Student intention of using Eco-cup rental machines: A Unified Theory of Acceptance and Use of Technology analysis

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Abstract: To tackle the increasing use of disposable cups in Taiwan, the government has introduced measures such as a ban on plastics and promoting reusable cups, including through rental machines for reusable cups, called eco-cup rental machines. We investigated the intention of university students using eco-cup rental machines on their campus. We analyzed the factors that influence the decision-making process of the students, based on the unified theory of acceptance and use of technology (UTAUT) model. The UTAUT model considers these factors, Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC), affecting individuals' behavior intention (BI) to adopt and use new technologies. In a survey covering 101 students from the campus, our results showed that PE (r = 0.48), EE (0.35), SI (0.46), and FC (0.38) had statistically significant correlations with BI. The multivariate relation and partial least squares structural equation model indicated that PE and SI had the largest relative importance influence on BI (38% and 41%, respectively). Our findings suggest that eco-cup rental machines, and similar drives towards reusable cups, need to be nudged forward through

improving their social acceptance, consequently providing positive social cues to individual users and designing easy-to-use schemes.

Keywords: UTAUT model; disposable cups; eco-cup rental machines; reusable cups; sustainable behaviour

1. Introduction

Office workers walking with hot coffee in the winter, passengers on public transport with drinks in hand, and people walking into beverage stores on the street to beat the summer heat – such scenes are becoming the norm for Taiwanese people [1]. As of November 2021, there were 26,000 beverage stores in Taiwan, most serving drinks in disposable cups and glasses [2]. According to the statistics from the Greenpeace Organization, about 2 billion disposable cups were used in Taiwan during 2020 [3]. Globally, every year, about 500 billion plastic cups are used [4]. Most of them end up in landfills and take up to 80 years to decompose [4, 5]. Waste management, including disposable cups, is a burden on resources and the environment as well as a concern for the move towards circular economy [6].

From April 2021, Taiwan has been enacting bans on single use plastics, particularly targeting disposable cups [7]. Since July 2022, all stores have been required to provide a discount of at least NTD 5 to customers with their own cups. Subsequently, from January 1, 2023, all convenience stores, and fast-food stores were required to provide a renewable cups loan service for customers [8, 9]. These have been important steps directed towards reducing use of disposable plastic cups.

Waste handling policies need to include both regulatory and behavioural approaches for consumers, such as suitable alternatives to single use cups [10]. The renewable cups loan

service not only encourages the use of reusable cups, but it also has a business model as its basis. In 2021, Greenpeace Organization launched the reusable cup project Plastic Free Alliance at Taichung Calligraphy Greenway. The project was supported by over 20 stores and the Taichung City Hall. Later in March 2022, the convenience store chain Family Mart announced that it would be initiating a reusable cup system in up to 400 of its stores in 2022 [11]. With the Taiwanese government actively promoting plastic reduction policies and the rise of green and sustainable practices [12, 13], eco-cup rental machines are receiving increasing attention [14, 15]. Eco-cup rental machines provide sustainable, reusable cups, as part of a closed, reusable cycle. Customers can borrow and return reusable cups at these machines for a small fee, and they do not have to be concerned with cleaning the cups or remembering to carry one on their person. These steps indicate a rising aspiration to move towards a circular economy. These aspirations are also in line with United Nations Sustainable Development Goals, specifically Goal 12 Responsible Consumption and Production, Target 12.5 "By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse".

Although the government has implemented corresponding policies and measures, how well these policies can promote consumer adoption of eco-cup rental machines needs to be studied. Using disposable cups is a behaviour. Shifting from disposable cups to using eco-cup rental machines is a change in behaviour and the adoption of new technology. In this work, we aimed to investigate the intention of students from a university campus to use eco-cup rental machines on campus and analyse the factors that influence their decision.

We used the unified theory of acceptance and use of technology (UTAUT) model for our analysis.

Previous works have taken a gross view of reusable cups or returnable cup services in their analysis, examining it as a matter of user behaviour [16]. The impact of financial incentives [17], environmental messaging [18], and institutional green initiatives [19]have been examined. These studies may be classified under the growing body of works that have been examining what prompts people to engage in environment friendly and/or sustainable behaviours [20]. However, to the best of our knowledge, the role of specific technological interventions that promote moving away from disposable cups, like the eco-cup rental machines, has not been analysed.

The success of such technological interventions is not solely a behaviour change; it is also the adoption of a new technology. The acceptance and successful use of new technologies/products by consumers is an important consideration. Researchers have proposed different models, such as the Theory of Reasoned Action (TRA) and Technology Acceptance Models (TAM, TAM2), for user/consumer acceptance behaviour of such products. The UTAUT model integrated perspectives from TAM and seven other prominent models of user acceptance, at that time point, to propose a unified model [21]. It proposes four components that influence consumer behaviour intention (BI): performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC). Further, there are four intervening variables (gender, age, experience, and voluntariness) [21].

Eco-cup rental machines can be considered as an evolving technological trend. In this work, we examined the acceptance of eco-cup rental machines from the perspective of students

on campus. As part of the developed methodology, we identified the key UTAUT constructs—PE, EE, SI, FC, and BI—to align with the context of eco-cup rental machines, developed a survey, building on prior UTAUT studies and tailored to the specific context of eco-cup rental machines, and statistical models were created to predict behaviour intention based on PE, EE, SI, and FC. To obtain feedback from students regarding their behaviour intention of using eco-cup rental machines, the questionnaire was distributed to students on campus and responses were collected through the Surveycake online survey platform (https://www.surveycake.com/en/).

Using the above methodological approach, we aimed to: (i) Investigate the relationships among performance expectancy, effort expectancy, social influence, facilitating conditions, and behaviour intention related to the use of an eco-cup rental machine, and (ii) Develop statistical models for BI, using PE, EE, SI and FC as predictors, to understand the relative importance of different factors and provide recommendations related to implementation of eco-cup rentals.

The study intended to provide insights into the prospects of eco-cup rental machines in Taiwanese university campuses, based on user intentions. These insights can facilitate the wider adoption of eco-cup rental machines and similar schemes for the reduction of disposable cup use. The methodology developed in the study can provide guidance on assessing the user adoption and success of schemes aiming to promote and facilitate reusable cups.

2. Methods

2.1. The UTAUT Model

The Technology Acceptance Model (TAM) was one of the early predecessors of UTAUT. TAM had two predictors: “Perceived Usefulness” (how much a user’s productivity is enhanced by the system) and “Perceived Ease of Use” (how free of effort is using the system) [22]. These two predictors ultimately relate to technology use, through different causal paths. However, TAM and similar models of consumer behaviour are simple; they state that a system which is useful and easy to use, is used more [23]. This information cannot help designers or policymakers improve the system or advance implementation. UTAUT evolved from TAM and other models like the Theory of Planned Behaviour (TPB), Innovation Diffusion Theory (IDT) and Social Cognitive Theory (SCT).

The UTAUT model is just over two decades old. It has been successfully applied to information systems and technology, as well as to systems like tablet PCs and digital learning. [24]. It is constructed with four significant predictors – Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) – and four moderating variables – age, gender, experience, and voluntariness of use. UTAUT theorizes that PE, EE, and SI influence the Behavioural Intention (BI) of using a technology [24]. The BI for a system is defined as “the degree to which a person has formulated conscious plans to” engage in a certain form of future behaviour. Further, BI and FC together determine the usage of a technology/system. As a model, UTAUT is not just a predictor of technology usage. Based on the four significant predictors and the four moderators, the construct provides information on how technology may be introduced and facilitated to improve adoption. Thus, it was a major advancement over TAM and similar models.

Previous works examining the use of reusable cups, as a behavioural change, have used diverse models to understand user behaviour, such as the theory of planned behaviour [19], the norm-activation method [16], and the stage model of self-regulated behavioural change [25]. On the other hand, the UTAUT model provides an ideal framework for understanding the use and adoption of eco-cup rental machines. It is a relatively new product/technology, and the intention is to understand its adoption and the improvements in implementation and policy changes that can bolster this process. To the best of our knowledge, no study so far has examined the usage of eco-cup rental machines using the UTAUT model. There has been an implementation of UTAUT in the Taiwanese context related to the adoption of clinical decision support systems by physicians [26]. Hence, we chose the UTAUT model for our analysis of eco-rental machine technology adoption in a university campus in Taiwan.

2.2. Research Hypotheses

Based on the definition from Venkatesh et al. [21] and other works related to performance expectancy [8] and effort expectancy [8,9], we posit the following null hypothesis (H0) and alternate hypothesis (Ha):

H_0: Performance expectancy, Effort expectancy, Social Influence, and Facilitating Conditions **do not** influence the Behavioural intention regarding the use of eco-cup rental machines.

H_a: Performance expectancy, Effort expectancy, Social Influence, and Facilitating Conditions influence the Behavioural intention regarding the use of eco-cup rental machines.

This is based on Neyman-Pearson hypothesis testing, with Type I error (α) set to 0.05.

2.3. Power analysis and participant numbers

We conducted an a priori power analysis using G*Power [27] to estimate the number of participants required for testing correlations (influence) between PE, EE, SI, and FC and the BI. For a two-tailed test, assuming medium sized effects, Type I error probability of 5% and Type II error probability of 5% (hence, power of 0.95), we arrived at a required sample size of 42. For examining multivariate regression relation of PE, EE, SI, and FC with BI (four predictors), assuming medium-sized effects, Type I error probability of 5% and Type II error probability of 5%, we arrived at a sample of 42 as well. Based on these power calculations, the minimum number of participants required would have been 42.

The designed survey was web-based. The average response rate for such surveys is just over 40%, with the best results obtained when sending out the survey to a clearly defined group of intended participants [28]. Since we had a clearly defined population (students at the university), we targeted to continue response collection until we obtain at least 42 responses, from the potential participants, i.e., students. Sample sizes used in previous works with UTAUT modelling varied from 1225 to 18 and several studies have used populations of less than 150 [29]. The sample size of 42, derived from a priori power analysis, also had a precedence in previous works that have used UTAUT to understand adoption of new behaviour and technology by a specific group, such as speech recognition technology for physicians, mobile phone use among seniors, and information and communication technology in government offices [29].

2.4. Survey Design

The questionnaire in this study was based on the UTAUT proposed by Venkatesh et al. [21].

A 5-point Likert scale was used in this study to measure responses. The scale ranged from

"strongly disagree" to "strongly agree," with scores ranging from 1 to 5. The questionnaire was divided into three parts: a brief introduction to the eco-cup rental machine, assessing participants' perceptions of the eco-cup rental machine (16 questions), and basic demographic information of the participants (3 questions). The questionnaire statements related to the UTAUT predictors have been provided as part of Supplementary Information (SI).

PE was defined as the degree to which utilization of the eco-cup rental machine contributes to beneficial outcomes in users' daily lives. EE was the level of ease and user-friendliness experienced by users when operating the eco-cup rental machine. Three questions each were used for assessing PE, EE, and FC. Four questions were used for SI, Table S1. BI was defined as the subjective willingness of consumers to use the reusable cup rental machine or their willingness to recommend it to others. We used three questions to assess BI, given below [30],[31]:

BI1. There is a high intention of me using the eco-cup rental machine to obtain the eco-cup in the future.

BI2. I am willing to use the eco-cup rental machine to get the eco-cup regularly.

BI3. I would like to recommend others to use the eco-cup rental machine to get an eco-cup.

2.5. Survey participants

The participants were university students of the Tunghai University. The university is located in Xitun District, Taichung. Students could have been in any year of their undergraduate studies and could be living on campus (in the university's dormitories), off-campus housing, or commuting.

As our study did not involve any invasive procedure, direct contact with respondents, or privacy concerns, it did not require ethical review or approval under Article 4 of Taiwan's Human Subjects Research Act. Participants provided informed consent by their participation in the study, as described in the preamble to the questionnaire.

2.6. Data collection and analysis

The questionnaire was created using the Surveycake online survey platform. Questionnaires were distributed on the University's students Facebook page. Responses were collated form the Surveycake platform into .csv files, through Microsoft Excel.

Responses were collated using Excel into .csv files. Statistical testing and analysis were carried out using R [32] on the RStudio environment. Most applications of UTAUT have focused on examining the influence of the main effects/predictors on consumer behaviour[22, 24]. We also focused our analysis on the main effects, viz., PE, EE, SI, and FC, and not the intervening variables like gender and age.

The responses were analysed for internal consistency of the questionnaire, by assessing Cronbach's Alpha. Exploratory analysis of the data was used to obtain summary statistics for the responses and correlations between the different responses for the main predictors. Exploratory factor analysis (EFA) was used to obtain the factor loadings for the items under each of PE, EE, SI, FC, and BI. The factor loadings were then used to provide a composite expression for each predictor. For example, PE had three items associated with it, PE1, PE2, and PE3.

$$PE = \rho_1 PE1 + \rho_2 PE2 + \rho_3 PE3 \quad (1)$$

The factor loadings ρ_1, ρ_2, ρ_3 in Equation 1 were calculated using EFA on the responses for PE1, PE2, and PE3 and the values were then used to calculate the composite response PE, as given in Equation 1. Similarly, composite responses were created for EE, SI, FC, and BI3 for correlation analysis and regression analysis.

Between BI and the rest of the predictors, Pearson product moment correlation was calculated, and bootstrapping was used to estimate confidence intervals for the correlations. To examine the impact of gender, which year the respondent was in the university, and where they lived, t-tests (for gender) and ANOVA (for the other two) were used on the BI responses. Linear regression relations were modelled between PE, EE, SI and BI as well as PE, EE, SI, FC and BI.

In addition to using multivariate linear regression to model the effect of composite PE, EE, SI, and FC indices on BI, a partial least squares structural equation model (PLS-SEM) was also used to model the BI survey data. Certain previous works have used PLS-SEM to model influential determinants of the behaviour of using disposable cups [16, 19]. More importantly, the study design and type of data support the use of PLS-SEM in our case. This is an exploratory work, applying UTAUT to understand adoption of sustainable technological interventions on campus. The survey responses are on Likert scales (hence, not normally distributed) and involves multiple constructs (PE, EE, SI, FC, BI), each having multiple indicators/components. These characteristics of the data indicate that PLS-SEM would be appropriate for use in this case. The sample size (101) is also ideal for a method like PLS-SEM [33]. More details of the developed PLS-SEM have been provided in the Supplementary Information.

The combination of EFA-linear regression and PLS-SEM complement each other. Using both approaches, we improved the robustness and validity of our findings. PLS-SEM allowed us to analyse the complex relationships in the model, while EFA-linear regression provided a simpler model with a more interpretable view of the data. PLS-SEM's is robust to non-normal data distributions, can work with small to medium sized data, and can analyse complex, underlying relationships. EFA-linear regression approach validated the dimensionality of the constructs, provided the direct relationships between the extracted factors and BI and identified the key factors influencing BI.

For hypothesis testing, when examining correlations and t-tests, the critical value for Z/t-distribution was taken as ±1.96, corresponding to $\alpha = 0.05$. Critical F values were determined for specific cases, depending on the degrees of freedom for the ANOVA or the regression model.

3. Results

We had aimed to collect at least 42 complete responses based on a priori power analysis. Over 100 (101) complete responses were collected within four weeks of the survey link being activated. Since the required number of responses had been gathered, the survey link was deactivated. Students could voluntarily choose to participate in the survey. Voluntary participation explained why all 101 responses were complete.

3.1. Exploratory data analysis

The results of Cronbach's Alpha coefficient analysis for response under each UTAUT component and for the overall questionnaire has been presented in Supplementary Information (SI), Table S2. Cronbach's alpha values of over 0.8 are considered good

indicators of internal consistency for a questionnaire and values of 0.7 or more are acceptable. For all components, as well as the combination of factors, the values obtained were over 0.7 though the 95% confidence interval for FC indicates a possibility of values going under 0.7.

The background information for the participants – gender, year in college, and living location – has been summarized in Table S3. During the survey period, there were 14,931 students enrolled in all courses in the university with roughly equal number of students in each of the four years. At the university level, 53.7% were female. Among our 101 participants, slightly over half of the participants were male (54.5%) and majority were sophomores (31.7%). In terms of residential location, more students resided off-campus in rented accommodations compared to dormitories, with 25 individuals (24.8%) and 23 individuals (22.8%), respectively.

Summary statistics of the responses relevant to the UTAUT model have been provided in Table S4. The responses were mostly on the "Agreement" side of the Likert scale, as apparent from the median values of 4. Also, effort expectancy items (EE) generated responses with less spread (2.5^{th} and 97.5^{th} percentile data) and more in agreement than the items under the other headings. The data distribution has been presented in Figure 1, using a stacked bar plot, highlighting the higher frequency of response towards the Agreement side.

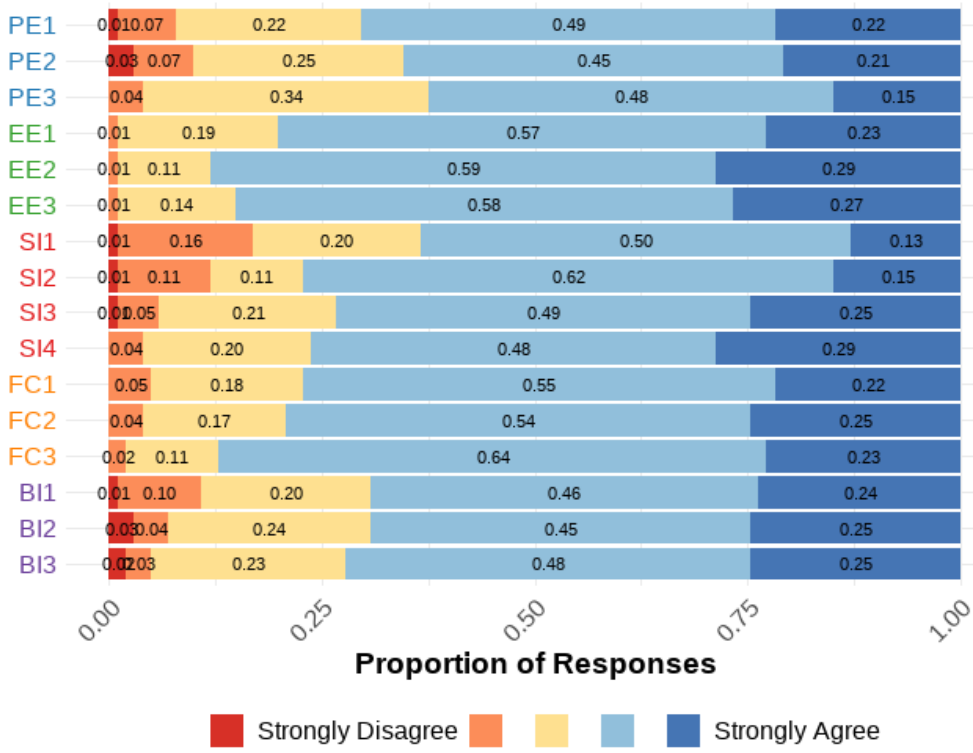

Figure 1. Frequency distribution of responses on the Likert scale for PE, EE, SI, FC, and BI questionnaire.

Pearson correlation (*r*) across all individual items in the questionnaire showed that all correlation values were less than 0.9 except for the correlation between SI3 and SI4 ($r = 0.91$, $p < 0.0001$). Since such high correlation implies that both items are essentially assessing the same parameter [34], for all subsequent analysis, we excluded SI4. Excluding SI4, the SI questions still retained a Cronbach's alpha of 0.88 (0.83, 0.93).

Exploratory factor analysis (EFA) for PE, EE, SI, FC, and BI, individually, was used to compute the factor loadings for the composite constructs for PE, EE, SI, FC, and BI, as described in Section 2.5. These factor loadings have been provided in Figure 2. The composite measures of PE, EE, SI, FC, and BI were thus constructed as weighted combination of the student responses. These measures were used in subsequent correlations and regression analysis.

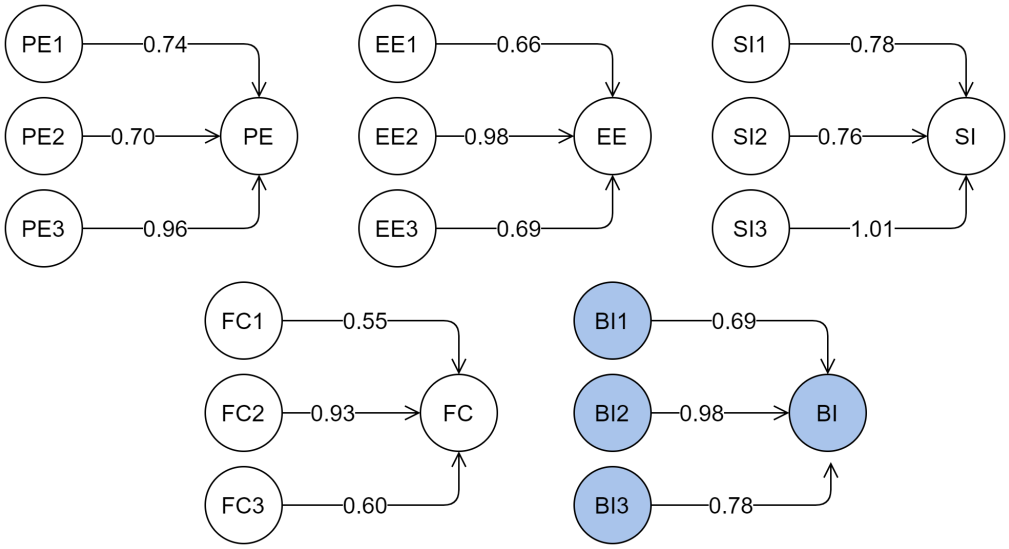

Figure 2. EFA derived weightings for each of PE, EE, SI, FC, and BI sub-questions used to construct composite PE, EE, SI, FC, and BI measures.

3.2. Participant background and influence on Behaviour Intention responses

Participant demographics varied across gender, their year in college, and where they lived (not all living on campus). Hence, we compared their responses based on these demographic parameters, using the composite BI as the index for comparison.

Gender did not significantly affect BI, $t = 1.27$, $p = 0.21$. Since the t value is lower than critical t value (1.96), at $\alpha = 0.05$, we conclude that gender did not have a significant influence on the response for behaviour intention. The ANOVA results for the year in college of the respondent also showed no significant impact on BI: F (4.96) = 0.55, $p = 0.7$. Similarly, where the participant lived did not significantly impact BI: F (2.98) = 0.08, $p = 0.93$.

3.3. UTAUT parameters' correlations

Pearson product-moment correlations were evaluated for BI with the four significant predictors, viz., PE, EE, SI and FC. All correlation tests, as per the hypothesis testing scenarios described in

Section 2.2, were two-sided. We used bootstrapping (resampling the responses to create synthetic datasets) to validate the correlation results. These results have been summarized in Table 1.

Table 1. Correlation between UTAUT predictors and BI

	r (*t, p*)	Bootstrapped correlation coefficient - mean, variance, (95% confidence interval)
PE ~ BI	0.48 (5.42, <0.0001)	0.48 - 0.0001, (0.24, 0.66)
EE ~ BI	0.35 (3.73, 0.0003)	0.35 - 0.0002, (0.09, 0.56)
SI ~ BI	0.46 (5.13, <0.0001)	0.46 - 0.0001, (0.23, 0.64)
FC ~ BI	0.38 (4.13, <0.0001)	0.38 - 0.0002, (0.15, 0.63)

Since for all the pairs the t-value exceeds the critical t-value of ±1.96, at α=0.05, we reject the null hypothesis and accept the alternate hypothesis, "Performance expectancy, Effort expectancy, Social Influence, and Facilitating Conditions influence the Behavioural intention regarding use of eco-cup rental machines." The mean bootstrapped correlation coefficients also closely matched the 'r' values calculated from our responses and they showed small variances.

3.4. Linear regression analysis

Linear regression equations were developed for BI with two different combinations of explanatory variables. The first model used all four of PE, EE, SI, and FC while the second model excluded FC. Both these models were using the composite indices developed for BI, PE, EE, SI, and FC, based on the factor loadings from EFA. For the first model, the following equation for BI was obtained:

$$BI = 0.24\,PE + 0.33\,EE + 0.26\,SI + 0.26\,FC - 0.70 \quad (2)$$

For Equation 2, R^2 = 0.36, adjusted R^2 = 0.34, F (4.96) = 13.6, p < 0.0001. Studentized Breusch-Pagan test of model residuals for homogeneity of variances, yielded BP (4) = 8.49, p = 0.08. Thus, model residuals had homogeneity of variance, an important requirement for linear regression models. Model parameters were tested for variance inflation factor (VIF). This test was used to check if the regression coefficients were inflated due to correlation between the predictor variables (which could lead to unreliable and unstable estimates). The variance values were 1.53, 1.21, 1.36, and 1.26 for PE, EE, SI, and FC coefficients, respectively, all values less than 5, indicating low multicollinearity between the model parameters and model stability. The model coefficients and confidence intervals from Equation 2 have been summarized in Table 2. For the regression model from Equation 2, the plots for each predictor against the dependent variable, BI, has been provided in Figure S1, in SI.

Table 2. Regression coefficients for Equation 2

	Estimate (std. error)	*t*-value, *p*	95% CI
Intercept	-0.70 (1.58)	-0.44, 0.66	(-3.83, 2.42)
PE	0.24 (0.11)	2.15, 0.03	(0.02, 0.47)
EE	0.33 (0.15)	2.15, 0.03	(0.03, 0.63)
SI	0.26 (0.09)	2.98, 0.004	(0.09, 0.44)
FC	0.26 (0.15)	1.72, 0.09	(-0.04, 0.57)

The estimates for the intercept and FC both had *t*-values less than the critical value (±1.96) and the 95% confidence interval (CI) for both include 0. This implies that the null hypothesis

(that these coefficients are 0) cannot be rejected. Thus, Equation 2 may be simplified to Equation 3 for the responses obtained in this study.

$$BI = 0.24\,PE + 0.33\,EE + 0.26\,SI \quad (3)$$

This simplification is in line with the initially proposed model from Venkatesh et al., which proposes that PE, EE, and SI influence BI, and through BI, impact usage while FC influences usage. Modelling BI with PE, EE, and SI resulted in Equation 4, with $R^2 = 0.34$, adjusted $R^2 = 0.32$, $F(3.97) = 16.81$, $p < 0.0001$ and BP (3) = 6.51, $p = 0.09$.

$$BI = 0.28\,PE + 0.40\,EE + 0.28\,SI + 0.28 \quad (4)$$

The VIF values were 1.47, 1.12, and 1.33 for PE, EE, and SI coefficients, respectively, indicating low multicollinearity and model stability. The model coefficients and confidence intervals from Equation 4 have been summarized in Table 3.

Table 3. Regression coefficients for Equation 4

	Estimate (std. error)	*t*-value, *p*	95% CI
Intercept	0.28 (1.48)	0.19, 0.84	(-2.66,3.22)
PE	0.28 (0.11)	2.51, 0.01	(0.06,0.50)
EE	0.40 (0.15)	2.68, 0.009	(0.10,0.70)
SI	0.28 (0.09)	3.21, 0.002	(0.11, 0.46)

As the *t*-value for the intercept is within the critical values range of ±1.96, Equation 4 can be further simplified as:

$$BI = 0.28\,PE + 0.40\,EE + 0.28\,SI \quad (5)$$

Equations 3 and 5 present similar coefficients for each predictor.

Relative importance of each contributor to Behavioural Intention of the participants, as related to using the eco-cup rental machine, were evaluated using the "relaimpo" package [35], with the recommended metrics 'lmg' and 'pmvd'. The evaluation was done for both Equations 2 and 4. The "relaimpo" package calculates relative importance of each regressor along with generating confidence intervals using 1000 bootstrap replicates. The relative importance metrics have been normalized to a sum of 1 (100%).

Table 4. Relative importance metrics for the regressors

Model		Relative importance metrics (95% CI)	
BI ~ PE + EE + SI + FC (Proportion of variance explained by model: 36.2%)	Regressors	lmg	pmvd
	PE	0.31 (0.08, 0.52)	0.33 (0.01, 0.77)
	EE	0.18 (0.03, 0.50)	0.17 (0.01, 0.66)
	SI	0.33 (0.10, 0.59)	0.37 (0.02, 0.75)
	FC	0.18 (0.02, 0.48)	0.13 (0.00, 0.67)
BI ~ PE + EE + SI (Proportion of variance explained by model: 34.2%)			
	PE	0.38 (0.12, 0.62)	0.38 (0.00, 0.81)
	EE	0.23 (0.04, 0.58)	0.21 (0.02, 0.70)

	SI	0.39 (0.15, 0.62)	0.41 (0.04, 0.75)

3.5. Partial least squares structural equation model

Based on our findings in Section 3.3, we did not include gender, residential location, and year in college into the PLS-SEM model since BI did not significantly differ across the different levels of these categorical variables.

The blocks' one-dimensionality results from PLS-SEM provided Cronbach's Alpha results for each construct's block. These values for Cronbach's alpha were consistent with the values from Section 3.1 – detailed results in Table S5 in SI. A summary of the outer model, with weights and correlations has been provided in Table S6. The weights are the contribution of each indicator to its respective construct and the correlations are between each indicator and its respective construct. All correlations were over 0.7, indicating strong relationships between the indicators and constructs.

The cross-loading correlations between all constructs and all indicators as well as the correlations between the latent variables have been provided in supplementary information, Table S7 and S8. Each indicator had the strongest correlations with its own construct, implying that each construct is distinct from the others and the indicators are appropriately measuring their intended latent variable.

The inner model of the PLS-SEM, providing the structural relationships between the latent variables, that is, how PE, EE, SI, and FC contribute to BI, is presented in Table 5. The estimates are accompanied with their bootstrapped estimates, mean value and 95% confidence interval. The model had an R^2 value of 0.40 (bootstrapped mean value of 0.44, 95% CI 0.24-0.64) and a goodness-of-fit measure of 0.55 (over 0.5 indicates a good fit). The estimates are the path coefficients for each construct, as relating them to BI. All estimates, except for the intercept, have t-values

greater than 1.96, indicating statistical significance. It may be noted here that in the linear models, the intercept value was also not statistically significant, indicating a fit through the origin in both models.

The high levels of block communality also indicate that the constructs capture a large portion of the variance in their indicators. For example, PE captures 76% of the variance in PE1, PE2, and PE3. A 50% or greater value is considered acceptable. The mean bootstrapped estimates show good consistency with the original model estimates, indicating the PLS-SEM model provided reliable results.

Table 5. Summary of PLS-SEM inner model, with bootstrapped estimates

	Estimate	Bootstrapped mean (95% CI)	Std. Error	*t*-value, *p*	Block communality
Intercept	0.00		0.079	0.000, 1	
PE	0.22	0.21 (0.00, 0.44)	0.099	2.22, 0.03	0.76
EE	0.18	0.18 (0.04, 0.40)	0.086	2.07, 0.04	0.73
SI	0.29	0.28 (0.09, 0.49)	0.093	3.06, 0.003	0.81
FC	0.20	0.20 (0.02, 0.40)	0.090	2.17, 0.03	0.64

4. Discussions

Eco-cup rental machines are a new technology. We used the unified theory of acceptance and use of technology (UTAUT) model to understand the acceptance of this new technology

among students in a university campus. Unlike previous works that have examined consumer intentions of moving to reusable cups based on aspects like social norms and environmental concern [25] [36], we focused on the adoption of a specific technological intervention that aims to provide a reusable cup alternative. Such interventions nudge consumer behaviour, going beyond an environmental awareness and altruistic perspective (Yang et al., 2024). This is an important addition to the repertoire of examining interventions towards sustainable growth. Not just user attitude towards a generic sustainability challenge but also their usage intention for specific technological solutions to the challenge need to be examined.

Post-hoc power calculation, based on 101 participants and effect sizes calculated from the correlation values and R^2 values obtained in the study, indicated a power of 0.91 for the correlation calculation and 0.99 for the multivariate regression. These values are close to the power of 0.95 we had aimed for in a priori calculations for deciding the number of participants (Section 2.3). The correlation values and R^2 values in UTAUT model lead to medium and large effect sizes. Hence, even with a small to medium sample size, the UTAUT model can be accessed with low probabilities of Type I and Type II error. This is one of the reasons why previous studies have successfully used a wide range of sample sizes when using UTAUT [29].

Our questionnaire indicated good consistency with Cronbach's Alpha test (> 0.7). The lowest Cronbach's Alpha was for the Facilitating Conditions questionnaire. The developed questionnaire can thus be useful for similar future studies, with some modification to framing of the Facilitating Conditions questions.

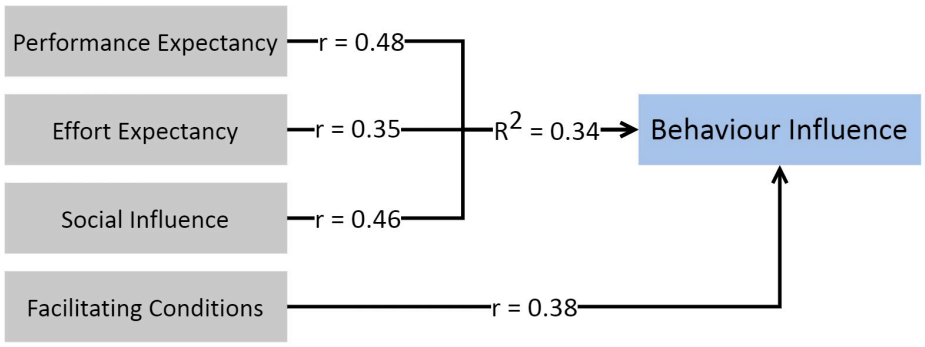

Figure 3. The UTAUT model of behaviour intention of university studnets' intention to use eco-cup rental machines, with the correlation coeffieicnts.

We showed that PE, EE, SI, and FC influence BI regarding use of eco cup rental machines, thus rejecting our null hypothesis. The correlations and the R^2 value of the multivariate regression model have been summarized in Figure 3.

Behavioural intention (BI) is the most direct determinant of individual behaviour [37]. We obtained the relative importance of PE:EE:SI for BI to be 38:21:41 (pmvd method). Thus, social influence and performance expectancy had the maximum influence on behaviour intention of using eco-cup rental machines. This implies that user behaviour is guided greatly by social cues from friends, peers, and family, along with the operational efficiency of the machines and user friendliness of the program. Similar observations have been made by studies related to adoption of smart waste sorting technologies [37, 38].

The PLS-SEM subsumed the individual steps we went through in the EFA-linear regression approach. But, like the EFA-linear regression approach, the PLS-SEM also indicated that SI had the greatest relative importance for BI, followed by PE – path coefficients of 0.29 and 0.22, respectively. The PLS-SEM model did present a slightly better R^2 value (0.36 vs 0.40) than the multivariate linear regression model, involving all four of PE, EE, SI, and FC. This

could relate with the PLS-SEM model being effective at analysing complex models with multiple constructs and relationships [39]. The consistency in results obtained using two different statistical models of different complexity, provides us cross-validation and improves confidence in our results.

A campus is a small community where peers and friends play a significant role, underlining the importance of social influence. Operators and policy makers can leverage word-of-mouth marketing to engage students. In addition to peers, social influence can also be built through the university collaborating with celebrities and social media influencers to promote a message. The importance of social influence in changing behaviour towards foregoing disposable cups has also been found in previous works [16, 19].

Performance expectancy, in different forms, has been found to have an important influence on moving towards reusable cups, aspects such as a convenient return process and perceived control over the process [16, 19, 38]. To aid on the performance expectancy front, high-traffic locations for students, e.g., libraries, student cafeterias, and sports facilities, can be chosen for deployment of the eco-cup rental machine. Such locations ease access. Incentives from operators, such as rewards and loyalty programs can also help improve performance expectancy. To influence effort expectancy, operators can enhance the usability of the eco-cup rental machine, simplify the rental and return processes. This can ensure that students' intention to use is not hindered by cumbersome procedures.

Overall, our findings suggest that the use of such small “nudges” [36] targeting PE and SI can influence student behaviour intention to using eco-cup rental machines. The nudges can relate to the user’s environment and thus PE, as in convenient locations for the eco-cup

rental machines. Or a nudge could target the user's self, through SI, such as university working with an influencer. While the impact of each, individual "nudge" can be small, they tend to add up [18]. This can work in the long run, without making it appear as sudden transition for users, closing the intention-behaviour gap [20]. As shown from prior studies, a move towards reusable cups, even with a small usage fee, like an eco-cup rental, would not impact the value of drink sales in the longer run (Poortinga & Whitaker, 2018).

Our findings on the importance of social influence and performance expectancy is echoed by existing literature on modifying consumer behaviour towards reducing use of disposable cups. The important difference being we explored a specific technology's acceptance instead of a generic evaluation of the acceptance of reusable cups.

4.1 Study limitations and future research

This work is a regional case study, and the findings cannot be generalized to a wider population. By the design of the study, we were limited to a relatively homogeneous participant population who were well educated, education being one of the important explanatory factors for use of reusable cups [17]. This could be one of the reasons why we obtained consistent responses. However, this also means the results may not be extrapolated to larger, more non-uniform groups. Limiting respondents to students on a campus was by choice, to focus on the largest and most active demographic in any campus. Considering students are the conceived sustainability leaders of the future, they are an important, though narrow, demographic.

Though the number of responses met requirements from statistical power calculations, it was still a small number to represent a whole campus population. Hence, to ensure reliability of

results, we used two different statistical models, and we used boot strapping for resampling. The numbers were not enough to explore gender or other demographic impacts on responses. Our findings did indicate though that for our respondents, the BI did not significantly differ across the levels of gender, residential location, and year in college. This allowed us to analyse all the responses together.

The use of UTAUT can prove to be useful for evaluating specific technological interventions can aid the move towards sustainable development. This goes beyond user attitude, altruism, and environmental concern to examine if a suggested intervention is likely to be adopted by users. Future multi-centre, collaborative studies can be designed to investigate adoption of this and similar technology at multiple campuses, in different regions, and with larger participation, to provide a more global picture and examine demographic influences.

The study gave us a view of consumer perspective at one time point. Future works can try to examine the consumer perception at different time points, before and after interventions, for a clearer picture of what impacts consumer adoption of eco-cup rental machines and similar technology and what steps can help improve such adoption. Our questionnaire and data analysis methodology can be a useful starting point for such works.

5. Conclusion

Analysing responses from university students in Taiwan, we found social influence and performance expectancy had the greater relative importance in determining behaviour intentions towards using the eco-cup rental machine technology. The results obtained through this study can facilitate the smoother implementation of policies related to eco-cup rental machines and other similar incentives trying to limit the use of disposable cups.

Our results are specific to the region and the demographic. They suggest that focusing on reducing user effort, providing a high performing service, and ensuring social acceptance are the key to successful adaptation of reusable cups and related policies. In a university campus, user acceptance can be influenced by social media campaigns, aided by influencers and encouraging acceptance across student clubs and societies. The eco-cup rental machines and the overall lending program need to be organised by university management, and at a higher level by policymakers to have an easy-to-use interface, convenient return process, and rewards and loyalty programs. For such campuses, the locating of the rental machines will also be an important decision. High traffic locations libraries, student cafeterias, and sports facilities should be preferred and the logistics of making suitable space available needs to be handled by management. Finally, university management and government policy makers can organise these steps small nudges to reliably close the intention-behaviour gap.

References

1. (2022) Using less plastic has become a new normal, along with regulations restricting the use of certain plastic products. - Fudy. https://www.fudy.com.tw/en/less-plastic-become-a-new-normal/. Accessed 9 Apr 2025
2. 經濟部統計處 [Department of Statistics, Ministry of Economic Affairs] (2016) 產業經濟統計簡訊 [Industry and Economic Statistics Bulletin]. In: 經濟部統計處 [Department of Statistics, Ministry of Economic Affairs]. https://www.moea.gov.tw/Mns/dos/bulletin/Bulletin.aspx?kind=9&html=1&menu_id=18808&bull_id=9579. Accessed 3 Jul 2023
3. (2023) 'Circular' cups can slash emissions: Greenpeace - Taipei Times. https://www.taipeitimes.com/News/taiwan/archives/2023/11/08/2003808867. Accessed 9 Apr 2025

4. Sisson A, Grisamore A, Jang J (2021) Green Practices with Reusable Drinkware at Music and Sporting Events: A Hospitality Undergraduate Student Perspective. Journal of Hospitality & Tourism Education 33:1–13. https://doi.org/10.1080/10963758.2020.1726772

5. EDN Staff (2022) Fact Sheet: Single Use Plastics. In: Earth Day. https://www.earthday.org/fact-sheet-single-use-plastics/. Accessed 18 Feb 2025

6. Zandieh Z, Thornley P, Chong K (2024) Progress of waste management in achieving UK's net-zero goal. J Mater Cycles Waste Manag 26:2601–2619. https://doi.org/10.1007/s10163-024-02003-8

7. (2025) Charting a plastic free future in Taiwan. In: Greenpeace International. https://www.greenpeace.org/international/story/11635/charting-a-plastic-free-future-in-taiwan/. Accessed 9 Apr 2025

8. (2022) Bring your own cup for discounts in Taiwan's bid to cut waste | Taiwan News | Apr. 27, 2022 16:04. https://taiwannews.com.tw/en/news/4520736. Accessed 9 Apr 2025

9. Discounts for bringing your own cup from July 1 - Taipei Times. https://www.taipeitimes.com/News/taiwan/archives/2022/04/28/2003777367. Accessed 9 Apr 2025

10. Widiyanti A, Rancak GT, Ramadan BS, Hanaseta E (2025) Comprehensive literature review of material flow analysis (MFA) of plastics waste: recent trends, policy, management, and methodology. J Mater Cycles Waste Manag 27:1–18. https://doi.org/10.1007/s10163-024-02110-6

11. (2025) Another plastic-free win! FamilyMart Taiwan to implement rental cup system. In: Greenpeace East Asia. https://www.greenpeace.org/eastasia/blog/7335/another-plastic-free-win-familymart-taiwan-to-implement-rental-cup-system/. Accessed 9 Apr 2025

12. China (Taiwan) M of FA Republic of (2024) MOENV vows continued promotion of plastic reduction policy. In: Taiwan Today. https://taiwantoday.tw/environment/top-news/262516/moenv-vows-continued-promotion-of-plastic-reduction-policy. Accessed 18 Feb 2025

13. Lai Y-Y, Lee Y-M (2022) Management strategy of plastic wastes in Taiwan. Sustainable Environment Research 32:11. https://doi.org/10.1186/s42834-022-00123-0

14. From Disposable to Reusable with a Togo-Container-Rental Service • Circular Taiwan Network. In: Circular Taiwan Network. https://circular-taiwan.org/en/case/goodtogo/. Accessed 18 Feb 2025

15. Taiwan's Single-Use Plastic Ban — LeKAC. https://lekac.com/packaging-news/taiwans-single-use-plastic-ban. Accessed 18 Feb 2025

16. Yang DJ, Chiu T-P, Ma M-Y (2024) How to Enhance Consumer's Engagement with Returnable Cup Services? A Study of a Strategic Approach to Achieve Environmental Sustainability. Sustainability 16:4761. https://doi.org/10.3390/su16114761

17. Nicolau JL, Stadlthanner KA, Andreu L, Font X (2022) Explaining the willingness of consumers to bring their own reusable coffee cups under the condition of monetary incentives. Journal of Retailing and Consumer Services 66:102908. https://doi.org/10.1016/j.jretconser.2022.102908

18. Poortinga W, Whitaker L (2018) Promoting the Use of Reusable Coffee Cups through Environmental Messaging, the Provision of Alternatives and Financial Incentives. Sustainability 10:873. https://doi.org/10.3390/su10030873

19. Wang X, Waris I, Bhutto MY, et al (2022) Green Initiatives and Environmental Concern Foster Environmental Sustainability: A Study Based on the Use of Reusable Drink Cups. International Journal of Environmental Research and Public Health 19:9259. https://doi.org/10.3390/ijerph19159259

20. Novoradovskaya E, Mullan B, Hasking P (2020) Choose to reuse: Predictors of using a reusable hot drink cup. Journal of Consumer Behaviour 19:608–617. https://doi.org/10.1002/cb.1834

21. Venkatesh V, Morris MG, Davis GB, Davis FD (2003) User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly 27:425–478. https://doi.org/10.2307/30036540

22. Venkatesh V (2015) Technology Acceptance Model And The Unified Theory Of Acceptance And Use Of Technology. In: Wiley Encyclopedia of Management. John Wiley & Sons, Ltd, pp 1–9

23. Venkatesh V, Davis FD (1996) A Model of the Antecedents of Perceived Ease of Use: Development and Test*. Decision Sciences 27:451–481. https://doi.org/10.1111/j.1540-5915.1996.tb00860.x

24. Venkatesh V, Thong JYL, Xu X (2016) Unified Theory of Acceptance and Use of Technology: A Synthesis and the Road Ahead

25. Keller E, Köhler JK, Eisen C, et al (2021) Why consumers shift from single-use to reusable drink cups: An empirical application of the stage model of self-regulated behavioural change. Sustainable Production and Consumption 27:1672–1687. https://doi.org/10.1016/j.spc.2021.04.001

26. Chang I-C, Hwang H-G, Hung W-F, Li Y-C (2007) Physicians' acceptance of pharmacokinetics-based clinical decision support systems. Expert Systems with Applications 33:296–303. https://doi.org/10.1016/j.eswa.2006.05.001

27. Faul F, Erdfelder E, Lang A-G, Buchner A (2007) G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods 39:175–191. https://doi.org/10.3758/BF03193146

28. Wu M-J, Zhao K, Fils-Aime F (2022) Response rates of online surveys in published research: A meta-analysis. Computers in Human Behavior Reports 7:100206. https://doi.org/10.1016/j.chbr.2022.100206

29. Dwivedi YK, Rana NP, Chen H, Williams MD (2011) A Meta-analysis of the Unified Theory of Acceptance and Use of Technology (UTAUT). In: Nüttgens M, Gadatsch A, Kautz K, et al (eds) Governance and Sustainability in Information Systems. Managing the Transfer and Diffusion of IT. Springer, Berlin, Heidelberg, pp 155–170

30. Ajzen I, Fishbein M (1975) A Bayesian analysis of attribution processes. Psychological Bulletin 82:261–277. https://doi.org/10.1037/h0076477

31. Ajzen I (1991) The theory of planned behavior. Organizational Behavior and Human Decision Processes 50:179–211. https://doi.org/10.1016/0749-5978(91)90020-T

32. R: The R Project for Statistical Computing. https://www.r-project.org/. Accessed 19 May 2024

33. Reinartz W, Haenlein M, Henseler J (2009) An empirical comparison of the efficacy of covariance-based and variance-based SEM. International Journal of Research in Marketing 26:332–344. https://doi.org/10.1016/j.ijresmar.2009.08.001

34. Kenny DA (1987) Statistics for the Social and Behavioral Sciences. Little, Brown

35. Groemping U (2007) Relative Importance for Linear Regression in R: The Package relaimpo. Journal of Statistical Software 17:1–27. https://doi.org/10.18637/jss.v017.i01

36. Loschelder DD, Siepelmeyer H, Fischer D, Rubel JA (2019) Dynamic norms drive sustainable consumption: Norm-based nudging helps café customers to avoid disposable to-go-cups. Journal of Economic Psychology 75:102146. https://doi.org/10.1016/j.joep.2019.02.002

37. Wang M, Cao K, Muhammad Khan N, et al (2025) A study of residents' behavior in participating in smart waste sorting system based on structural equation modeling. J Mater Cycles Waste Manag 27:354–368. https://doi.org/10.1007/s10163-024-02115-1

38. Zhang D, Li J, Lou S (2024) Reducing environmental pollution: what affects the waste sorting of Chinese urban residents? The theory of planned behavior with community convenience. J Mater Cycles Waste Manag 26:2084–2098. https://doi.org/10.1007/s10163-024-01943-5

39. (2025) A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). In: SAGE Publications Ltd. https://uk.sagepub.com/en-gb/eur/a-primer-on-partial-least-squares-structural-equation-modeling-pls-sem/book270548. Accessed 18 Feb 2025