management and in operations as well as in providing services to customers so that they can make purchases more conveniently.

7) Information technology is involved throughout everyday life in all walks of life.

2.2 Negative Impacts

1) Advances in information technology have resulted in big changes. People who cannot tolerate change will tend to get anxious and become stressed due to a fear that computers and information technology could cause them to be unemployed.

2) Information technology constitutes cultural reception and exchange, e.g., changes in the way people dress and changes in consumption.

3) Information technology can ruin the morality of society, and this tends to be quite significant, particularly for young people.

4) The use of information technology could result in people's lack of social participation and the likelihood of them staying at home or remaining at work.

5) Violations of personal freedom exist, caused by the dissemination of personal information or images, or both, to the public.

6) Information technology creates a social gap, with the poor being less likely to benefit.

7) Network crimes related to information technology could occur.

8) Information technology could cause health problems, e.g., staring at a computer screen for a long time has led to negative effects, such as eye disorders, vertigo, and mental illnesses.

3. Green Information Technology in the Present and in the Future

Green Information Technology (Green IT) has been developed to support and facilitate the efforts of its users to save money and energy. (Sureerattanan, 2010).

Since 2005, Dell has produced desktops that were 81 percent smaller than the mini-tower type, used up to as much as 70 percent less energy, and were encased with reusable materials. This has helped to save 2.2 billion US dollars and has reduced carbon dioxide emissions by 22.4 million tons. In addition, Dell has enacted policies to recycle computer devices worldwide. Michael Dell, Chairman and CEO of Dell, presented the idea that within ten years, Green IT would not only reduce the impact of climate variability but it would also strengthen industry around the world (Kachintorn, 2008).

Green IT is a management approach and an alternative designed to optimize management of power, reduce energy consumption and greenhouse gas emissions as well as reduce electronic waste. The ultimate goals are that all electronic devices must be reused, must not have any toxic components, and must be more efficient by requiring less power. The government issued the Energy Development and Promotion Act of 1992 and the 20-year Ministry of Energy Strategy (2011-2030) to promote the creation of alternative energy, including the adoption of green technology concepts for energy sustainability. At present, it is implemented by governmental and private sectors.

4. Evaluation of the Impact throughout the Life Cycle of Smartphone Production

Watokung (2016) mentioned that the smartphone, as a communicative device, had become the fifth necessity of modern human life. The smartphone was introduced after the launch of the iPhone, by Apple, which has since resulted in a revolution in communication. Smartphones have begun to replace older mobile phones, and they can perform very similarly to a computer. They could even be called a small computer.

It has been accepted that during the past few years, smartphone manufacturers have changed from being mobile phone manufacturers. The examples are Samsung, LG, China's Huawei, and Oppo. The competitive landscape of the smartphone market has become the battle of two regions, East and West.

Gartner, a leading US research and consulting company, collected data relevant to global smartphone manufacturers with sales growth in 2015 and in the first half of 2016. During that time, global smartphone sales figures rose to 344 million units. Table 1 represents the smartphone market shares in 2015 and 2016.

Table 1. Worldwide Smartphone Sales to End Users by Vendors in 2016 (Thousands of Units)

Company	2016 Units	2016 Market Share (%)	2015 Units	2015 (Market Share (%)
Samsung	76,743.5	22.3	72,72.5	21.8
Apple	44,395.0	12.9	48,085.5	14.6
Huawei	30.670.7	8.9	26,454.4	8.0
Oppo	18,489.6	5.4	8,073.8	2.4
Xiaomi	15,530.7	4.5	15,464.5	4.7
Others	158,530.3	46.0	160,162.1	48.5
Total	**344,359.7**	**100.0**	**330,312.9**	**100.0**

Source: Gartner (2016)

Gartner also found that the sales figures of Apple fell in several regions around the world—in the United States, Europe, China, and the Asia Pacific region. Except for the Eurasia region, Central Africa, and Eastern Europe, its sales have continued to grow. The matter to be pointed out is that Chinese smartphone manufacturers have risen to the top five in sales, with brands such as Huawei, Oppo, and Xiaomi, becoming more popular. This is due to the added functions, such as image stabilization and quick-charging technology. Each brand has conducted a carbon footprint assessment in order to evaluate the environmental impact throughout the life cycle of the smartphones as follows:

1) Samsung

Samsung, a Korean company, made a life cycle assessment of its smartphone products in 2016. The highest carbon emission rate found in the pre-manufacturing process was 52.6 percent, followed by the distribution process, or transportation process, at 23.9 percent, and the smartphone use which had a carbon emission rate of 15.7 percent.

2) Apple

Apple, an American company, made a life cycle assessment of its smartphone products in 2015. The highest carbon emission rate found in the manufacturing process was 77 percent, followed by the product using rate of 17 percent, and the transportation process rate of 4 percent.

3) Huawei

Huawei, a Chinese company, made a life cycle assessment of its smartphone products in 2016. The highest carbon emission rate found in the usage process was at 9.48 percent, followed by the manufacturing and assembly process with 9.19 percent, and the transportation process with a rate of 0.28 percent.

Based on the Life Cycle Assessment reports of these three smartphone manufacturers, it can be seen that the highest carbon emission process is during manufacturing, followed by usage and transportation.

Conceptual Framework

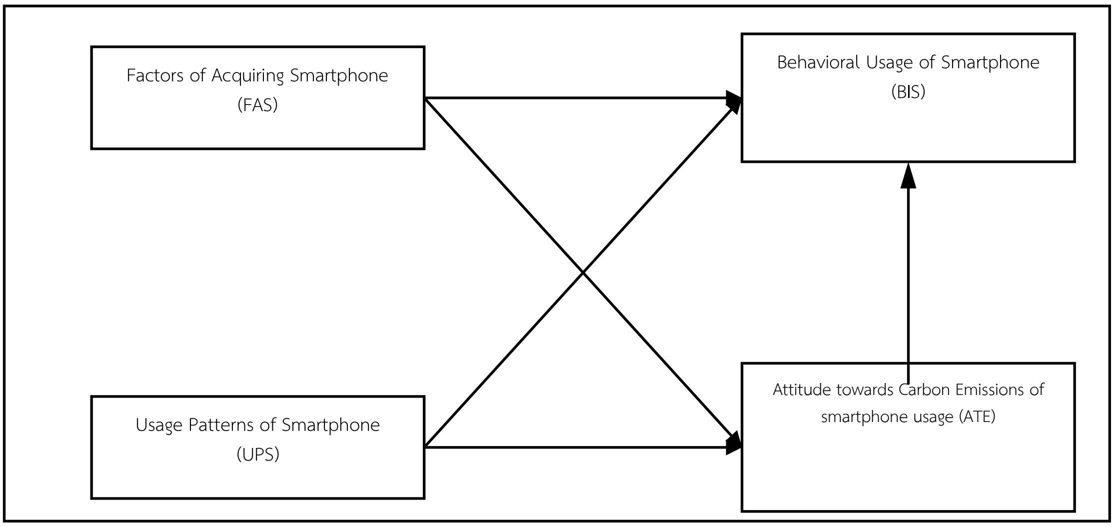

Figure 1. Research Framework of Causal Relationships among FAS, UPS, ATE and BIS.

Table 2. Definition of Latent Variables

Variable	Definition
FAS	Factors of Acquiring Smartphone
UPS	Usage Patterns of Smartphone
ATE	Attitude towards Carbon Emissions of Smartphone Users.
BIS	Behavioral Usage of Smartphone

Methodology

1. Population and Sample

The population totaled 7,501 undergraduate students in the regular program at Mahasarakham Rajabhat University during the second semester of the 2016 academic year (The Registrar, 2017).

The sample of 400 students was selected by multistage random sampling technique, calculated with Yamane's formula, yielding the confidence co-efficiency of 95 percent (Yamane, 1973).

2. Research Tools

2.1 The questionnaire was composed of five sections, i.e., the demographic features, the attitude of the and questions pertaining factors of acquiring smartphone, smartphone usage patterns, attitude towards carbon emissions of smartphone users, and behavioral usage of smartphone.

2.2 Assessment of Research Tools

The assessment procedure was as follows:

1) Reviewing the basic principles and the research related to smartphone buying factors, smartphone usage patterns, attitude towards carbon emissions, and behavioural usage of smartphone.

2) Setting and writing definitions of terms and attributes, using features from other research and various sources.

3) Creating the questionnaire as follows:

3.1 Smartphone purchase factors = 30 items

3.2 Smartphone usage pattern = 35 items

3.3 Attitude towards carbon emissions = 15 items

3.4 Behavioral usage of smartphone = 25 items

4) Submitting the updated questionnaire to experts for content validation, structural integrity, language accuracy, and the appropriateness of the content in order to find the IOC—Index of Objective Congruence (Rovinelli and Hambleton, 1977). Questions that had a consistency index between 0.6-1.00 were selected for use.

5) Administering the updated questionnaire with 50 undergraduate students of Sripatum University, who were not the actual sample, to find reliability, using the alpha coefficient (α-Coefficient), according to Cronbach's method. The Cronbach’s alphas of the questionnaire are shown in Table 3.

Table 3. Cronbach’s Alphas of the Questionnaire on FAS, UPS, ATE and BIS.

Questions	Cronbach’s Alpha
Factor of Acquiring Smartphone (FAS)	0.796
Usage Pattern of Smartphones (UPS)	0.662
Attitude towards Carbon Emissions (ATE)	0.889
Behavioral Usage of Smartphone (BIS)	0.874
Total	**0.907**

3. Data Collection

The researchers collected data using the questionnaire, completed by the undergraduate students of Mahasarakham Rajabhat University, as follows:

3.1 The researcher and the research assistant distributed the questionnaires directly, allowing the respondents a period of one week.

3.2 The researcher and the research assistant examined the returned questionnaires and the completeness of the questionnaires. Also, the data was categorized so that they could be analyzed purposefully.

3.3 The data was then analyzed statistically.

4. Data Analysis

4.1 Descriptive statistical analysis such as frequency distribution, percent, mean, and standard deviation were used for descriptive purposes.

4. The LISREL Program for Windows Version 8.3 was used for hypothesis testing and causal relationship. (Joreskog and Thillo, 1972; Joreskog and Sorborn, 1981).

Results of the Research

1. Demographic Features

The majority of the sample used was women (71.00 percent). Most of the students in the sample were first-year undergraduate students (31.75 percent), followed by third-year undergraduate students (27.25 percent)—most of whom were students from the Faculty of Education (24.50 percent)—followed by students from the Faculty of Science and Technology (19.25 percent). In addition, the respondents were between 18 and 24, with the average age of 20.48 (SD = 1.29). The details are shown in Table 4.

Table 4. Demographic Features

Demographic Features	Numbers N	Percent %
Gender		
Male	116	29.00
Female	284	71.00
Total	400	100.00
Age Min. 18 years old, Max. 24 years old, Average ($\bar{X}$)= 20.48 SD = 1.29		
Class		
Year 1	115	28.75
Year 2	102	25.50
Year 3	95	23.75
Year 4	76	19.00
Year 5 (5 - year curriculum)	12	3.00
Total	400	100.00

Table 4. (continued)

Demographic Features	Numbers N	Percent %
Faculty		
Faculty of Education	58	14.50
Faculty of Science and Technology	57	14.25
Faculty of Management Science	57	14.25
Faculty of Agricultural Technology	57	14.25
Faculty of Humanities and Social Sciences	57	14.75
Faculty of Information Technology	57	14.25
Faculty of Law and Government	57	14.25
Total	400	100.00

Table 5. Direct Effect (DE), Indirect Effect (IE) and Total Effect (TF) among FAS, UPD, ATS and BIS.

Causes	Effects					
	ATE			BIS		
	TE	IE	DE	TE	IE	DE
FAS	-0.09	-	-0.09	0.13**	0.03	0.10**
	(0.08)		(0.08)	(0.035)	(0.045)	(0.051)
UPS	0.74*	-	0.74*	0.51**	0.21**	0.30**
	(0.085)		(0.85)	(0.056)	(0.058)	(0.064)
ATE	-	-	-	0.28**	-	0.28**
				(0.041)		(0.041)
χ^2 = 162.19; df = 96; CN=245.15		P = 0.00000		χ^2/df = 1.690		
GFI = 0.95 ; AGFI = 0.92		RMSEA = 0.045		RMR = 0.040		

From Table 5, it was found that the Linear Structural Relationship of the proposed model was in accordance with the empirical data, since chi-square values divided by degrees of freedom (χ^2/df) was less than 5 (χ^2/df = 2.11), Goodness of Fit Index (GFI) and the Adjusted Goodness of Fit Index (AGFI), being 0.95 and 0.91, respectively. Moreover, Critical N (CN) that equaled 245.15, which was higher than

200, indicating that the model was consistent with the empirical data.

Figure 2. depicts causal relationship among the latent variables as represented by their respective observable indicators.

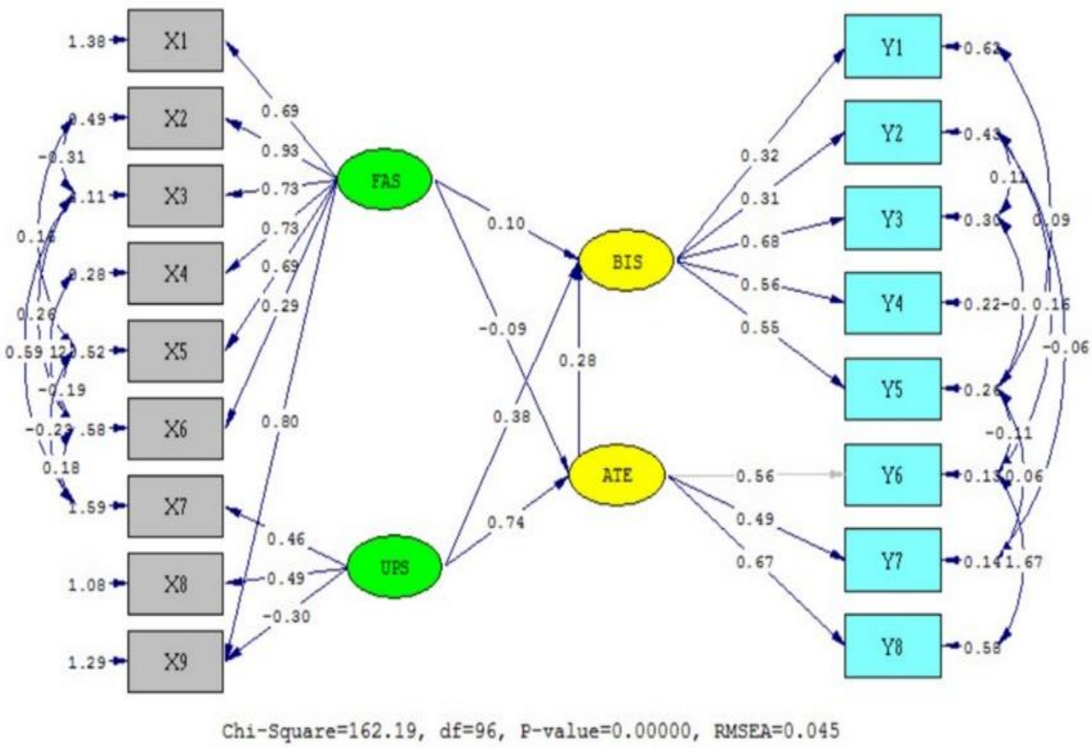

Figure 2. The Causal Relationship among FAS, UPS, ATE and BIS.

From Figure 2, the results of the causal analysis were as follows:

1. Direct influence of FAS on ATE was not statistically significant, whereas its direct influence on BIS was not statistically significant either. But its indirect influence on BIS was statistically significant at 0.01, with the effect value being 0.28.

2. Direct influence of UPS on ATE was statistically significant level at 0.05, with the effect value being 0.74. In addition,UPS directly influenced BIS was not statistically significant at 0.05. It also had an indirect influence on BIS, with the effect value being 0.28.

3. ATE had a direct influence on BIS statistically significant at 0.01, with the effect value being 0.28.

Equation (1) demonstrates that BIS was significantly dependent upon ATE, FAS and UPS at p = 0.05. all the independent variables accounted for 45 percent variance in BIS.

BIS = 0.28*ATE + 0.10*FAS + 0.30*UPS..(1)

$R^2 = 0.45$

The structural equation in which ATE was the dependent variable whereas UPS and FAS were independent variables is presented below:

ATE = -0.09*UPS +0.74*FAS ....(2)

$R^2 = 0.52$

Equation (2) reveals that ATE was significantly dependent upon UPS and FAS at $P \leq 0.05$, and both of which accounted for 52 percent variance in ATE.

Discussion

The results of the study were in accordance with the results of the study by Sangkaew (2016), who studied the environmental conservation knowledge and the environmental education affecting conservation behavior of lower secondary school students and their inspiration for public mind. The research found that the inspiration for public mind had the greatest influence on the ecological and environmental conservation behavior at 0.78, followed by the environmental education and the ecological and environmental conservation knowledge at 0.29 and 0.27, respectively. In addition, the results of this study were consistent with the results of the study by Jumrearnsan, et al., (2012) who studied the structural relationship between psychological factors and the environment. The study was aimed at undergraduate students of Mahasarakham University. The results showed that the factors that influenced environmental conservation behavior to reduce global warming the most was environmental education, followed by the inspiration for public consciousness, situational consciousness, and original consciousness respectively. These four components could explain the variance of environmental conservation behavior to reduce global warming at 84.00 percent.

Recommendations

Smartphone usage is likely to increase, and smartphones will continue to play a role in almost every human activity, which can also lead to higher carbon emissions. Therefore, the effort to have smartphone usage behavior towards environmental sustainability should be seriously taken into consideration. There should be encouragement to enhance knowledge on natural conservation, using the media, An attempt should be made through all channels of mass media to reach all levels of users to strengthen the knowledge and awareness of both direct and indirect impacts of smartphones on the environment. This will lead to the prevention and resolution of the current problems and those that could arise in the future.

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