APPLICATION OF TECHNOLOGY ACCEPTANCE MODEL TO INVESTIGATE INFLUENTIAL FACTORS ON STUDENTS' INTENTION TO USE CARBON FOOTPRINT CALCULATOR

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ABSTRACT
Carbon footprint calculator (CFC) is a tool for people to know the carbon emissions generated by their activities. If more and more people use the CFC to manage and control their carbon emissions, global warming problem might be eased. This study applied persuasive technologies to build a new CFC to improve the ease-of-use and the usefulness of existing CFCs. A survey was conducted to first assess the significance of the improvement, and afterwards, grounded on the Technology Acceptance Model, to investigate the potential factors that affect a student’s intention to use CFC. Investigation results indicated that the application of persuasive technologies significantly increased the levels of students’ perceived ease-of-use and perceived usefulness of CFC. Moreover, students’ environmental awareness was positively and significantly related to their perceived usefulness of CFC, attitude toward using CFC and intention to use CFC. The ease-of-use of CFC positively and significantly affected students’ perceived usefulness. Students’ perceived usefulness and attitude had a positive and significant effect on their behavioral intention. To motivate students to use CFC, this study recommends the application of persuasive technologies to improve the existing CFCs and the development of educational programs enhance students’ environmental awareness.

Keyword: Carbon footprint calculator, Persuasive technologies, Technology Acceptance Model
INTRODUCTION

During the past decade, extreme weather phenomena have lead to inestimable economic losses around the world. IPCC (Intergovernmental Panel on Climate Change), based on its long-term observations on the Earth changes, pointed out that global warming is the main cause of the extreme weather phenomena and the continuous global temperature rise is majorly contributed by the observed increase in anthropogenic greenhouse gas (GHG) concentrations (IPCC, 2007).

To reduce global GHG concentrations and then to protect the climate system for the benefit of present and future generations, some international and domestic actions are taken around the world. For example, the United Nations Framework Convention on Climate Change (UNFCCC) initialized the Kyoto Protocol in 1997 and launched it in 2005. The 193 signatories, under the Kyoto Protocol, agreed to reduce their collective emissions of GHG by 5.2% compared to the year 1990 between 2008 and 2012.

Carbon emission reduction in recent years has received considerable attention (Edwards, 2007; Ferrari, 2009; Goodall, 2007; Mooney, 2009; Yuana, Zhou, & Zhou, 2011). A great number of studies urged on people the importance of carbon emission reduction (Cossham, 2009; IPCC, 2007; Islam, 2010; Roosa & Jhaveri, 2009). Reducing carbon emission is more than just an issue at national or international level. It’s everyone's responsibility. If people have proper environmental awareness, attitude, behavior and practice toward our living environment, environmental degradation will be prevented.

In the last decades, ICT (Information and Communication Technology) has made remarkable advances in supporting people to protect environment. Using ICT, Zapico, Turpeinen and Brandt (2009) promoted the concept of “climate persuasive services” and Kosugi (2009) developed an integrated approach for organizations to set GHG emission targets. Moreover, “Scorecard.org” uses persuasive technologies to motivate people to be pro-environmental (King & Tester, 1999), in which the persuasive technologies are interactive products designed to change the user’s attitude or behavior or both by making desires and outcomes easier to achieve (Fogg, 2003). In addition, various organizations, World Wildlife Fund (WWF) for example, have developed many ICT-based Carbon Footprint Calculators (CFCs) for use by individuals to determine their daily carbon emissions. Padgett, Steinemann, Clarke, and Vandenerbergh (2008) and Rahman, O'Brien, Ahamed, Zhang, and Liu (2011) expressed their opinions that despite inconsistencies, the existing CFCs were critical in reducing carbon emissions. That is, motivating individuals to use CFC to manage and control their personal carbon emissions is a potential way to solve the global warming problem. Unfortunately, most existing CFCs provide inconvenient user
interaction interface, which lead to poor user experience (Rahman et al., 2011). Besides, those CFCs provide simple functions and limited information about the calculation results. As a result, it is difficult to attract people to constantly use those CFCs.

This study applied persuasive technologies to build a new student-centered CFC to improve the ease-of-use and the usefulness of CFC. A survey was afterwards conducted to achieve the following objectives.

(1) Assess the significance of the improvement made by the application of persuasive technologies to the design of CFC (called CFC+ in this study).
(2) Identify factors that affect a student’s intention to use CFC and investigate the relationships among the factors. The factors are a student’s environmental awareness and the factors in TAM, including perceived ease-of-use and perceived usefulness, attitude toward using, and intention to use.
(3) Propose suggestions to increase students’ intentions to use CFC.

The rest of this paper is organized as follows. Section 2 reviews the relevant literatures. Section 3 introduces the framework of the CFC+. Section 4 demonstrates the research models and develops research questionnaire, and Section 5 conducts a survey, analyzes collected data and discusses the results. Section 6 draws conclusions and recommends directions for future research.

LITERATURE REVIEW

Previous researches related to this study, including carbon footprint calculator, persuasive technology, environmental awareness and Technology Acceptance Model (TAM), are reviewed in this section.

Carbon Footprint Calculator

Carbon footprints have been multiply defined from various perspectives to identify causes of climate change. The British Petroleum Company (2005) defined the personal carbon footprint as the amount of carbon dioxide that is emitted by a person’s daily activities. Cleveland and Morris (2009), in their published dictionary, defined the human carbon footprint as the total amount of GHG that is generated to directly and indirectly support human activities. The Carbon Trust (2007) defined a product’s carbon footprint as a metric of GHG emissions from each activity within a supply chain process. Wiedmann and Minx (2008) defined it as the total amount of carbon dioxide emissions that is directly or indirectly produced by an activity or is accumulated over the life stages of a product. In summary, carbon footprints are measured at various levels, including the country, city, locale, business, product, and individual.
Individuals are the leading causes of environmental pollution (Vandenbergh, 2005). Bin and Dowlatabadi (2005) noted that in the US, more than 80% of CO₂ emissions are driven by consumer demand and economic activities. Vandenbergh and Steinemann (2007) developed a model to demonstrate that individuals contribute roughly one-third of the carbon dioxide emissions of the United States.

Typically, a person’s carbon footprint is associated with the use of a car, public transportation, electricity, clothes and personal items, heating and cooling, as well as by eating and drinking, and recreational activities. The variation among individuals derives largely from variations of lifestyle and location (Jones & Kammen, 2011). A UC Berkeley Newsletter stated that everyone has a unique carbon footprint and no one-size-fits-all set of actions should be taken by all people. Recognition of individual variations in values, attitudes, beliefs, habits and abilities is critical to the implementation of emission reduction measures (Sanders, 2011). Accordingly, understanding of the distribution of personal carbon footprints can be helpful in developing carbon reduction strategies.

A small shift in individual behavior can result in significant emission reductions if people can be self-managed (Jones & Kammen, 2011; Vandenbergh & Steinemann, 2007). The identification of carbon footprint reduction opportunities has attracted interest. Dandeneau conducted the ConservED project to help homeowners change behaviors that involve energy use, transportation, consumption and waste by providing educational programs (Edwards, 2007). Goodall (2007) elaborated the idea of living a low-carbon lifestyle and guided people toward a sustainable low-carbon society. Many online carbon footprint calculators have recently been developed to help individuals calculate their personal carbon footprints and estimate equivalent carbon emissions.

CFC is a software application used to calculate the contribution that a particular operation or activity makes to total carbon dioxide output. Many CFCs, such as those of the WWF (http://footprint.wwf.org.uk/) and Carbon Footprint Ltd (http://www.carbonfootprint. com/calculator.aspx), are available on the Internet. Using CFC is a pro-environmental behavior which plays a fundamental role in reducing carbon emission through individual behavior changes (Padgett, et al., 2008). However, the poor user interface and limited information provided by the existing CFCs might prevent people from using them. Consequently, how to increase people’s intention to constantly use CFC is a problem and has not yet been investigated.

**Persuasive Technologies**

Persuasion is an interactive process by which people influence others through communications. Simon (1976) defined the persuasion as the human communication
designed to influence others by modifying their beliefs, values, or attitudes. Miller (2009) considered the persuasive communication as any message intended to shape, reinforce, or change the responses of others. O’Keefe (2002) shared his observations on the persuasions and concluded that the features of a successful persuasion includes: (1) persuasion goal, (2) intention to reach the persuasion goal, (3) persuadee's free will, (4) persuader's communication with the persuadee, and (5) a change in the mental state of the persuadee. Kenzie (2009) reviewed 15 persuasion theories and categorized these theories into six models, message effects, attitude-behavior approaches, cognitive processing, consistency, inoculation, and functional approaches, which allow practitioners to employ appropriate persuasive strategies.

With the rapid development and growing pervasiveness of information technology, using computer as the persuasive tool in the past decade has been gaining great success in many fields, especially in the marketing, health, safety and environment. “Scorecard.org” for example is a typical application of persuasive technology that provides information about local community pollution and motivates people to take actions (King & Tester, 1999). Persuasive technology is an interactive product designed to change attitude or behavior or both by making desires and outcomes easier to achieve (Fogg, 2003). Fogg in 1996 first coined the term Captology that stands for Computer As Persuasive Technology (Wikipedia, 2012). Captology is a study of the design, research, and analysis of interactive computing products created for the purpose of changing people’s attitudes or behaviors (Fogg, 2003). Fogg (2003) identified seven types of persuasive technologies as shown in Table 1. The technologies have great possibility to enhance the ease-of-use and usefulness of CFCs and then encourage people to use them. In this study, contribution of the persuasive technologies made to CFC was going to be evaluated.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction</td>
<td>Making target behaviors easier by reducing a complex activity to a few simple steps.</td>
</tr>
<tr>
<td>Tunneling</td>
<td>Leading users through a predetermined sequence of actions or events, step by step.</td>
</tr>
<tr>
<td>Tailoring</td>
<td>Providing information relevant to individuals to change their attitudes or behaviors or both.</td>
</tr>
<tr>
<td>Suggestion</td>
<td>Suggesting a behavior at the most opportune moment.</td>
</tr>
<tr>
<td>Self-monitoring</td>
<td>Allowing people to monitor themselves to modify their attitudes or behaviors to achieve a predetermined goal or outcome.</td>
</tr>
<tr>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Surveillance</td>
<td>Allowing one party to monitor the behavior of another to modify behavior in a specific way.</td>
</tr>
<tr>
<td>Conditioning</td>
<td>Using principles of operant conditioning to change behaviors.</td>
</tr>
</tbody>
</table>

**Environmental Awareness**

Environmental awareness (EA) is an understanding of the impact made by human behavior on the environment (Kollmuss & Agyeman, 2002). Zsóka (2005) extended the EA definition into five components: ecological knowledge, environmental values, environmental attitudes, willingness to act, and actual behavior. Prior studies indicated that people having more EA would behave more pro-environmentally (Gatersleben, Steg, & Vlek, 2002; Madsden, 1996; Schmidt, 2007). Palmer (1998) believed that people should acquire appropriate EA so that they can make suitable judgments for their activities. However, the above-mentioned results were inconsistent with those acquired by Csutora (2012), Kollmuss and Agyeman (2002), Bratt (1999) and Wiidegren (1998). These arguments lead to an assessment of whether the environmental awareness affects an individual’s intention to use CFC.

**Technology Acceptance Model (TAM)**

Technology Acceptance Model (TAM) was proposed based on the Theory of Reasoned Action (TRA) by Davis in 1985. TRA, created by Fishbein and Ajzen (1975), was first developed to study the effects of behavioral intention, attitude, and subjective norms on an individual’s actual behavior. In TRA, the strength of behavioral intention is affected by one’s attitude toward that behavior and the subjective norms that impact a person’s thought patterns as follows: $BI = A + SN$ (Paladino & Ng, 2012). Attitude consists of beliefs with the consequences of performing a behavior multiplied by an evaluation of consequences (Fishbein & Ajzen, 1975).

TAM is a well-known model widely used in identifying the determinants of IS/IT adoption and is a model that has been empirically proven to have high validity (Kim, 2008). During the last decades, TAM has been used to study the acceptance of a great variety of technologies, such as m-banking (Lule, Omwansa, & Waema, 2012), e-books (Tsai, 2012), smart power meters (Kranz, Gallenkamp, & Picot, 2010), and course management system (Sivo & Pan, 2005). In TAM, influential factors of an individual’s technology acceptance are identified to explain how the factors correlate with each other impact his/her actual use of a technology in a given context. Those factors are users’ perceived usefulness (PU), perceived ease-of-use (PEOU), attitude (AT) and other external variables. Davis (1989) defined PU as "the degree to which a
person believes that using a particular system would enhance his/her job performance” and PEOU as “the degree to which a person believes that using a particular system would be free of effort.” On the other, AT consists of beliefs with the consequences of performing a behavior multiplied by an evaluation of consequences (Fishbein & Ajzen, 1975). TAM assumes that PEOU affects PU, PEOU and PU affect AT, PU and AT affect BI and BI affects actual behavior. Based on empirical results, Davis, Bagozzi, and Warshaw (1989) found that AT only partially mediated the effects of PEOU and PU and therefore omitted this construct from the original TAM. However, many recent studies build their research models upon the original model (Kranz et al., 2010).

Grounded on TAM and literature analysis, Venkatesh and Davis (2000) proposed TAM2 (Technology Acceptance Model 2), which predicts and explains user acceptance in terms of social influence process (including subjective norm, voluntariness, and image) and cognitive instrumental process (including job relevance, output quality, result demonstrability, and perceived usefulness). Moreover, Venkatesh, Morris, Davis, and Davis (2003) developed another model UTAUT (Unified Theory of Acceptance and Use of Technology), which integrates four key constructs to directly predict user intention to adopt technologies and four variables to mediate the impact of the four key constructs. The four key constructs are performance expectancy, effort expectancy, social influence and facilitating conditions; the four variables are gender, age, experience, and voluntariness of use.

The common statistical methodologies of TAM analysis are (1) SEM, (2) Partial Least Square, (3) Confirmatory Factor Analysis (CFA), (4) Regression Analysis and (5) Multivariate Analysis of Variance (MANOVA). SEM is the most commonly used method in TAM analysis (Aggorowati, Suhartono, & Gautama, 2012).

This study applied TAM to investigate the determinants of a student’s intention to use CFC, which have never been discussed to date. This study assumed that the application of persuasive technologies and environmental awareness were additional influential factors of TAM and tested the impacts of the factors on students’ intention.

**CARBON FOOTPRINT CALCULATOR WITH PERSUASIVE TECHNOLOGIES (CFC*)**

This study applied persuasive technologies to construct a new carbon footprint calculator (CFC*). The CFC* helps students do the following duties. (1) Estimate their personal carbon footprint corresponding to the critical activities of ranging from campus living, family living, transport usage, dining, and waste disposal to waste recycle. (2) Know their proportions of personal daily carbon footprints. (3) Monitor the tendency of their personal carbon emissions. (4) Compare their own carbon
footprints with others’, and (5) Obtain simple customized persuasive messages on reducing and controlling carbon emissions. In CFC+, the persuasive technologies were used to enhance the usefulness and ease-of-use of the typical CFCs to increase students’ intention to use the system and then, students can do self-reflections to change their behaviors toward carbon reduction, reduce their personal carbon emissions, and reinforce their low-carbon behaviors.

**Application of Persuasive Technology**

The system design strategies according to Fogg’s persuasive technologies were formulated as shown in Table 2.

<table>
<thead>
<tr>
<th>Type</th>
<th>Design strategy</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction</td>
<td>(1) Simplify a student’s daily activities into critical question items, in which a student can quickly describe his/her daily activities. (2) Provide slide bars for students to easily and conveniently input the scale value of every question item.</td>
<td>Enhance PEOU</td>
</tr>
<tr>
<td>Tunneling</td>
<td>Guide students to input the scale values of their activities from one construct to another, step by step.</td>
<td>Enhance PEOU</td>
</tr>
<tr>
<td>Tailoring</td>
<td>Provide students the following personal information: (1) Daily carbon emissions. (2) Major activity items contributing most to the carbon footprints. (3) Past carbon footprint records. (4) Tendencies of carbon footprints. (5) Average carbon footprints in each construct.</td>
<td>Enhance PU</td>
</tr>
<tr>
<td>Suggestion</td>
<td>Provide a short message as the suggestions for students to reduce and control their carbon emissions.</td>
<td>Enhance PEOU and PU</td>
</tr>
<tr>
<td>Self-monitoring</td>
<td>Provide students the following personal information to monitor themselves: (1) Past carbon footprint records.</td>
<td>Enhance PU</td>
</tr>
<tr>
<td>Type</td>
<td>Design strategy</td>
<td>Goal</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Surveillance</td>
<td>Provide students bar chart about the comparison between the student and the others’ average daily carbon footprints in each construct.</td>
<td>Enhance PU</td>
</tr>
<tr>
<td>Conditioning</td>
<td>Use encouragement messages for students to reinforce their low-carbon behaviors.</td>
<td>Enhancing PU</td>
</tr>
</tbody>
</table>

**System Framework**

The proposed CFC⁺ was integrated four modules – one for data storage, a carbon footprint calculator, an analysis tool, and one for presenting analysis results and giving personalized advices about carbon reduction. The carbon footprint calculator and presentation modules were designed with built-in persuasive technologies to interact and communicate with the system users. Figure 1 presents the system framework.

In Fig. 1, the data storage was designated (1) to maintain user accounts to verify the students’ personal identities; (2) to provide the GWP (global warming potential) coefficients for the calculation tool to estimate the carbon emission of the students’ daily activities; (3) to manage the students’ profiles and, (4) to record the students’ individual carbon footprint data for the analysis tool to perform analysis. The GWP
coefficients were determined by referring to some well-known CFCs.

The calculation tool was designated (1) to ask students 36 questions, as listed in Appendix A, to help them describe their daily activities; (2) to provide user interface, as shown in Fig. 2, for the students to interact with the management system; (3) to calculate students’ personal carbon footprint according to their daily activities and; (4) to write the students’ individual carbon footprint records to the data storage. The question items in Appendix A were categorized into six constructs, containing campus activities, family living, transport usage, dining and personal waste to recycling. The questions were determined from a survey as covering critical items for students concerning the carbon emissions associated with their daily life. The user interface in Fig. 2 was the final user interface that was established by iterative revisions following several quick trials and taking the students’ reactions and suggestions into account. The user interface allows students to use their mice simply to slide the bar in response to each question and then to describe their personal daily activities.

The analysis tool was designated (1) to summarize a student’s daily carbon emission report; (2) to sum the student’s daily carbon emissions in each construct; (3) to determine the major items in each construct of the student’s emission and their contribution to the carbon footprints; (4) to draw comparisons between today’s and past carbon footprint records; (5) to use regression to calculate trends in the student’s current and past carbon footprints, and (6) to compare the student’s average daily carbon footprint in each construct with those of others.
The presentation module delivers tailored messages to individual students based on the results generated by the analysis tool. It displays the following information for a student user: (1) a summary of the carbon footprint report with the user’s name, the report generation time, and the total carbon footprint (Fig. 3); (2) a pie chart with a table and statement of the proportions of the carbon emissions associated with five constructs, the carbon emissions associated with all six constructs, and the construct associated with the largest carbon emission (Fig. 4); (3) the major items associated with the largest absolute and proportional carbon emissions associated with each construct (Fig. 5); (4) a line chart with short messages that include the 50 most recent carbon footprint records with suggestions for reducing and controlling carbon emissions (Fig. 6), and (5) a bar chart that compares the mean carbon footprints associated with each construct between the student (red bar) and others (blue bar) (Fig. 7).

The CFC+ was implemented by using web-based technologies and centralized database. Students can access the personal management system at http://cfp.npust.edu.tw/.

Figure 3 Summary of the carbon emission report

Figure 4 Presentation of carbon emissions in each constructs
RESEARCH MODEL AND QUESTIONNAIRE

Research Model

In applying TAM to the acceptance of CFC, this study investigated the factors that likely affect students’ behavioral intention to use CFC/CFC+ (BI). Factors addressed are application of persuasive technologies (AOTP), environmental awareness (EA), perceived usefulness of CFC/CFC+ (PU), perceived ease-of-use of
CFC/CFC\(^+\) (PEOU), and attitude toward using CFC/CFC\(^+\) (AT). To assess the differences between CFC and CFC\(^+\) and the causal relationships among the factors, the following hypothesis are formulated.

H01: No significant difference exists in PEOU between CFC and CFC\(^+\).

H02: No significant difference exists in PU between CFC and CFC\(^+\).

H03: EA is significantly and positively correlated with PU.

H04: EA is significantly and positively correlated with AT.

H05: PEOU is significantly and positively correlated with PU.

H06: PEOU is significantly and positively correlated with AT.

H07: PU is significantly and positively correlated with AT.

H08: PU is significantly and positively correlated with BI.

H09: AT is significantly and positively correlated with BI.

Figure 8 shows the research model comprising the nine hypotheses.

![Figure 8 Research model](image)

**Questionnaire**

One questionnaire with five parts of 28 question items, represented in APPENDIX B, was used to collect the required data for the study. The first part has seven (five positive and two negative) items that were developed by referring to Steg's work in 1999 (Gatersleben et al., 2002) to measure the extent an individual is concerned about global warming and GHG effects. The rest four parts were developed based on Davis et al.'s TAM (1989) to measure PU (seven items, all positive), PEOU (seven items, two positive and five negative), AT (four items, all positive), and BI (three items, all positive). Those question items were slightly altered to fit the context of this study. A five-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree) was used for all items.
agree) was used to score responses to each item.

DATA COLLECTION, ANALYSIS AND DISCUSSION

Freshmen and sophomores at a university in Taiwan were selected as the study population. This study used convenience sampling method. The data collection started by giving students a 20 minutes explanation and introduction of what the carbon footprint is and how the survey will be processed. After the introduction, each student was randomly assigned to use either the typical CFC or CFC+ (mentioned in the previous section) and then fill in the questionnaire. The typical CFC, offered by Taiwan’s local government as shown in Fig. 9, provides simple interface and functions for users to input the activity data manually and get their carbon footprints.

![Typical CFC](image)

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Quantity (件)</th>
<th>CO2 Emission (公斤)</th>
</tr>
</thead>
<tbody>
<tr>
<td>電熨斗</td>
<td>0</td>
<td>0.836 公斤/度</td>
</tr>
<tr>
<td>水電</td>
<td>0</td>
<td>0.19 公斤/度</td>
</tr>
<tr>
<td>天然氣</td>
<td>0</td>
<td>2.09 公斤/度</td>
</tr>
<tr>
<td>煤氣</td>
<td>0</td>
<td>3.19 公斤/公斤</td>
</tr>
<tr>
<td>汽油</td>
<td>0</td>
<td>2.26 公斤/公斤</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Quantity (件)</th>
<th>CO2 Emission (公斤)</th>
</tr>
</thead>
<tbody>
<tr>
<td>電器</td>
<td>0</td>
<td>0.0966 公斤/時</td>
</tr>
<tr>
<td>照明</td>
<td>0</td>
<td>0.0345 公斤/時</td>
</tr>
<tr>
<td>向日葵</td>
<td>0</td>
<td>0.0069 公斤/時</td>
</tr>
<tr>
<td>電腦</td>
<td>0</td>
<td>0.0138 公斤/時</td>
</tr>
<tr>
<td>洗衣機</td>
<td>0</td>
<td>0.2139 公斤/時</td>
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<td>電熱水瓶</td>
<td>0</td>
<td>0.414 公斤/時</td>
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<tr>
<td>普通印表機</td>
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<tr>
<td>熱水器</td>
<td>0</td>
<td>0.069 公斤/時</td>
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<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Quantity (件)</th>
<th>CO2 Emission (公斤)</th>
</tr>
</thead>
<tbody>
<tr>
<td>電器</td>
<td>0</td>
<td>0.0455 公斤/時</td>
</tr>
<tr>
<td>冷氣機</td>
<td>0</td>
<td>0.021 公斤/時</td>
</tr>
<tr>
<td>米飯鍋</td>
<td>0</td>
<td>0.0167 公斤/時</td>
</tr>
<tr>
<td>電暖器</td>
<td>0</td>
<td>0.414 公斤/時</td>
</tr>
<tr>
<td>空氣清淨機</td>
<td>0</td>
<td>0.0414 公斤/時</td>
</tr>
<tr>
<td>吸塵器</td>
<td>0</td>
<td>0.0267 公斤/時</td>
</tr>
<tr>
<td>液晶40W</td>
<td>0</td>
<td>0.0414 公斤/時</td>
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<tr>
<td>日光燈20W</td>
<td>0</td>
<td>0.0173 公斤/時</td>
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<tr>
<td>省電型LED</td>
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<td>0.0117 公斤/時</td>
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<td>電熱水瓶</td>
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<tr>
<td>電熱水煮</td>
<td>0</td>
<td>0.552 公斤/時</td>
</tr>
<tr>
<td>冰箱</td>
<td>0</td>
<td>0.298 公斤/時</td>
</tr>
</tbody>
</table>

Figure 9 Typical CFC

Statistical Techniques Applied to Analyze Survey Data

The SPSS software was used to perform reliability analysis and t-test, and the AMOS to test the SEM of whether the casual relationships among the constructs were significant. The t-test was used to test the hypotheses H01 and H02, and SEM to determine causality as described in hypotheses H03 to H09.
Results and Discussion

Descriptive Statistics

In total, 167 students in four classes completed the questionnaire. Of the responses, 155 were valid (93%). The respondents were distributed as follows. The students were aged between 19 and 21. Gender ratios for males and females were 42.6% (66) and 57.4% (89) respectively. Besides, 16.1% had ever used carbon footprint calculator.

Reliability and Validity

To confirm that the hypothesized model provided a good fit to the collected sample data, this study investigated the reliability and validity. First, Cronbach’s $\alpha$ and Composite Reliability (CR) were used to test the internal consistency of the model. Next, convergent validity were used to examine the relations among constructs. The test results of reliability and validity are shown in Table 3 and 4 respectively.

Nunnally (1978) offered his opinion that 0.7 and above of Cronbach’s $\alpha$ coefficient is ideal. In Table 3, the Cronbach’s $\alpha$ for all constructs ranged from 0.84 to 0.94, which proved their reliability. Hair, Anderson, Tatham, and Black (1998) suggested that the common threshold value for CR is 0.70. In Table 3, all the five constructs are over 0.7 with respect to their CR values, which indicated that within each construct, the question items were internally consistent. In short, the research model reached an acceptable level of reliability.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Cronbach’s $\alpha$</th>
<th>Composite Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>PEOU</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>PU</td>
<td>0.87</td>
<td>0.88</td>
</tr>
<tr>
<td>AT</td>
<td>0.88</td>
<td>0.87</td>
</tr>
<tr>
<td>BI</td>
<td>0.81</td>
<td>0.80</td>
</tr>
<tr>
<td>Overall</td>
<td>0.95</td>
<td></td>
</tr>
</tbody>
</table>

Fornell and Larcker (1981) and Hair et al. (1998) indicated that a construct with an AVE (Average Variances Extracted) of at least 0.5 is considered satisfactory for the convergent validity. Besides, Nunnally (1978) and Hair et al. (1998) in their books commonly mentioned that for a model, the convergent validity is acceptable if the factor loadings of all measured variables to its construct are greater than 0.5. The
factor loadings were calculated by confirmatory factor analysis (CFA). Hair et al. (1998) suggested that the minimum sample size required for the CFA in SEM is 100 to 200. This survey received 155 valid responses which met the requirement suggested by Hair et al. (1998). In Table 4, the AVE values and the item factor loadings respectively ranged from 0.66 to 0.91 and 0.50 to 0.80 across all constructs, which indicated that, in this study, the research model has good convergent validity.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Item Factor Loading</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA</td>
<td>0.89-0.91</td>
<td>0.80</td>
</tr>
<tr>
<td>PEOU</td>
<td>0.71-0.81</td>
<td>0.59</td>
</tr>
<tr>
<td>PU</td>
<td>0.66-0.78</td>
<td>0.50</td>
</tr>
<tr>
<td>AT</td>
<td>0.74-0.83</td>
<td>0.63</td>
</tr>
<tr>
<td>BI</td>
<td>0.75-0.77</td>
<td>0.58</td>
</tr>
</tbody>
</table>

**Assessment of research model**

The independent sample t-test was used to assess the significance of the effects of AOPT on PEOU and PU. In the collected data, 78 and 77 students were randomly assigned to use CFC+ and CFC respectively. The test results, presented in Tables 5 and 6, demonstrated that AOPT had a significant effect on student’s PEOU and PU. Therefore H01 and H02 were not supported. That is, CFC+ than CFC had greater levels of PEOU and PU.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Stdv</th>
<th>t –test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEOU1</td>
<td>CFC+</td>
<td>2.99</td>
<td>.781</td>
</tr>
<tr>
<td></td>
<td>CFC</td>
<td>2.06</td>
<td>.439</td>
</tr>
<tr>
<td></td>
<td>CFC+</td>
<td>3.00</td>
<td>.684</td>
</tr>
<tr>
<td>PEOU2</td>
<td>CFC</td>
<td>2.13</td>
<td>.375</td>
</tr>
<tr>
<td></td>
<td>CFC+</td>
<td>2.96</td>
<td>.711</td>
</tr>
<tr>
<td>PEOU3</td>
<td>CFC</td>
<td>2.09</td>
<td>.403</td>
</tr>
<tr>
<td></td>
<td>CFC+</td>
<td>3.13</td>
<td>.812</td>
</tr>
<tr>
<td>PEOU4</td>
<td>CFC</td>
<td>2.05</td>
<td>.320</td>
</tr>
<tr>
<td></td>
<td>CFC+</td>
<td>2.96</td>
<td>.780</td>
</tr>
<tr>
<td>PEOU5</td>
<td>CFC</td>
<td>2.06</td>
<td>.375</td>
</tr>
<tr>
<td></td>
<td>CFC+</td>
<td>3.13</td>
<td>.843</td>
</tr>
<tr>
<td>PEOU6</td>
<td>CFC</td>
<td>2.04</td>
<td>.342</td>
</tr>
</tbody>
</table>
The paths of SEM as shown in Fig. 8 were analyzed by estimating the regression coefficient of every hypothesized causal relation between constructs. The indices values of RMSEA (Root Mean Square Error of Approximation) = 0.008 (within the recommended level of below 0.05), AGFI (Adjust Goodness of Fit Index) = 0.846 (close to the recommended level of 0.90), and normed chi-square ($\chi^2/df$) = 1.010 (within the recommended levels of 1.0 to 2.0) indicated that model fit is acceptable. A significant path coefficient indicates the significant effect of a construct on another one. To effectively make comparisons between the effects among constructs, standardized path coefficient was used to represent the effect of an independent construct on a dependent construct in the path model. The analysis results are revealed in Fig. 10 and Table 7.
As demonstrated in Fig. 10, all seven path coefficients were positive, in accordance with the hypotheses that EA positively affected PU and AT, PUOU positively affected PU, and AT and PU positively affected BI in high or very high significance level. However, AT was insignificantly affected by PEOU and PU via this test. The standardized regression coefficients for the causal relations of the constructs are shown in Table 7.

![Figure 10. Assessment of Research model](image)

**Table 7. Standardized regression coefficients**

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Relation</th>
<th>Regression coefficients</th>
<th>Test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>H03</td>
<td>PU ← EA</td>
<td>0.61***</td>
<td>Supported</td>
</tr>
<tr>
<td>H04</td>
<td>AT ← EA</td>
<td>0.78***</td>
<td>Supported</td>
</tr>
<tr>
<td>H05</td>
<td>PU ← PEOU</td>
<td>0.59***</td>
<td>Supported</td>
</tr>
<tr>
<td>H06</td>
<td>AT ← PEOU</td>
<td>0.13</td>
<td>Not supported</td>
</tr>
<tr>
<td>H07</td>
<td>AT ← PU</td>
<td>0.17</td>
<td>Not supported</td>
</tr>
<tr>
<td>H08</td>
<td>BI ← PU</td>
<td>0.44***</td>
<td>Supported</td>
</tr>
<tr>
<td>H09</td>
<td>BI ← AT</td>
<td>0.34**</td>
<td>Supported</td>
</tr>
</tbody>
</table>

significant level **<.01, ***<.001
Table 7 indicates that the hypothesis H03 and H04 were supported. The standardized path coefficients for these two causal relations were 0.61 and 0.78 respectively. The results implied that the higher the level of a student’s environmental awareness, the more useful s/he perceives the CFC to be and the more positive attitude s/he will have toward using CFC. Likewise, H05 was supported by the statistical results with standardized path coefficients 0.59, which meant that a student’s perceived usefulness of CFC will be affected by his/her perceived ease-of-use of the CFC. Moreover, H08 and H09 were supported by the statistical results, which meant that a student’s intention to use CFC will be very likely affected by his/her attitude toward using CFC and the perceived usefulness of the CFC. The standardized path coefficient of the attitude and perceived usefulness to intention were 0.34 and 0.44 respectively. Apart from the aforementioned hypothesis, H06 and H07 were not statistically supported, which meant that a student’s perceived use-of-use and usefulness of CFC had no significant effects on his/her intention to use the CFC.

Discussion and suggestion

The t-test results in Tables 5 and 6 showed that the persuasive technology can be introduced into CFC to improve its ease-of-use and usefulness. Therefore, this study recommends the application of persuasive technologies to the design of CFC. Despite of the significant improvement made by persuasive technology, nevertheless, the mean values of students’ perceived ease-of-use (in the range of 2.06 to 3.13) and perceived usefulness (in the range of 2.76 to 3.01) of the CFC were not very high. The statistical results implied there is room for further improvement in the design of CFC. This study suggested that emerging technologies, mobile communication technology and other persuasive technologies for example, can be introduced into the design of CFC to help people record their daily activities and calculate their personal carbon footprints more conveniently.

The path analysis results in Fig. 10 and Table 7 indicated that a student’s intention to use CFC can be increased using two approaches. First, formulate a student’s positive attitude toward using CFC by enhancing his/her environmental awareness. Second, increase the usefulness and ease-of-use of CFC.

CONCLUSION AND FUTURE RESEARCH DIRECTION

Increasing people’s intention to constantly use CFC to manage and control their personal carbon footprints has been deemed to be one of the feasible ways to ease the global warming problem of the Earth. Prior studies showed that the ease-of-use and the usefulness are the critical characteristics of an information system to attract people to accept it. This study applied persuasive technologies to build a new
student-centered CFC to improve the ease-of-use and the usefulness of existing CFCs. Furthermore, this study conducted a survey by extending TAM to investigate the relationships among the potential factors that affect an individual’s intention to use CFC and proposed suggestions to increase students’ intentions to use CFC. The survey results indicated that (1) the application of persuasive technologies had a significant effect on a student’s perceived ease-of-use and perceived usefulness of CFC; (2) a student’s environmental awareness had significant and positive effect on his/her perceived usefulness of CFC and attitude toward using CFC; (3) a student’s perceived ease-of-use of CFC had a significant and positive effect on his/her perceived usefulness of CFC, and (4) a student’s perceived usefulness and attitude toward using CFC positively affected his/her intention to use CFC. Accordingly, this study recommends the application of persuasive technologies to improve the existing CFCs and the development of educational programs to enhance students’ environmental awareness.

Based on the findings of this study, the following future directions are suggested. First, implement the CFC+ in ubiquitous computing environment to further improve its ease-of-use and usefulness. Second, apply other advanced persuasive technologies to the design of CFC. Third, enlarge sample size and more diversely collect sample data for this study. Forth, consider other potential factors that might also influence an individual’s intention to use CFC, and last, measure the long-term practical effect of using CFC+ on an individual’s carbon footprint reduction.

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REFERENCE


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**Appendix**

**A. Question Items for Carbon Footprint Calculator**

1. Campus
   - Number of classmates (person)
   - Hours spent in general classroom today (hour)
   - Hours spent in language classroom today (hour)
   - Hours spent in computer classroom today (hour)
   - Hours spent in audiovisual classroom today (hour)
   - Hours spent in auditorium today (hour)
   - Hours spent in physics laboratory today (hour)
   - Hours spent in earth science laboratory today (hour)
   - Hours spent in biology laboratory today (hour)
   - Hours spent in chemistry laboratory today (hour)
   - Bottles of 600cc mineral water drunk today (bottle)
   - Number of times tap water has been used to wash hands today
   - Number of times toilet has been flushed today
   - Is toilet water-saving? (yes/no)
   - Number of times urinal has been flushed today
   - Is urinal water-saving? (yes/no)

2. Family
   - Number of family members (person)
• Amount of most recent tap water bill (NTD)
• Amount of most recent electricity bill (NTD)
• Amounts of most recent natural gas bill (NTD)
• Mass of liquefied petroleum gas (kg)
• Period of recharging of liquefied petroleum gas (month)

3. Transport
• Distance traveled on motorcycle today (km/day)
• Distance traveled in car today (km/day)
• Distance of traveled by bus today (km/day)
• Distance of traveled by rapid transit today (km/day)
• Distance of traveled by train today (km/day)
• Distance traveled by bicycle today (km/day)
• Distance walked today (km/day)

4. Dining
• Number of times dined out today

5. Waste
• Mass of waste generated today (kg)

6. Offset
• Mass of paper recycled this week (kg)
• Mass of glass products recycled this week (kg)
• Mass of alumina cans recycled this week (kg)
• Mass of plastic products recycled this week (kg)
• Mass of steel cans recycled this week (kg)
• Mass of kitchen waste recycled this week (kg)

B. Questionnaire

General question
G1. Gender (male/female)
G2. I have used CFC before (yes/no).
G3. The CFC version I am using (CFC/CFC+).

Environmental awareness (EA)
EA1. Global warming problems have consequences for my life
EA2. I worry about global warming problems.
EA3. I can see with my own eyes that the environment is deteriorating.
EA4. The attention given to the greenhouse effect is exaggerated.
EA5. I am optimistic about the environmental quality in the future.
EA6. A better environment starts with me.
EA7. People who do not take the environment into account try to escape their responsibility.

*Perceived Ease-of-use (PEOU)*

PEOU1. I become confused when I use the CFC.
PEOU2. I make errors when using CFC.
PEOU3. Interacting with the CFC requires a lot of my mental effort.
PEOU4. The CFC is rigid and inflexible to interact with.
PEOU5. I find it cumbersome to use the CFC.
PEOU6. My interaction with the CFC is easy for me to understand.
PEOU7. It is easy for me to remember how to calculate carbon footprints using the CFC.

*Perceived Usefulness (PU)*

PU01. My carbon footprint would be difficult to know without CFC.
PU02. CFC helps me manage and control my daily carbon emissions.
PU03. Using CFC won't waste me too much time.
PU04. CFC enables me to calculate my carbon footprint quickly.
PU05. CFC motivates me to reduce my carbon emissions.
PU06. CFC reminds me to adopt low-carbon behavior.
PU07. Using CFC makes it easier to know my daily carbon footprint.

*Attitude (AT)*

AT1. I like using CFC.
AT2. I find CFC boring.
AT3. I learned a lot through using CFC.
AT4. I would like to change my behavior to mitigate CO₂ emissions.

*Behavioral Intention (BI)*

BI1. I intend to use CFC to manage and control my carbon footprint.
BI2. I intend to recommend CFC to others.
BI3. I will consult the CFC when I encounter carbon-footprint-related problems.