STUDY ON SOLID WASTE BEHAVIOUR BY STRUCTURAL EQUATION MODELING (SEM) - A MINI REVIEW

TỔNG QUAN VỀ ỨNG DỤNG MÔ HÌNH CẤU TRÚC TUYẾN TÍNH (SEM) TRONG NGHIÊN CỨU HÀNH VI QUẢN LÝ CHẤT THẢI RẮN

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Abstract - This paper aimed to present a mini review on applying Structural Equation Modeling (SEM) for behavioural research on solid waste management. This paper examined the literature on behavioural research of solid waste management across various geographical regions. Households were the ubiquitous research subject of the studies on waste separation behaviour, while business sectors - accounting for a large amount of waste generation - were not pervasively studied. Theory of planned behaviour (TPB) was the dominant theory model for studies on waste separation behaviour. However, waste separation behaviour would be extremely complex so base theory integration was highly recommended. Five-point and seven-point Likert scales were the most ubiquitous scales utilised. PLS-SEM would be a "Silver bullet" due to its advantages in data analysis. The results of this study are expected to be a reference for managers, decision-makers, policymakers, researchers, and other stakeholders in solid waste management studies and projects.

Key words - Behavior Modelling; Recycling; Structure Equation Modeling (SEM); Waste Management; Waste Separation

Tóm tắt - Nghiên cứu này đã thực hiện tổng quan các tài liệu nghiên cứu về áp dụng Mô hình cấu trúc tuyến tính (SEM) nghiên cứu hành vi thực hiện quản lý chất thải rắn (QLCTR). Kết quả nghiên cứu thể hiện rằng hộ gia đình là đối tượng nghiên cứu phổ biến về hành vi QLCTR. Các nghiên cứu về các đối tượng hoạt động trong lĩnh vực thương mại, dịch vụ và các cơ sở sản xuất còn hạn chế. Lý thuyết hành vi có kế hoạch (TPB) là mô hình lý thuyết phổ biến cho các nghiên cứu về QLCTR. Tuy nhiên, do đặc thù phức tạp của hành vi QLCTR, sự tích hợp các lý thuyết nền cần được xem xét. Thang đo Likert năm điểm và bảy điểm là những thang đo được sử dụng phổ biến nhất. Mô hình phương trình cấu trúc dựa trên bình phương tối thiểu riêng phần (PLS-SEM) được kỳ vọng là "Viên đạn bạc" nhờ những ưu điểm trong phân tích dữ liệu. Kết quả của nghiên cứu này là tài liệu tham khảo cho các nghiên cứu và dự án về QLCTR.

Từ khóa - . Mô hình cấu trúc tuyến tính (SEM); Mô hình hóa hành vi; Phân loại chất thải rắn; Quản lý chất thải rắn; Tái chế

1. Introduction

The current linear economy has resulted in disposal systems collapsing with desperate environmental, economic, and social consequences [1]. Thus, the circular economy is expected as a solution due to its advantages in resource consumption and lower pollution rate [2]. Additionally, a circular economy would promote solid waste management in an eco-friendly approach and enhance disassembly and reintegration into the manufacturing cycles of other supply chains, as well as reduce improper disposal and create nascent opportunities for business and job hunters [3].

Human beings are one of the most important components of the economy and solid waste management system. Thus, understanding human behaviour plays a vital role in enhancing the circular economy and solid waste management system. For understanding social behaviours of human beings, there are two main groups of behavioural research: qualitative research and quantitative research based on the treatment of data. Multivariate Data Analysis (MDA) - a quantitative research technique - has been widely applied due to available statistical evidence. Notably, Structure Equation Model (SEM) - an MDA technique - has been applied to gain deep knowledge about human behaviour due to the capability of addressing a multi-variate, multiequation, and research problem with a single analysis [4]. Model of SEM - combining factor analysis and regression or path analysis - has been being used ubiquitously in behavioural research [5]. Moreover, SEM is a multivariate statistical tool consisting of measurement and structural models [6]. Interestingly, SEM can conduct simultaneous assessments of interrelationships between a plethora of independent and dependent variables [7].

The first ideas about the linear causal model - a prerequisite of SEM - should be dated back to Sewall Wright (1918) in agricultural science as well as Wold and Jureen (1953), Simon (1957), and Blalock (1964) in social research [8]. The SEM was considered to be first introduced in 1975 by Duncan, Otis Dudley in the book with title: "Introduction to Structural Equation Models" [9]. Simultaneous maximum likelihood estimation of a theory was also introduced thanks to Jöreskog and Sörbom in the late 1960s and early 1970s. After that, the boom in studies that applied SEM was denoted, especially in the decade of 1900s. Thanks to the development of computer processing power, SEM has been omnipresent in social science due to its ability to analyse complex behavioural models [4].

The ubiquity of applying psychological theories to pro-environmental behaviours has been denoted for the last recent decades. In 1981, Bentler and Speckart [10] published a paper to examine the results of analysis from different types of measurement for environmental concern.

This paper offered a clear picture illustrating hypothesized behavioural model of authors. A similar paper - offered a picture illustrating a research hypothesis about ecological concern and voting behaviour - was also published in 1986. These papers were considered as starting papers for the proliferation of studies applying SEM for pro-environmental research in the next decades.

The original studies - would be the first efforts to apply SEM into solid waste management - were recognized in 1990s namely studies about household recycling and composting intentions [11], recycling behaviour [12-14], recycling consumer behaviour [15], the behaviour of paper recycling [16], relationships of personal values, attitudes and beliefs about recycling, and the recycling of solid waste products [17]. Recently, the studies on behaviour in solid waste management have been enhanced by adopting new generation of statistical techniques such as the covariance-based approach (CB-SEM) and variance-based partial least squares approach (PLS-SEM).

Despite the popularity of applying SEM in behavioural studies, the picture of using SEM in behavioural studies on solid waste management has not been well updated recently. Notably, the state-of-the-art method for data analysis has been upgraded to fulfil the requirement of social and pro-environmental studies. To be specific, PLS-SEM has been gradually well-known as a competitor of traditional second-generation statistical technique - CB-SEM - for dealing with social modelling.

As a result, this paper aimed to present a mini review on the application of SEM for behavioural research on solid waste management with a focus on advances of PLS-SEM. The specific research aims are i) Describing a general picture of the application of SEM for behavioural research on solid waste management, ii) identifying base theory for SEM (solid waste management), and iii) examining the advantages of application of PLS-SEM for behavioural research on solid waste management.

2. Method

A literature search was conducted to collect papers for this research — with a focus on papers applied PLS-SEM for data analysis. At first, we used a string — Solid waste management (All Fields) and SEM (All Fields) and behaviour (All Fields) — to search in the database of Web of Science. The reference lists of all papers were also researched to have more papers published within the scope of this study. All irrelevant studies, which have not belonged to the scope of this study: solid waste management, SEM, and behaviour modelling — were eliminated from the results of the literature search. Additionally, this study will focus on the papers published within two recent decades due to the objective of updating research trend for applying SEM into solid waste management. As a result, 47 original papers (two recent decades) were chosen for further analysis within scope of this study.

3. General features of studies

Figure 1 illustrates the number of studies that applied SEM to solid waste management from 2010 to 2023 due to the results of literature searching. The number of studies published increased rapidly, especially from one study (2012) to ten studies (2021), six studies (2022), and seven studies (2023) as a result of literature searching. This denoted the accentuating interest of the science world toward applying SEM in researching the behaviour in solid waste management.

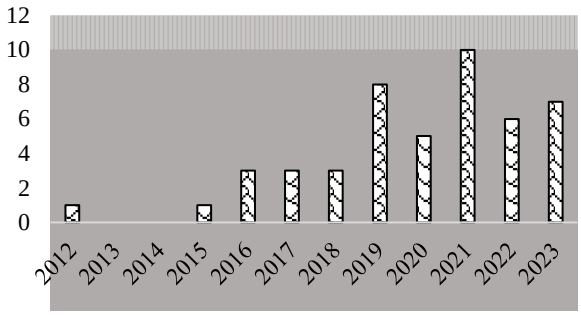

Figure 1. *The number of studies found by years*

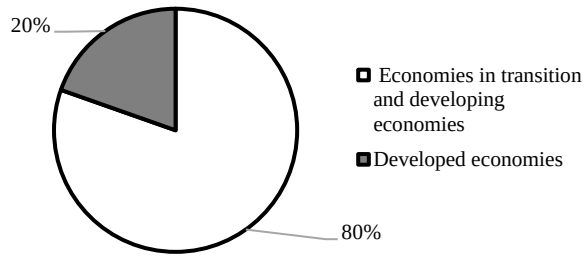

Figure 2. *The proportion of studies conducted by economies*

Figure 2 illustrates the percentages of studies conducted by economies. Interestingly, the number of studies implemented in economies in transition and developing economies (80%) was significantly higher compared with developed economies (20%), in which China was the highest contributor (n=17, 31%) in comparison to other countries. Besides, some cities with distinct characteristics were also chosen for studies. In Vietnam, Hanoi [18-20], Danang [21-23], and Hoi An [24, 25] were three pervasive research areas where the number of studies applied SEM outweighed other cities. These cities - Hanoi, Danang, and Hoi An - are areas where pilot projects of solid waste separation at source or compulsory solid waste separation programs are implemented, attracting a host of studies about the behaviour of waste generators.

Notably, the studies which played a pioneering role in applying SEM to solid waste management, substantially came from developed economies namely The United States of America (USA). These studies were conducted to enhance the recycling of material in the society in USA in the decade of 1990s [12, 15, 17, 26].

Figure 3 depicts the number of studies by research areas. The majority of studies focused on topics of waste separation behaviour (n =22, 47%), followed by recycling behaviour (n=7, 15%) and predicting behaviour (n=7, 15%).

Regarding category of waste separation behaviour, studies clarified factors which contribute to behaviours of solid waste separation at source [24, 27-38] and factors affecting intention of waste separation [18, 19, 39-42]. The model of TPB and its extended versions were

omnipresently applied to these studies. Integration of TPB and other models was also implemented to understand decision-making mechanism toward solid waste separation and recycling [43]. Moreover, the problems and challenges of conducting solid waste separation at source were also researched to have modifications for enhancing the effectiveness of solid waste management system [44].

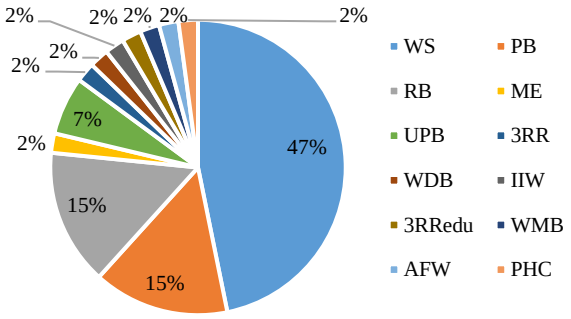

Figure 3. *The percentage of studies by category*

Notes: WS: Waste separation; PB: Predicting behaviour; RB: Recycling behaviour; ME: Measuring effect; UPB: Understanding on proenvironmental behaviour; 3RR: 3R behaviour: Reuse; WDB: Waste disposal behaviour; IIW: Intention to invest for solid waste management; 3Rredu: 3R behaviour: Reduce; WMB: Waste management behavior; AFW: Attitude toward food waste; PHC: Participation in home composting

Recycling behaviour has been a ubiquitous topic for applying SEM to solid waste management even in the early stage of applying SEM into solid waste management in 1990s [11-14, 16, 17]. Due to result of literature search within scope of this study, studies on recycling behaviour clarified the driving force of solid waste recycling among people and business sectors in parts of the world such as South Africa [45], Vietnam [20, 46], Indonesia [47], Malaysia [48], China [48, 49], and USA [50]. The TPB extended and modified knowledge-attitude-practice (KAP) model were two prominent models applied for recycling behaviours.

Regarding category of prediction, studies applied principles of SEM into prediction of solid waste generation behaviour [51], intention and behaviour of solid waste separation at source [34, 52, 53], the behaviour of recycling and waste minimization [54, 55], as well as the effect of promotion measure on enhancing solid waste separation at source [23]. Although these studies were classified as prediction, the basic ideas of prediction originated from the base theory such as TPB and NAM with popular technical analysis namely descriptive analysis, CB-SEM, and PLS-SEM. The most considerable difference would be the focus on prediction on behaviour and intention of waste generators. Interestingly, aspects of 3R such as reduction and reuse were also topics of behavioural studies in solid waste management. However, these studies only examined people's intentions about solid waste reduction [56] and reusing food containers [57]. The difficulty in measuring the behaviour would be one of the reasons why studies did not integrate behaviour into the research model.

Moreover, the main subject of studies was households (n=37, 79%). The business sector was not well researched (n=2, 4%) despite accounting for a large proportion of municipal solid waste generation [58, 59]. Despite two studies published about the recycling waste among commercial and industrial sectors [48, 49], more studies should be conducted to enrich the understanding of the behaviour of commercial and industrial sectors toward solid waste management and the environment. This is a research gap for studies on applying SEM to solid waste management behaviour.

4. Base theory for applying Structural equation modelling (SEM) into solid waste management

The theory of Planned Behavior (TPB) was dominantly utilized (n=28, 60%) in studies about behaviour modelling. Besides, Norm Activation Model (NAM) was the second omnipresent theory (n=4, 9%) applied to behavioural studies on municipal solid waste management.

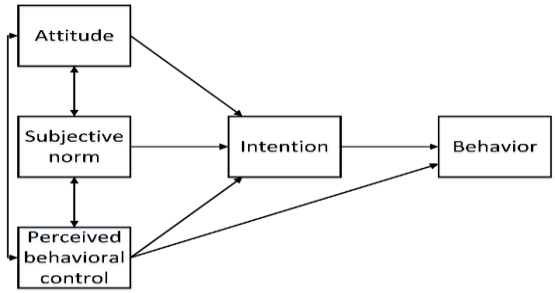

Figure 4. *Theory of planned behaviour (TPB) [60]*

The TPB was first introduced by Ajzen and Fishbein as the Theory of Reasoned Action (TRA), being the forerunner of the TPB, with the addition of predictions of specific intentions and behaviour [61]. The TPB can be understood as an expansion on the TRA by adding perceived behavioural control (PBC), reflecting people's beliefs or control over their actions [62], as well as an illustration of the "available resources and opportunities" [62].

Figure 4 illustrates the original TPB model. Due to this model, the behaviour of human beings is strongly affected by human intention and their perceived behavioural control. Additionally, human intention is affected by attitude, subjective norm, and perceived behavioural control. Interestingly, these variables would also associate with each other.

Due to results of the review, TPB was applied - as the theoretical framework of SEM - to promote waste separation at source [18, 19, 24, 27-31, 34, 36, 38-44, 51], recycling behaviour [20, 45, 47-49], waste reduction [56], 3R behaviour: Reuse [57], waste disposal behaviour [63], intention to invest on solid waste management project [64], general waste management behaviour [65], and recycling and composting behaviour [11].

Similarly, NAM was first introduced by Schwartz in 1977, which could contribute as a tool to discover the driving force of human intention towards altruistic and pro-environmental behaviours [67]. The variables of NAM model would be awareness of consequences attitude (AC), ascription of responsibility (AR), personal norms (PN), behavioral intention (BI), and behavior. The relationships between variables of NAM model are illustrated in Figure 5.

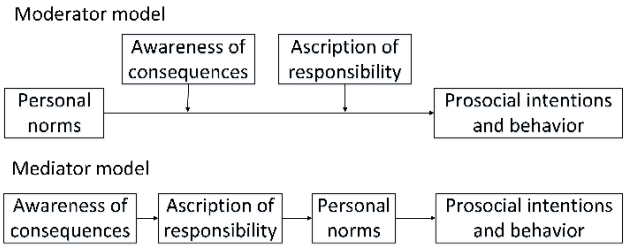

Figure 5. *Norm activation model (NAM) [66]*

NAM was applied - as a theoretical framework of SEM - to predict household food waste behaviour [55] as well as enhance waste separation at source [35] and 3R behaviour: Reduce [55].

The TPB and NAM, despite being ubiquitously applied in behavioural studies on solid waste management, the additional latent variables namely trust [18, 19, 24], benefit [19, 29, 31, 48, 49], satisfaction with policy [30], environmental concern [40, 65], institutional motivation [63], higher-order variable of behavioural expectation [57] were normally added to TPB and NAM models to have a more comprehensive model for explaining the behaviours of the research subject. Moreover, due to the complexity of human psychology, the one theory itself cannot fully explain the driving force toward the behaviour of waste generators. As a result, integrating theory into explaining the behaviours of waste generation is an undeniable trend. For example, a study integrated TPB and NAM intending to have an understanding of the intention of Malaysians toward reducing food waste [56]. Similarly, a study - implemented in China - integrated TPB and Attitude-Behavior-Condition theory to have understandings of decision-making mechanism of citizens toward disposal behaviours [43]. Notably, the integration of the theory of reasoned action (TRA) and the social exchange theory (SET) was conducted to investigate the Leave No Trace (LNT) behaviour of hikers in Hong Kong, China [43].

5. Likert scale for measuring indicator

The utilisation of the Likert scale for applying SEM to behavioural studies of municipal solid waste management was pervasive. The five-point and seven-point Likert scale were widely conducted for measuring indicators. This has been proper with the trend of using the Likert scale in other industries. For example, the five-point Likert scale would include (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, and (5) Strongly agree while seven-point Likert scale would have (1) Strongly disagree, (2) Disagree, (3) Slightly disagree, (4) Neutral, (5) Slightly agree, (6) Agree, (7) Strongly agree. There were 33 studies (70%) that utilised five-point or seven-point Likert scale while two studies (1%) utilised four-point Likert scale - five-point scale which deleted option of "Neutral". Many studies confirm that data from the Likert scale becomes considerably less accurate when the number of scale points is below five or above seven [68]. However, there has been a shortage of opinions on using these two types of scales [68]. A five-point scale - preferred to a seven-point scale - helps improve both response rate and response quality [69] and is simple in use [70]. Moreover, a five-point reliability coefficient comparison with other research using five-point Likert Scales [50] would be possible. On the other hand, a seven-point scale offers more options, increasing the probability of meeting people's objective reality, and is more accurate [71, 72].

Recently, there were studies that the five-point Likert scale would be deleted neutral choice, utilising a four-point Likert scale [44, 73]. This was an effort of the authors to enhance the data quality, eliminating answers from lazy or not severe survey attendants. The choice between a five-point Likert scale and seven-point Likert scale should be considered in a comprehensive manner. A five-point Likert scale would be simple and easier for data collection and analysis in comparison to a seven-point Likert scale. The seven-point Likert scale would offer more specific information than the five-point Likert scale.

6. PLS-SEM as a "silver bullet"?

At present, there are two universal approaches for examining SEM: CB-SEM and PLS-SEM [74, 75]. Recently, PLS-SEM has been more omnipresent than CB-SEM due to some reasons. Firstly, PLS-SEM can identify the most effective factor in predicting the behaviour [76]. Secondly, the normal distribution of data can be ignored [33]. Thirdly, construct - having less than three indicators - can also be analysed [33]. Fourthly, some indicators would not need to be eliminated to have an acceptable model fit in comparison to CB-SEM. Fifthly, the requirement for the sample size of PLS-SEM was not as strict as CB-SEM [74, 77, 78]. Regarding sample size, it would be hard to identify an exact number for small sample size, large sample size, or proper sample due to the variety in statistical power, contexts and complexity of the research model for both CB-SEM and PLS-SEM. However, the minimum sample size for CB-SEM has been recommended as 200 [79] while the minimum sample size for PLS-SEM could be less than 100 [4]. This denoted a gap between the requirement for the sample size of CB-SEM and PLS-SEM. Notably, these minimum sample sizes for CB-SEM and PLS-SEM would be the minimum number mentioned by theory. Application of SEM, again, should consider the context and other requirements for statistical power regarding sample size.

Sixthly, it is convenient to use PLS-SEM for analyzing the moderating effect [80]. Seventhly, PLS-SEM is a technique appropriate for research with the extension of an underlying theory [78]. Finally, PLS-SEM has the capability to analyse complex models containing latent variables [78].

However, the number of studies that adopted CB-SEM was similar to PLS-SEM from 2012 to 2023 (Figure 6). Despite the new, well-known method for data analysis - PLS-SEM, the number and trend of behavioural studies that adopted CB-SEM and PLS-SEM in solid waste management were similar (Figure 6). This would depict the confirmation of base theory and founding a new model attracting similar interest from researchers. CB-SEM is often used to confirm established theories, while PLS-SEM is often implemented for exploratory research [75]. Moreover, it is not a stressful situation to fulfil the

requirement of a normal distribution of behavioural studies on solid waste management despite the fact that the normal distribution of data is seldom satisfied [75].

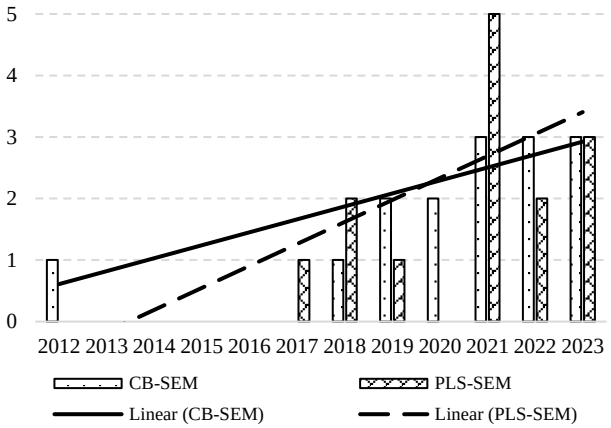

Figure 6. *The number of studies applied CB-SEM and PLS-SEM by year*

Trend for behavioural studies of solid waste management would not be an exception in the flow of behavioural research. The increased rate of studies applying PLS-SEM compared with those of CB-SEM would be higher (Figure 6). Thus, the number of studies adopting PLS-SEM is expected to be rapidly increased in the near future.

7. Conclusion

This briefly describes applying SEM to behavioural studies in solid waste management. Despite an increase of behavioural studies using SEM, studies on the behaviour of the business sector - accounting for a considerable amount of municipal solid waste generation - were limited. The TPB was undeniably the most ubiquitous base theory applied, followed by the NAM. However, integrating a variety theory in behavioural studies (solid waste management) would be the trend due to the development and complexity of human society. The five-point Likert scale and the seven-point Likert scale were two popular scales for indicators. CB-SEM has been a popular data analysis method despite the expeditious development of PLS-SEM.

The limited number of behavioural studies of the business sector leads to the urgent need to fill this research gap, especially for future research. Besides, the next studies should consider eliminating the neutral answers of the Likert scale to improve the quality of the survey and data. Finally, PLS-SEM is a potential tool for its advantages, being powerful for establishing new models or examining new research with a small sample size (<100) depending on some conditions [4].

This study would be a reference for managers, decision-makers, policymakers, researchers, and other stakeholders in conducting solid waste management studies and projects. Moreover, the limitation of this study is considered as a mini review on applying SEM into behavioural research of solid waste management, thus future research should consider expanding the scope of literature review to have a more comprehensive picture of behavioural research in solid waste management.

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