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A Structural Equation Model of Individual Greenhouse Gas Emission Behaviours for Khon Kaen: A Low Carbon City

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Abstract: ***This study investigates a structural equation model (SEM) of factors that influence individual greenhouse gas emission behaviours in the context of Khon Kaen city, northeast Thailand. The study discusses behavioural changes that are central to reducing greenhouse gas emission in a city. The study employs an exploratory, sequential mixed-method design. This qualitative study indicates that individual greenhouse gas emission behaviours consisted of seven conditions: Characteristics; knowledge; social support; motivation; attitudes; role models; and information. The model in the second phase fits with the empirical data, with p-value = 0.21758, Chi-Square/df = 1.134, GFI = 0.98, AGFI = 0.94, RMSEA = 0.019, and*** R^2 ***= 0.88. It is found that social support, motivation, attitudes, and role models played a more important role for individual greenhouse gas emission behaviours with an effect size of 0.42, 0.34, 0.29, and 0.12, respectively. Meanwhile, characteristics, knowledge, and information did not affect individual greenhouse gas emission behaviours. The authors strongly suggest that environment preservation policies, especially behavioural changes to reduce greenhouse gas emission which place importance on people's knowledge amelioration and information publicity should be improved by focusing on developing social structures, strengthening motivations, enhancing people's attitudes, and increasing the number of role models.***

Keywords: Structural equation model, Greenhouse gas emissions, Behaviour, Low carbon city

1. INTRODUCTION

The Paris agreement established a global warming goal to keep temperatures less than 2°C above pre-industrial averages and increase the ability of low greenhouse gas emission development (Streck et al., 2016). The cause of higher global average temperatures since the mid-20th century is the increase in anthropogenic greenhouse gas emission (IPCC, 2007). Urbanization is a global trend and is associated with elevated energy consumption and

greenhouse gas emissions, with urban areas accounting for 67–76% of energy use and 71–76% of energy-related CO2 emissions (IPCC, 2014). Therefore, the highest priority solution for environmental preservation and solving global warming should be focused on reducing greenhouse gas emissions from urban areas.

The low carbon city is a sustainable urbanization approach that aims to reduce the greenhouse gas emission of cities (Ismaila and Yakubu, 2019). The solutions to achieve a reduction in greenhouse gas emissions require a combination of technological development, infrastructure investments, and behavioural change (Milner et al., 2012). Lifestyle changes are of considerable importance as solutions to reduce greenhouse gas emissions (IPCC, 2014; Moriarty and Wang, 2014; Schanes et al., 2016; Samadi et al., 2018) within the next two decades (Moriarty and Wang, 2014). Behavioural changes therefore play an important role for a low carbon city approach.

Khon Kaen is a secondary city of Thailand that has been raised to distinction as a regional economic and logistic hub in Thailand's north-eastern region (Sudhipongpracha and Dahiya, 2019). The city's economic growth and urban population have led to increased greenhouse gas emissions. Khon Kaen Municipality' goal for their four-year plan (2018-2021) to achieve a low carbon city and the primary implementation of the plan places importance on enhancing people's knowledge and attitudes.

In recent decades, research into the factors that influence individual greenhouse gas emission behaviour has increased. Previous studies found that personal characteristics (Zhang et al., 2015; Yue et al., 2013; Han et al., 2013; Hori et al., 2013), knowledge of reduction in greenhouse gas emissions (Han et al., 2013; Chen and Li, 2019), environmental preservation attitudes (Hori et al., 2013; Chen and Li, 2019; Ngo et al., 2009; Hamamoto, 2013), and motivations (Han et al., 2013; Shalev, 2015) influence individual greenhouse gas emission behaviours. Most scholars explored these factors using linear statistical models that have some limitations when used as a model within the social sciences.

Structural equation modelling (SEM) is currently one of the most distinguished analytical strategies in many fields of the social sciences (Evermann and Tate, 2009). However, few studies illustrate the use of SEM in the factors influencing individual greenhouse gas emission behaviour in the context of urban areas in Thailand. The concept of low carbon city planning does not depend on only a single discipline and it unavoidably requires the use of multidisciplinary application (Cao and Li, 201; Young and Middlemiss, 2012) and social science perspectives are urgently required (Young and Middlemiss, 2012). Furthermore, many environmental preservation policies and management, especially behavioural changes to reduce greenhouse gas emission, are often based on the belief that enhancing people's knowledge and attitudes can lead to behavioural changes (Barr and Gilg, 2007). Nonetheless, it is important to understand whether attitudes and knowledge are sufficient to change behaviour. Furthermore, it is important to identify which factors influence individual greenhouse gas emission behaviour. This interesting issue has received little attention which is the main inspiration for this study. This research integrates various fields including social sciences, energy, environmental science, and statistics to investigate a structural equation model of factors that influence individual greenhouse gas emission behaviour in the context of Khon Kaen as a low carbon city.

2. MATERIALS AND METHODS

Materials

The materials of this study are a literature review and a conceptual framework. A literature review of human behavioural theories found various theories or concepts of people's behaviour. For instance, Akintunde (2017) concluded that although there are many theories of environmental preservation behaviour, none of these theories can independently and entirely explain human-environment behaviour, yet a combination of these theories would undoubtedly provide further insights and possible solutions for increasing emissions in the 21st century.

A social cognitive theory proposed by Bandura (1986) concluded that people are driven by personal and environmental factors. Personal factors include attitudes, other individual motivational forces and environmental factors represent situational influences and the environment in which behaviour is performed. Further, the practice of everyday life concept proposed by De Certeau (1984) concluded that people's activities can manipulate the environment around them through everyday actions, even though everyday life is dominated by consumerism due to individual loss, but this dominance is not complete, and people have the potential and tactics that scramble for benefits from the social structure. Besides, Giddens (1986) proposed the structuration theory, a sociological concept that offers perspectives on human behaviour based on a synthesis of structure and agency. Giddens described that social structure and agency are a duality, with humans as the creator of the social structure, yet they are simultaneously influenced by the structure of society.

Previous studies (Zhang et al., 2015; Yue et al., 2013; Han et al., 2013; Hori et al., 2013; Chen and Li, 2019; Ngo et al., 2009; Hamamoto, 2013; Shalev, 2015) and related theories and concepts (Akintunde, 2017; Bandura, 1986; De Certeau, 1984; Giddens, 1986) enable the drawing of a conceptual framework that suggests which factors have a tendency to influence individual greenhouse gas emission behaviours, as presented in Figure 1.

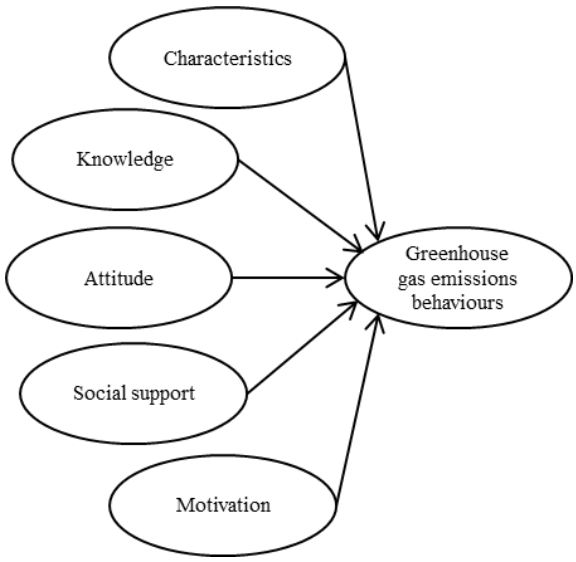

Figure 1. Conceptual framework

Research Design

This study employed an exploratory sequential mixed-method design, with both a qualitative and a quantitative phase (Creswell and Plano Clark, 2018). The qualitative study aimed to understand the conditions or factors that tend to influence individual greenhouse gas emission behaviours. The qualitative results were applied to design a questionnaire and develop a model in the next phase. The objective of the second phase was to investigate a structural equation model of factors that influence individual greenhouse gas emission behaviours using a quantitative approach.

Qualitative Phase

The study applied a snowball sampling technique, with data collected through in-depth interviews with 16 key informants who had participated in low carbon or environment preservation activities. Interview guidelines applied from the conceptual framework were a tool for data collection. In-depth interviews were conducted in 2018 with each lasting for 60 - 90 minutes for each interviewee. Data was analysed by content analysis and the analysis tool was ATLAS.ti. In the data analysis, a triangulation technique was utilized to check multiple sources and coders in order to offset bias and validate data for interpretation.

Quantitative phase

Sample Size

According to formula (1) which was introduced by Cochran (Cochran, 1977) to calculate the sample size in a large population case, a sample size of 385 respondents was deemed to be required, with a margin of error (e) of 5% at a 95% confidence level (Z=1.96).

$$n = \frac{Z^2 pq}{e^2}$$

Where: n – Sample size
Z – Standard normal score
p – Proportion of elements in the population that has a particular attribute: p=0.5
q – $1 - p$
e – Margin of error

This sample size (n=385) is large enough for SEM according to formula (2) (Marsh et al., 1998), a sample size of 116 respondents is required when there are 30 observed variables and 8 latent variables.

$$n \geq 50r^2 - 450r + 1100$$

Where: r – p/k
p – Number of observed variables
k – Number of latent variables

Sampling

Data was collected between 2018 and 2019, with the average survey questionnaire completion time of 30–45 minutes. The sampling applied a multi-stage random sampling as follows:

I Selected communities using simple random sampling (SRS).
II Selected house numbers using systematic sampling.
III Selected a single person per house number using SRS.

Data Analysis

This study illustrates the use of SEM in the factors influencing individual greenhouse gas emission behaviours using LISREL 8.72. The model fit based on five criteria was as follows: p-value > 0.05, Chi-Square/df < 2, 0.95 < GFI < 1.00, 0.90 < AGFI < 1.00, and 0 < RMSEA < 0.05 (Bollen, 1989; Diamantopoulos and Siguaw, 2000). A flow chart of the materials and methods of the present study is illustrated in Figure 2.

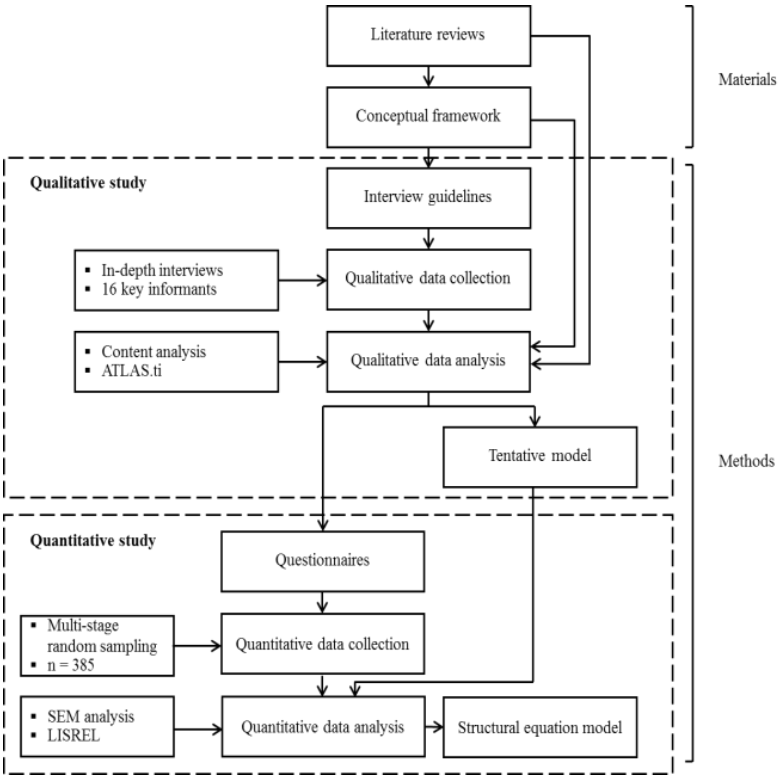

Figure 2. Flow chart of materials and methods of this study

3. RESULTS

Qualitative Results

The participants answered the following main questions: *How can you reduce your greenhouse gas emissions in your everyday life, and what are the conditions or factors that tend to influence individual greenhouse gas emission behaviours in Khon Kaen Municipality areas?* In accordance with literature reviews, supporting theories, and the qualitative data, it is found that energy-saving, selecting efficient equipment, equipment maintenance, use of

green products, and effective waste management were related to individual greenhouse gas emission behaviours. Meanwhile, the conditions or factors that had a tendency to influence the individual greenhouse gas emission behaviours include five latent variables as follows: Characteristics (comprising four observed variables, sex, education, age, and income); attitude (comprising two observed variables, perspective of environmental preservation, and environment preservation participation); knowledge (comprising five observed variables, energy-saving knowledge, equipment knowledge, maintenance knowledge, green product knowledge, and waste management knowledge); motivation (comprising five observed variables, passive income, saving, security, convenience, and self-esteem); and social support (comprising five observed variables, energy-saving activities, efficient equipment shops, equipment maintenance services, green products and services, and waste management systems). Furthermore, two latent variables were also found to positively correlate with attitude and knowledge, namely role model (comprising two observed variables, neighbourhood and celebrity) and information (comprising two observed variables, social media and traditional media).

The above findings and related theories allow a tentative model to be developed with conclusions regarding the factors that influence individual greenhouse gas emission behaviours in the context of Khon Kaen city. The relationships of this are mapped in Figure 3.

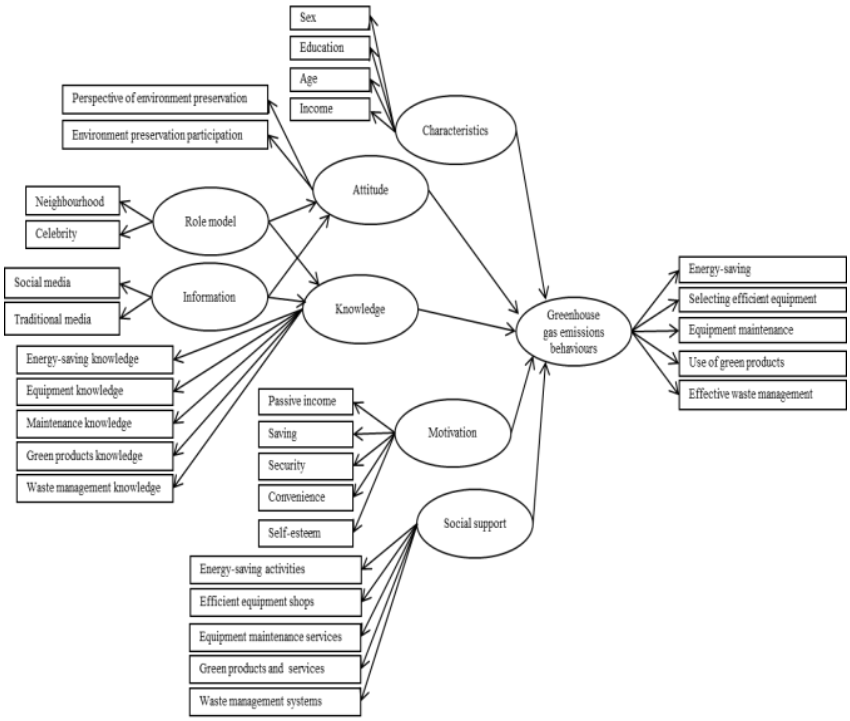

Figure 3. Tentative model of the factors that influence individual greenhouse gas emission behaviours

Quantitative Results

The tentative model and supporting theories were applied to develop a structural equation model of factors that influence individual greenhouse gas emission behaviours in the

quantitative phase. Table 1 demonstrates the sample characteristics, while Table 2 presents descriptive statistics and factor loadings of all variables in the model.

Table 1. Sample characteristics

Characteristics	Characteristics	n (%)
Gender	Male	152 (39.5)
	Female	233 (60.5)
Age (years)	< 20	32 (8.3)
	20 - 29	111 (28.8)
	30 - 39	78 (20.3)
	40 – 49	72 (18.7)
	50 – 59	47 (12.2)
	> 60	45 (11.7)
Education level	Primary school	66 (17.1)
	High school	112 (29.1)
	Diploma	37 (9.6)
	Bachelor's degree	170 (44.2)
Monthly income (Thai baht)	< 10,000	183 (47.6)
	10,000 – 20,000	136 (35.3)
	20,000 – 30,000	34 (8.8)
	> 30,000	32 (8.3)

Table 2. Descriptive statistics and factor loadings of all variables in the model

Latent variables	Observed variables	$\bar{x}$	Std. Dev.	Factor loadings
Social support	S1	2.71	0.52	0.65
	S2	2.77	0.61	0.81
	S3	2.72	0.60	0.82
	S4	2.75	0.64	0.80
	S5	2.62	0.63	0.64
Motivation	M1	2.47	0.73	0.57
	M2	2.69	0.57	0.64
	M3	2.61	0.70	0.74
	M4	2.69	0.61	0.70
	M5	2.67	0.67	0.48
Attitude	A1	2.98	0.54	0.95
	A2	2.80	0.48	0.82
Role model	R1	2.33	0.63	0.45
	R2	2.62	0.58	0.57
Greenhouse gas emission behaviours	B1	2.60	0.36	0.36
	B2	2.77	0.56	0.90
	B3	2.58	0.58	0.73
	B4	2.60	0.53	0.67
	B5	2.45	0.41	0.73

Note: S1=Energy-saving activities, S2=Efficient equipment shops, S3=Equipment maintenance services, S4=Green products and services, S5=Waste management systems, M1=Passive income, M2=Saving, M3=Security, M4=Convenience, M5= Self-esteem, A1=Perspective of environment preservation, A2=Environment preservation participation,

R1=Neighbourhood, R2=Celebrity, B1=Energy-saving, B2=Selecting efficient equipment, B3=Equipment maintenance, B4=Use of green products, and B5=Effective waste management

The model is presented in Figure 4 and fits with the empirical data with the five criteria in Table 3. The model shows that individual greenhouse gas emission behaviours (R^2= 0.88) account for 88% of the model's predictive accuracy.

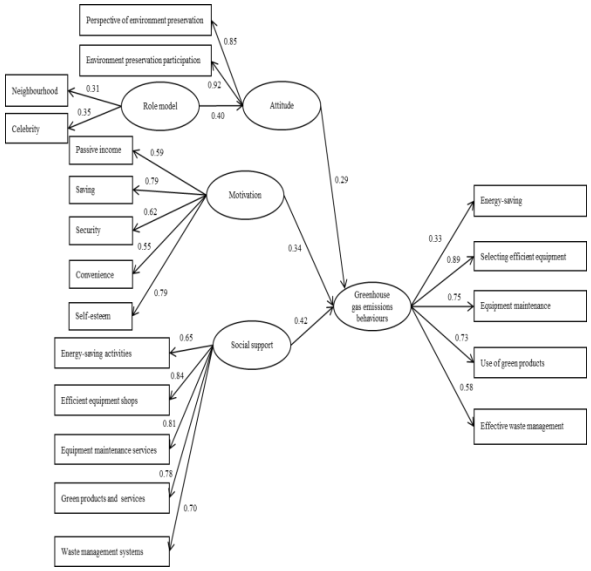

Figure 4. Structural equation model of the factors that influence individual greenhouse gas emission behaviours

Table 3. Model fit

Goodness of fit indices	Criteria	Result
p-value = 0.21758	> 0.05	Pass
χ^2/df = 1.134	< 2	Pass
GFI = 0.98	0.95 < GFI < 1.00	Pass
AGFI = 0.94	0.90 < AGFI < 1.00	Pass
RMSEA = 0.019	0 < RMSEA < 0.05	Pass

In sum, this model shows that social support, motivation, attitudes, and role models are positively correlated with individual greenhouse gas emission behaviours. The effect of the variables on the individual greenhouse gas emission behaviours is presented in Table 4.

Table 4. Effect of the variables on individual greenhouse gas emission behaviours

Variable	Effect	Attitude	Behaviours
Role model	TE	0.40	0.12
	IE	-	0.12
	DE	0.40	-
Attitude	TE		0.29

	IE		-
	DE		0.29
Motivation	TE		0.34
	IE		-
	DE		0.34
Social support	TE		0.42
	IE		-
	DE		0.42

Note: TE =Total Effect, IE = Indirect Effect, DE = Direct Effect.

4. DISCUSSION

The qualitative study confirms that five factors (characteristics, knowledge, social support, motivation, and attitude) from the conceptual framework tended to influence individual greenhouse gas emission behaviours. Furthermore, two factors (role model and information) are found to be positively correlated with attitude and knowledge. However, the model in the quantitative phase shows that social support, motivation, attitudes, and role models play a more important role for individual greenhouse gas emission behaviours, while characteristics, knowledge, and information do not. This study aims to investigate a structural equation model, so for the research design, the quantitative research approach is more dominant than the qualitative study, supporting the research design by Creswell and Plano Clark (2018) which proposed that the exploratory sequential mixed-method study can prioritize either the qualitative or quantitative components.

The research findings support the claim that social support in energy-saving activities, efficient equipment shops, equipment maintenance services, green products and services, and waste management systems positively affect and strongly impact individual greenhouse gas emission behaviours. This finding concurs with Giddens (1986) who described that the structure of society can stipulate people's behaviour. Moreover, Bandura (1986) proposed that people are driven by environmental factors, while the present study findings suggest that the structure of society and environmental factors are social supports for low carbon implementation.

The model supports that motivation, comprised of passive income, saving, security, convenience, and self-esteem, has a positive, direct influence and significant impact on individual greenhouse gas emission behaviours. This finding concurs with Han et al. (2013) and Shalev (2015) who confirmed that motivation is highly correlated with behaviour. This result is also consistent with Bandura (1986) who proposed that motivational forces drive people’s behaviour. Besides, the researchers argue that motivations of greenhouse gas emission behaviours imply that they benefits people’s needs, as conceptualized by De Certeau (1984).

In addition, the model also indicates that attitudes which measured through perspectives of environmental preservation and environment preservation participation efforts had positive effects on individual greenhouse gas emission behaviour, supported by the results of Hori et al. (2013), Chen and Li (2019), Ngo et al. (2009), and Hamamoto (2013). Further, the model also shows that role models of low carbon behaviour from the neighbourhood and celebrities have a direct influence on attitudes.

Finally, another important finding is that personal characteristics do not significantly influence individual greenhouse gas emission behaviours, which disagrees with the findings of Zhang et al. (2015), Yue et al. (2013), Han et al. (2013), and Hori et al. (2013). Meanwhile, people's knowledge amelioration is not found to positively influence individual low carbon behaviours, which is in opposition to the findings of Han et al. (2013) and Chen and Li (2019). Furthermore, information publicity is not found to correlate with enhancing people's attitude. The authors argue increasing public knowledge and information publicity do not currently have a significant effect on individual low carbon behaviours.

5. CONCLUSION

This research integrates various fields including social sciences, energy, environmental science, and statistics and employs an exploratory sequential mixed-method design to investigate a structural equation model (SEM) of factors that influence individual greenhouse gas emission behaviours in the context of Khon Kaen city, northeast Thailand. The model shows that social support, motivation, attitudes, and role models have a more significant influence on individual greenhouse gas emission behaviours, with an effect size of 0.42, 0.34, 0.29, and 0.12, respectively. Meanwhile, characteristics, knowledge, and information did not have a significant influence on individual greenhouse gas emission behaviours. The researchers strongly suggest that the environment preservation policy, especially behavioural changes to reduce greenhouse gas emission which place importance on increasing people's knowledge and information publicity should be improved by focusing on developing social structures, strengthening motivations, enhancing people's attitudes, and increasing the number of role models.

The findings from the present study have some limitations that must be acknowledged. First, only cross-sectional data was used, and second this study only focused on individual greenhouse gas emission behaviours. Future studies could therefore focus on long-term observations and organizational behaviour changes.

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