

Structural Pathway of Use of Electronic Cigarettes among Adult Cigarette Smokers: A Cross-Sectional Study in Samarahan and Kuching Division, Sarawak

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Received April 27, 2024; Revised June 25, 2024; Accepted July 21, 2024

Cite This Paper in the Following Citation Styles

(a): [1] Sivanandhan Selleyitorea, Md Mizanur Rahman , "Structural Pathway of Use of Electronic Cigarettes among Adult Cigarette Smokers: A Cross-Sectional Study in Samarahan and Kuching Division, Sarawak," *Universal Journal of Public Health*, Vol. 12, No. 4, pp. 687 - 696, 2024. DOI: 10.13189/ujph.2024.120408.

(b): Sivanandhan Selleyitorea, Md Mizanur Rahman (2024). *Structural Pathway of Use of Electronic Cigarettes among Adult Cigarette Smokers: A Cross-Sectional Study in Samarahan and Kuching Division, Sarawak*. *Universal Journal of Public Health*, 12(4), 687 - 696. DOI: 10.13189/ujph.2024.120408.

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Abstract The rapid increase in electronic cigarette use presents new challenges and opportunities in public health and policy. Currently, emphasis has been placed on electronic cigarettes, and there is a high trend of use among the adult population. This study examines the structural pathways of using e-smoking by applying an integrated technology acceptance model and the theory of planned behaviour. This cross-sectional study was conducted among 446 adult e-cigarette smokers in the Samarahan and Kuching Divisions. Adults were selected from vape outlets orderly and interviewed face to face using a structured questionnaire. IBM SPSS version 29 and Jamovi version 2.3.26 were used for data analysis. A p-value <.05 was considered statistically significant. The structural pathway highlighted that the intention to use ECs strongly predicted actual use ($\beta = 0.760$, $p < .001$), with perceived usefulness ($\beta = 0.239$, $p < .001$), ease of use ($\beta = 0.216$, $p < .001$), and positive attitudes towards ECs ($\beta = 0.392$, $p < .001$) significantly contributing to this intention. Subjective norms did not significantly influence intention ($\beta = 0.038$, $p = 0.494$), indicating a negligible role of social influence in CE uptake. Furthermore, knowledge of e-smoking was negatively correlated with subjective norms ($\beta = -0.086$, $p = 0.002$), suggesting that increased awareness could dampen the effect of social pressures. The study concludes that the transition to ECs is significantly influenced by individual attitudes and perceptions rather than by social

norms. This highlights the importance of targeting these factors in public health interventions and policies designed to address the use of EC. However, the findings should be interpreted in the context of the limitations of the study, including its geographical and methodological scope. Future research should be extended to a broader demographic to validate these findings and guide comprehensive health policy planning.

Keywords E-cigarettes, Attitude, Intention, Theory of Planned Behaviour, Technology Acceptance Model, Sarawak

1. Background

In the rapidly evolving landscape of tobacco consumption, the emergence of electronic cigarettes (ECs) and electronic nicotine delivery systems (ENDSs) has marked a significant and transformative development. Since their introduction in 2004, ECs have brought about substantial changes in the dynamics of nicotine use, aligning with broader societal and technological trends [1, 2]. In particular, between 2011 and 2018, there was a remarkable 900% increase in EC use among adults around the world, accompanied by a notable decline in traditional

cigarette smoking [1, 2]. This shift, indicative of evolving consumer preferences, raises critical questions about the long-term implications of ECs, which are considered less harmful but carry largely unexplored extended-term effects.

Our study investigates the complex factors that motivate people to adopt ECs as an alternative nicotine source. E-cigarettes contain fewer toxic chemicals than traditional cigarettes, but they are not risk-free. They still contain nicotine, which is highly addictive, and other potentially harmful substances such as heavy metals and cancer-causing chemicals [3, 4]. The growing popularity of ECs presents significant considerations for public health, regulatory policies, consumer behaviour, and addiction [5-7]. By examining the attitudes, beliefs, and motivations of EC users, this study aims to shed light on the nuanced patterns of EC consumption and the factors influencing this behaviour.

The Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB) have been widely used to understand the factors that influence the adoption and use of electronic cigarettes among adult smokers [4, 8]. TAM posits that perceived usefulness and ease of use determine an individual's intention to use technology [9, 10], while TPB suggests that attitude, subjective norm, and perceived behavioural control shape behavioural intention [10, 11]. Integrating these two frameworks can provide a more comprehensive understanding of the complex relationship between individual, social, and technological factors that drive the use of e-cigarettes among adult smokers.

The hypothesis of this study draws on a theoretical framework that integrates the Technology Acceptance Model (TAM) and the Theory of Reasoned Action [11, 12]. This study examines the influence of perceived usefulness and ease of use (key TAM constructs) on electronic smoking. It also investigates how motivation and perceived beliefs (Theory of reasoned action components) shape intentions to use e-cigarettes. This combined approach aims to address a research gap by offering a holistic model of e-cigarette use, extending beyond simple device perceptions to encompass broader individual motivations and beliefs. The structural framework for this research merges specific elements from the Technology Acceptance Model (TAM) and the Theory of Reasoned Action (TRA). TRA components assess the influence of subjective norms and attitudes on behavioural intention regarding the use of e-cigarettes. Simultaneously, we examined the TAM constructs of perceived usefulness and ease of use of e-cigarettes. This framework posits that intentions to smoke e-cigarettes and subsequent behaviour are influenced by a combination of social pressures, individual attitudes, and how users perceive the technology itself.

Our primary goal is to outline the characteristics of EC users, identify the reasons behind EC usage, and map current smoking patterns connected to these devices. We also explore the complex relationship between EC use and

factors such as knowledge, attitudes, and motivation. Focussing on the Borneo region, specifically Sarawak, offers valuable and unique insights from a less studied geographical area.

2. Methods

2.1. Setting, Population, and Samples

This study aimed to determine the uses of electronic smoking. The study design was an observational and cross-sectional study using a quantitative research methodology. The researcher conducted an observational and cross-sectional study. Smokers or vapers aged 18 years and older, regardless of gender, living in Samarahan and Kuching Divisions of Sarawak, Malaysia, were included as samples. Subjects with preexisting mental disease or cognitive impairment were excluded. The study was conducted from October 2022 to August 2023. We used a single proportion cluster sampling technique to select our participants. The target study population included all smokers who had visited vape outlets and smoked in the Samarahan and Kuching districts. We used a base prevalence of 5% for electronic cigarettes smokers to obtain a precise estimate of electronic smokers [13]. The required sample size would be 200, a multiple-by-design effect (here, we considered 1.95, based on 20 respondents from each cluster/vape centre) and would become 395. The sample size was further inflated using a 15% non-response. Thus, the final sample size was 474. Participants were chosen from vape outlets using a two-tier sampling method, focussing on significant electronic cigarette purchase locations and gathering spots for the target group. Seven vape shops in Samarahan and 15 in Kuching were included on the basis of relevance, accessibility, and participant potential. Customers in these shops were systematically included until the desired sample size was reached. This approach enabled a thorough understanding of the various electronic cigarette purchases and usage regions.

2.2. Collection Instruments and Measurement Procedure

Our study used a comprehensive questionnaire modified from different sources [14-16] and questions administered through face-to-face interviews. The questionnaire, which was divided into five parts, encompassed a range of topics such as sociodemographic and personal characteristics, knowledge of electronic cigarettes, attitudes, motivations, and beliefs about electronic cigarettes. It also used questions about the Technology Acceptance Model (TAM) to assess subjective norms, perceived usefulness, and ease of use. Concepts from the Theory of Reasoned Action and personal behaviour control were incorporated to expand the assessment, and all items used a 7-point Likert scale for participant responses. This structured approach provided a

multifaceted perspective on participants' profiles, knowledge, attitudes, and behaviours regarding e-cigarette use. All participants received information about the study and provided written consent before face-to-face interviews using a structured questionnaire. Data was also collected from individuals who visited vape shops. The respondent was consecutively interviewed at the exit point.

2.3. Data Entry and Analysis

This study used Microsoft Excel for data entry with validation checks. We thoroughly checked and cleaned all data before analysis and imputed missing data using multiple imputations. Descriptive and exploratory data analysis was performed using IBM SPSS version 29. The descriptive analysis is presented in a table with frequencies, mean, standard deviation, and minimum and maximum values.

We conducted a pretest of our research instruments before the main study to evaluate their acceptability, feasibility, and comprehensibility. To carry out this pretest, we chose a non-sample area in a separate district, which closely resembled our main study's setting but was not included in the primary study. We recruited 30 participants for the pretest sample. We retained all items in the questionnaire during the pretest but made minor modifications to improve clarity. We assessed the internal consistency of elements within each domain using Cronbach's alpha [17]. Our reliability analysis revealed acceptable Cronbach's alpha values ranging from 0.65 to 0.75 for the instruments. Furthermore, we evaluated the measurement model using convergent and discriminant validity before proceeding with the structural path analysis. This comprehensive approach ensured the robustness of our instruments and analytical methods before implementing them in the main study.

We focussed on establishing both convergent and discriminant validity. For convergent validity, we ensured that item loadings exceeded 0.5 [18], Cronbach's alphas were at least 0.60, and composite reliability met the 0.60 threshold [19]. We used the Fornell-Larcker [20] Criterion to establish discriminant validity, verified cross-loadings and calculated the HTMT ratio (aiming for values below 0.85 or 0.90) [20, 21]. Finally, we use structural equation modelling [9] to analyse the relationships between observed and latent constructs in the use of e-cigarettes (think behaviour, intention, attitudes, etc.). Data analysis involved both JAMOVI and a p-value of 0.05 for statistical

significance.

2.4. Ethical Considerations

The authors obtained ethics approval from the Ethics Committee of the Universiti Malaysia Sarawak (UNIMAS) (Ref: UNIMAS/TNC(PI)/09 – 65/02 (27)). All participants were briefed and their written informed consent was obtained before the interview.

3. Results

3.1. Characteristics of the Respondents

Table 1 illustrates the characteristics of the participants. The average age was 24.8 years. Most of them are male (83.4%) and of Malay or Bumi ethnicity. Approximately half follow Islam and almost a third have a degree or higher education. Families in this group typically have around 5.4 members. Their monthly income is around MYR 1780.0; many are students (37.0%) or work in the private sector (33.2%).

3.2. Measurement Model

The measurement model is a crucial component of the SEM that examines the relationship between latent variables and their measures. It is measured by convergent and discriminant validity. Convergent validity was demonstrated through high factor loadings, with β values well above the 0.50 threshold and high construct reliability values. The average variance extracted (AVE) for each construct also exceeded the recommended value of 0.50, confirming the suitability of the representations of the construct and internal consistency (**Table 2**).

Regarding discriminant validity, the constructs showed distinctiveness, as evidenced by the heterotrait-monotrait (HTMT) ratio of correlations below the stringent 0.90 threshold. For example, intention and behaviour had an HTMT of 0.848, and motivation was correlated with usefulness, subjectiveness and attitude, yielding HTMT values of 0.878, 0.877, and 0.898, respectively, all under the 0.90 benchmark. These results, in accordance with the recommendations of [22] and [21], verify that each construct is sufficiently differentiated from the others, eliminating concerns about multicollinearity and ensuring that there are no overlapping elements within domain constructs (**Table 3**).

Table 1. Characteristics of the respondents (N=446)

Variables	Frequency	%	Statistics
Age in years			Mean = 24.8, SD = 8.9 years
Gender			
Male	372	83.4	
Female	74	16.6	
Ethnicity			
Malay	201	45.1	
Bumi	206	46.2	
Others (Chinese, Indian)	39	8.8	
Religion			
Islam	226	50.7	
Christian	197	44.2	
Others (Buddhists, Hindus)	23	5.1	
Level of education			
Primary school	10	2.2	
Secondary school	137	30.7	
Diploma	145	32.5	
Degree and above	154	34.6	
Family size			Mean =5.4, Sd = 2.2, MD = 5.0
Monthly Income			MD = MYR 1780.0
Working Status			
Student	165	37.0	
Private	148	33.2	
Workers	57	12.8	
Government	31	7.0	
self-employed	26	5.8	
Business	19	4.3	

Table 2. Convergent validity

Latent	Variables	β	α	AVE
Behaviour	The curiosity of trying an e-cigarette would encourage me to use it	0.863	0.865	0.746
	Adhering to the law would not prevent me from using an e-cigarette	0.911		
	The different flavours of e-cigarettes make me use electronic cigarette	0.815		
Intention	I do have curiosity about trying an e-cigarette	0.815	0.853	0.680
	I intend to use e-cigarettes regularly	0.899		
	It is mostly up to me whether I use an electronic cigarette or not	0.830		
	It is my decision whether I use an electronic cigarette or not	0.721		
	If any of my friends offer me to smoke electronic cigarettes, I will accept it	0.849		
Subjective norm	My peers, who are important to me, think that I should use an e-cigarette	0.936	0.951	0.909
	My close friends think I should switch to electronic cigarette	0.980		
	Electronic cigarettes are more socially acceptable to use than smoking conventional cigarettes	0.943		
Usefulness	Electronic cigarettes are more enjoyable to use than traditional cigarettes	0.870	0.925	0.747
	An e-cigarette could help to reduce the number of cigarettes consumed per day	0.696		
	An e-cigarette could increase the motivation to join a smoking cessation program	0.933		
	An e-cigarette could help to stop conventional cigarette smoking	0.937		
Ease to use	An electronic cigarette is easily available in the market	0.774	0.906	0.678
	It is comfortable to use the electronic cigarette	0.587		
	Electronic cigarette device is easy to use	0.870		
	I would find it easy to switch on the electronic cigarette rather than light up a conventional cigarette.	0.913		
	It would be easy to become skilful at using an electronic cigarette.	0.881		
	Electronic cigarettes are more convenient or easier to use than conventional cigarettes	0.871		
	Using e-cigarettes is fun	0.872		
Attitude	E-cigarette helps to cut down conventional smoking	0.948	0.89	0.767
	Electronic cigarettes are less addictive than traditional cigarettes	0.899		
	Electronic cigarettes will not produce as many cravings as traditional cigarettes	0.853		
	Electronic cigarettes can reduce cravings for traditional cigarettes	0.800		
	Electronic cigarettes are safer to use than conventional cigarette	0.942		
Motivation	Electronic cigarette enhances one's performance	0.826	0.906	0.729
	Electronic cigarette improves one's image	0.872		
	Electronic cigarettes are safer to use than conventional cigarette	0.942		
	Electronic cigarette is not a serious public health concern	0.938		
	Electronic cigarettes can be used to quit or cut down on smoking conventional cigarettes	0.905		
	Electronic cigarettes are less harmful to the users' health than conventional cigarettes	0.587		

Table 3. Discriminant validity

	Behaviour	Intention	Subjective	Usefulness	Ease	Attitude	Motivation
Behaviour							
Intention	0.848						
Subjective	0.629	0.703					
Usefulness	0.696	0.737	0.893				
Ease	0.576	0.692	0.662	0.779			
Attitude	0.690	0.788	0.793	0.768	0.548		
Motivation	0.700	0.726	0.877	0.878	0.573	0.898	

The analysis utilised the DWLS method [23] and was optimised through NLMINB [24]; the model effectively handles ordinal or non-normal data, achieving convergence after 133 iterations, indicative of an optimal solution. The model encompasses 446 observations with 230 free parameters, employing robust standard errors and a 'mean adjusted scaled and shifted' test statistic for enhanced robustness. Across various indices, a good fit was demonstrated. Despite a statistically significant chi-square test, which can be misleading in large samples, other relative fit indices, such as the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI), approach values close to 1. This indicates that the user and baseline models demonstrate an excellent fit. The RMSEA values fall within the acceptable range of less than 0.08, and the SRMR is within acceptable limits. Hoelter's critical N (CN) suggests the significance of the model at reduced sample sizes. The Goodness of Fit Index (GFI) and Adjusted Goodness of Fit Index (AGFI) are close to 1, with the Parsimony Goodness of Fit Index (PGFI) and McDonald Fit Index (MFI) slightly lower, indicating some model complexity. The R-squared values elucidate the variance in the dependent variables accounted for by the independent variables in the model. Behaviour is well predicted with an R^2 of 0.578, intention has a moderate R^2 of 0.517, and Subjective Norm is robustly predicted with an R^2 of 0.710. The measurement model, which is integral to the structural equation modelling framework [25], delineates the relationships between latent constructs and their indicators, confirming the factor structure. Their observed variables effectively define constructs such as behaviour, intention, and subjective norms.

3.3. Structural Relationships

Structural path analysis indicated a robust positive association between intention to use and behaviour (actual use) towards e-cigarettes ($\beta = 0.760$, $p < .001$, 95% CI [0.698, 0.824]). The subjective variable norm was not significantly associated with intention ($\beta = 0.038$, $p = 0.494$, 95% CI [-0.071, 0.146]). Other variables such as usefulness ($\beta = 0.239$, $p < .001$, 95% CI [0.098, 0.378]), ease of use ($\beta = 0.216$, $p < .001$, 95% CI [0.089, 0.341]),

and attitude towards e-smoking ($\beta = 0.392$, $p < .001$, 95% CI [0.244, 0.537]) exhibited a significant positive association with intention. There was a negative association between subjective norm and knowledge of e-smoking ($\beta = -0.086$, $p = 0.002$, 95% CI [-0.01, -0.002]). In contrast, a positive association was observed between subjective norm and attitude towards e-smoking ($\beta = 0.165$, $p < .001$, 95% CI [0.074, 0.256]) and subjective norm and motivation to use e-cigarettes ($\beta = 0.676$, $p < .001$, 95% CI [0.563, 0.788]) (Table 4).

Structural path analysis revealed that the intention to use e-cigarettes significantly and positively affected actual behaviour ($\beta = 0.760$, $p < .001$). Furthermore, usefulness, ease of use, and attitude towards e-smoking were significantly and positively associated with intention ($p < .001$). However, the subjective norm did not significantly affect intention ($p = 0.494$). Knowledge of e-smoking negatively influenced the subjective norm ($p = 0.002$), whereas the subjective norms were positively associated with both the attitude towards e-smoking and motivation ($p < .001$). The indirect effects of subjective norms, attitudes, and motivation on behaviour through intention were not significant. Meanwhile, usefulness, ease of use, and knowledge had significant positive indirect effects on behaviour through intention ($p < .001$) (Figure 1).

Table 5 presents the indirect effects in a structural equation model involving various paths between different variables leading to behaviour (use of e-cigarettes). The indirect effect of subjective norms on behaviour through intention was not statistically significant ($\beta = 0.029$, $p = 0.495$, 95% CI [-0.054, 0.111]). However, indirect effects of usefulness ($\beta = 0.182$, $p = 0.001$, 95% CI [0.071, 0.291]), ease of use ($\beta = 0.164$, $p < .001$, 95% CI [0.067, 0.260]), and knowledge of e-smoking on behaviour through intention ($\beta = 0.298$, $p < .001$, 95% CI [0.187, 0.407]) were statistically significant. However, the indirect effect of knowledge on behaviour through subjective norm and intention was not significant ($\beta = 0.005$, $p = 0.504$, 95% CI [-0.009, 0.019]). Similarly, the indirect effects of the attitude towards e-smoking ($\beta = -0.002$, $p = 0.516$, 95% CI [-0.001, 0.000]) and motivation ($\beta = 0.019$, $p = .496$, 95% CI [-0.037, 0.075]) on behaviour through subjective norm and intention were not significant.

Table 4. Structural relationship between the use of electronic cigarettes and its predictors

Parameters	Estimate	SE	LL	UL	β	p	Hypothesis
Behaviour←Intention	0.761	0.032	0.698	0.824	0.760	< .001	Accepted
Intention←Subjective norm	0.038	0.055	-0.071	0.146	0.038	0.494	No accepted
Intention←Usefulness	0.238	0.071	0.098	0.378	0.239	< .001	Accepted
Intention←Ease	0.215	0.064	0.089	0.341	0.216	< .001	Accepted
Intention←Attitude	0.39	0.075	0.244	0.537	0.392	< .001	Accepted
Subjective norm←Attitude	0.165	0.047	0.074	0.256	0.165	< .001	Accepted
Subjective norm ←Motivation	0.676	0.057	0.563	0.788	0.676	< .001	Accepted

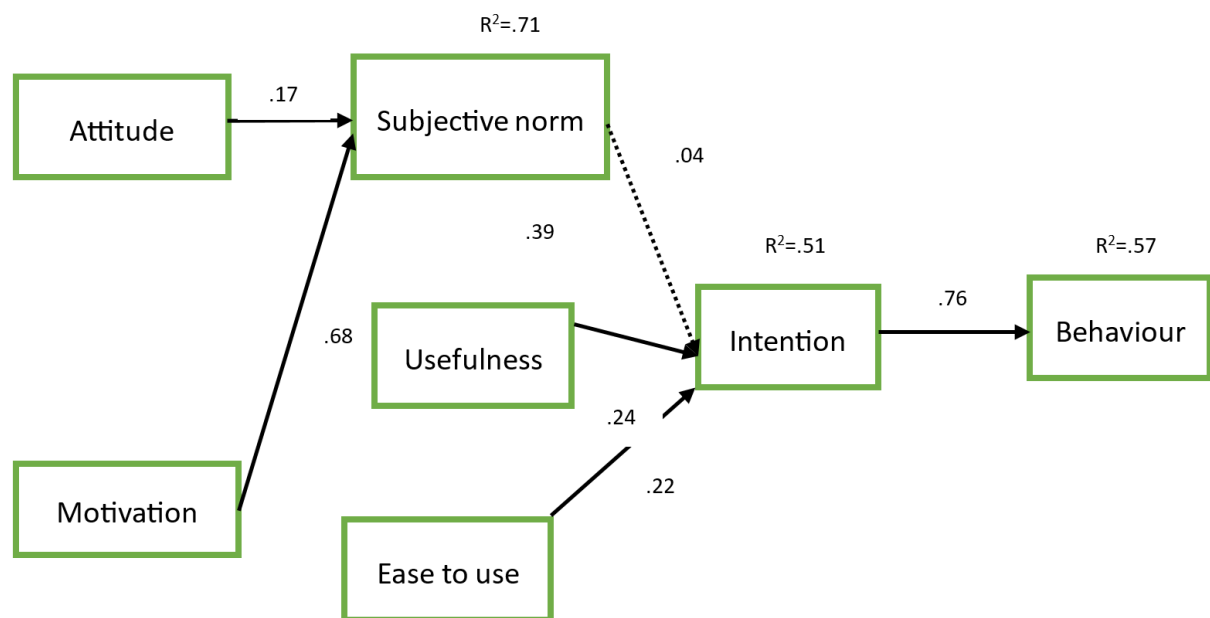


Figure 1. Structural Path Diagram

Table 5. Indirect effects on the use of e-cigarettes and their predictors

Description	Estimate	SE	LL	UL	β	p
Subjective \Rightarrow Intention \Rightarrow Behaviour	0.029	0.042	-0.054	0.111	0.029	.495
Usefulness \Rightarrow Intention \Rightarrow Behaviour	0.181	0.056	0.071	0.291	0.182	<.001
Ease \Rightarrow Intention \Rightarrow Behaviour	0.163	0.049	0.067	0.260	0.164	<.001
Total Knowledge \Rightarrow Intention \Rightarrow Behaviour	0.297	0.056	0.187	0.407	0.298	<.001
Attitude \Rightarrow Subjective \Rightarrow Intention \Rightarrow Behaviour	0.000	0.000	-0.001	0.000	-0.002	.516
Motivation \Rightarrow Subjective \Rightarrow Intention \Rightarrow Behaviour	0.019	0.029	-0.037	0.075	0.019	.496

4. Discussion

The findings of the structural analysis have emphasised that the intention to use e-cigarettes significantly and positively impacted the actual behaviour of the respondents. This finding was similar to the two previous studies that were conducted [26, 27]. One study even mentioned that adults who have never smoked EC would have a greater intention to try it soon because of its flavour and smell.

Furthermore, after the final analysis run, the usefulness and ease of use in e-smoking with the results of ($\beta = 0.182, p = 0.001$) and ($\beta = 0.164, p < .001$) were significantly and positively associated with intention. These findings are consistent with those of other studies that have found that perceived usefulness and ease of use are significant predictors of the use of e-cigarettes [28]. It can be concluded that this intention is a strong predictor in all of the analyses that have been conducted. However, the

subjective norm did not significantly affect intention. Knowledge of e-smoking negatively influenced the subjective norm, while the subjective norm was positively associated with both attitudes towards e-smoking and motivation. The subjective norm did not significantly affect intention, which is somewhat surprising, as other studies have found that social influence can play a role in the use of e-cigarettes [29].

Finally, based on the structural equation model analysis, we can conclude that people's intention to use e-cigarettes positively impacts their actual behaviour. In addition, factors such as the usefulness and ease of using e-cigarettes and one's attitude towards e-smoking were found to have a significant and positive connection with their intention. All these factors have a significant connection if we compare them with other previous studies [30, 31]. However, subjective norms were found to have no effect on people's intentions. Enough knowledge of e-smoking was found to influence subjective norms, whereas subjective norms were positively associated with both attitudes towards e-smoking and motivation. The indirect effects of norms, attitude, and motivation on behaviour through intention were not statistically significant.

On the other hand, usefulness, ease of use, and knowledge positively and indirectly affect behaviour through intention. These findings imply that the decision of people to use e-cigarettes is influenced by how they perceive the usefulness and ease of use of these devices as their attitudes towards e-cigarettes. The absence of a relationship between norms and intention indicates that social pressure does not play an important role in determining whether individuals choose electronic cigarettes. The inverse correlation between understanding e-cigarettes and personal beliefs implies that knowing about e-cigarettes could lessen the impact of norms on individual behaviour. More research is required to explore these connections.

The study results and findings are limited by the data collection method, which relied solely on face-to-face interviews with respondents. This reliance on memory introduces potential bias and subjectivity into the reported data, especially for older participants recalling specific details such as the age at which tobacco use was initiated or the monthly consumption of cigarettes. The scope of the study was limited to selected vape outlets in Samarahan and Kuching, which may not fully represent the entire population or division. Including all divisions and districts could lead to varied results. Therefore, the findings should not represent the patterns of use of e-cigarettes in Sarawak because of specific contexts and limitations. The unique characteristics of the sampled locales may not reflect the broader demographic and behavioural patterns in Sarawak.

5. Conclusions

This study comprehensively examines the factors influencing adults' electronic cigarette use in Sarawak's

Samarahan and Kuching divisions. The findings reveal that the intention to use EC, shaped by perceived usefulness, ease of use, and attitudes towards e-smoking, significantly predicts usage behaviour. Contrary to expectations, subjective norms did not significantly influence intentions, suggesting that social pressures may be less impactful in this context. Knowledge of electronic smoking was found to negatively influence subjective norms, indicating that increased awareness could mitigate the influence of social factors on the use of CE. The implications of this study are crucial for public health strategies, educational campaigns, and policy-making, highlighting the role of individual perceptions and attitudes over social influences in the adoption of EC. These insights contribute to a broader understanding of tobacco consumption patterns, with a particular focus on the emerging prevalence of ECs. Several policy implications emerge based on the research conducted. These include the need for enhanced surveillance of e-cigarette use patterns, implementation of regulatory measures similar to those for conventional tobacco products, and development of targeted public health strategies to protect youth [32]. The study's findings may also inform policies on cessation support, further research initiatives, and economic considerations such as taxation [33]. Additionally, the results could guide integrating e-cigarette regulations with broader tobacco control measures to create a comprehensive approach to reducing tobacco-related harm [32, 34]. However, the findings are subject to limitations of the scope and methodology of the study, which may affect their generalisability beyond the immediate research setting. More research is recommended to explore these dynamics in diverse populations and contexts.

Acknowledgements

We extend our heartfelt gratitude to the vape owner and study participants for their invaluable participation and cooperation, which made this research possible. We also acknowledge the faculty ethics committee for their rigorous review and granting of ethics approval, ensuring the ethical integrity of our study. Furthermore, we appreciate the Universiti Malaysia Sarawak (UNIMAS) for supporting this research endeavour and providing resources and guidance that contributed to the successful completion of this study.

Funding

Self-funded.

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