AN INTEGRATED MODEL OF ENHANCED ANALYTIC HIERARCHY PROCESS AND SYSTEM DYNAMICS TO EVALUATE ANTI-SMOKING STRATEGIES

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Abstrak

Penggunaan tembakau telah menjadi topik kontroversi sejak beberapa tahun kebelakangan ini. Semuanya bermula dengan peningkatan jumlah kematian pramatang di seluruh dunia. Sebagai tindak balas, Pertubuhan Kesihatan Sedunia (WHO) telah menggubal satu perjanjian, iaitu Konvensyen Rangka Kerja Kawalan Tembakau (FCTC). Perjanjian ini mewakili satu set strategi untuk mengawal penggunaan tembakau dan mengurangkan kelaziman merokok yang meliputi (i) pembungkusan dan pelabelan, (ii) harga dan percukaian, (iii) iklan tembakau, promosi dan penajaan, (iv) undang-undang bebas asap rokok, dan (v) pendidikan, komunikasi, dan kesedaran masyarakat. Melalui strategi ini, Malaysia menetapkan sasaran untuk mencapai sebagai sebuah negara yang bebas dari sebarang bentuk amalan merokok pada tahun 2045, dengan kelaziman merokok kurang dari 0.05. Walaupun terdapat pelbagai strategi anti-merokok yang telah dilaksanakan, merokok masih dianggap sebagai penyebab utama kematian yang dapat dicegah. Berfokuskan isu ini, kajian sebelumnya telah menggunakan pelbagai pendekatan pemodelan. Walau bagaimanapun, kaedah ini mempunyai beberapa kekurangan dan dapat diperbaiki dengan pendekatan integrasi. Oleh itu, penyelidikan ini bertujuan untuk membangunkan satu model bersepadu yang menggunakan teknik Proses Hierarki Analitik Dipertingkatkan (EAHP) dan Sistem Dinamik (SD) dalam menilai kesan strategi anti-merokok terhadap pengurangan kelaziman merokok. Dalam kajian ini, sinergi antara keutamaan dan simulasi diketengahkan, dan model bersepadu ini dikenali sebagai model EAHPSD. Mengenal pasti faktor pendorong untuk merokok dan menilai kesan dominan strategi anti-merokok dalam mengurangkan kelaziman merokok adalah langkah penting untuk melihat tahap kemajuan Malaysia dalam pertempuran global menentang risiko kesihatan yang dapat dicegah di dunia. Hasilnya, model EAHPSD ini memberi panduan yang bermanfaat kepada pihak berwajib dengan menyarankan agar aktiviti pendidikan, komunikasi, dan kesedaran masyarakat perlu dilaksanakan dengan menumpukan pada aspek psikososial dalam masyarakat. Dengan itu, strategi yang sesuai untuk aktiviti kawalan tembakau untuk mengurangkan kelaziman merokok di Malaysia telah dikenal pasti.

Kata kunci: Sistem dinamik, Proses hierarki analitik dipertingkatkan, Strategi anti-merokok, Kawalan tembakau, Model EAHPSD bersepadu.

Abstract

Tobacco use has become a controversial topic in recent years. It all begins with a tremendous increase in the number of premature mortalities worldwide. In response, the World Health Organisation (WHO) has enacted a treaty, namely the Framework Convention on Tobacco Control (FCTC). This treaty represents a set of strategies for controlling tobacco use and reducing smoking prevalence which covers (i) packaging and labelling, (ii) pricing and taxation, (iii) tobacco advertising, promotion, and sponsorship, (iv) smoke-free legislation, and (v) education, communication, and public awareness. Through these strategies, Malaysia set a target to achieve tobacco endgame by 2045, with a smoking prevalence of less than 0.05. Despite various anti-smoking strategies that have been implemented, smoking is still deemed the leading cause of preventable death. Focusing on this issue, previous studies have been utilising various modelling approach. However, these stand-alone methods have some shortcomings and can be improved by the integration approaches. Hence, this research aims to develop an integrated model that utilises the Enhanced Analytic Hierarchy Process (EAHP) and System Dynamics (SD) techniques in evaluating the impact of anti-smoking strategy towards reducing smoking prevalence. In this study, the synergy between prioritisation and simulation is highlighted, and the integrated model is known as the EAHPSD model. Identifying the driving forces of the smoking habit and evaluating the dominant effect of the anti-smoking strategy in reducing smoking prevalence is a crucial step to see Malaysia's level of progress in the global battle against the world's most important preventable health risk. As a result, the integrated EAHPSD model provides a beneficial guide to the authorities by suggesting that the education, communication, and public awareness activities are best to be implemented by focusing on the psychosocial aspects within society. Consequently, the suitable strategy of tobacco control activities for reducing smoking prevalence in Malaysia was identified.

Keywords: System dynamics, Enhanced analytic hierarchy process, Anti-smoking strategies, Tobacco control, Integrated EAHPSD model.

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List of Abbreviations

ABM	Agent-Based Modelling
AHP	Analytic Hierarchy Process
CI	Consistency Index
CLD	Causal Loop Diagram
CR	Consistency Ratio
DES	Discrete-Event Simulation
EAHP	Enhanced Analytic Hierarchy Process
FCTC	Framework Convention on Tobacco Control
MOH	Ministry of Health
SD	System Dynamics
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
WHO	World Health Organisation

CHAPTER ONE
INTRODUCTION

The tobacco epidemic is one of the world's biggest health challenges. It all begins with rampant tobacco use, which leads to a continuous increase in the number of premature mortality worldwide (World Health Organisation, 2013, 2020). The escalating number of premature deaths due to smoking-related diseases caused seven deaths per minute (Cheah & Naidu, 2012). The growing burden of smoking-related diseases is evident among individuals, families, health systems, and broader systems, causing increased pressures on health, economic productivity, and welfare resources. Therefore, the urgency to control tobacco use is one of the main approaches to reverse the upward trend in smoking prevalence. As the tobacco system is made up of various interrelated components, it is becoming increasingly complex to solve the problem. Thus, developing an understanding of the complexity by identifying the dominant cause and effect relationship in the tobacco system is essential to reducing smoking prevalence.

1.1 Global Tobacco Epidemic at a Glance

The tobacco epidemic is a major contributor to pre-mature mortality worldwide and continues to affect global health patterns (Ng et al., 2014; World Health Organisation, 2008). By the year 2030, 8 million people will die from these diseases (Eriksen, Mackay, & Ross, 2012; World Health Organisation, 2008). If the current trend of tobacco use continues until the year 2100, nearly 1 billion people could die as a result of tobacco use (Eriksen et al., 2012; World Health Organisation, 2008). Cigarettes generally dominate tobacco use compared to other tobacco products. This highly addictive product is commonly consumed by all segments of the population, including women and adolescents. As to date, tobacco use remains the single leading preventable cause of disease and premature deaths in the world.

The World Health Organisation (WHO) has reported that the global consumption of tobacco is growing worldwide and is significantly increasing in low-income countries, which accounts for 82% world's smokers (Tan & Dorotheo, 2014, 2016). According to the Southeast Asia Tobacco Control Alliance Report (Tan & Dorotheo, 2014), 56% of the world cigarette consumption is recorded from the Asia Pacific region, followed by Europe (24%), America (11%), and Eastern Mediterranean and Africa (9%). In the Asia Pacific region, the Association of South Asian Nations or ASEAN region contributed to 10% of the world's smokers. The world cigarette consumption by region is illustrated in Figure 1.1.

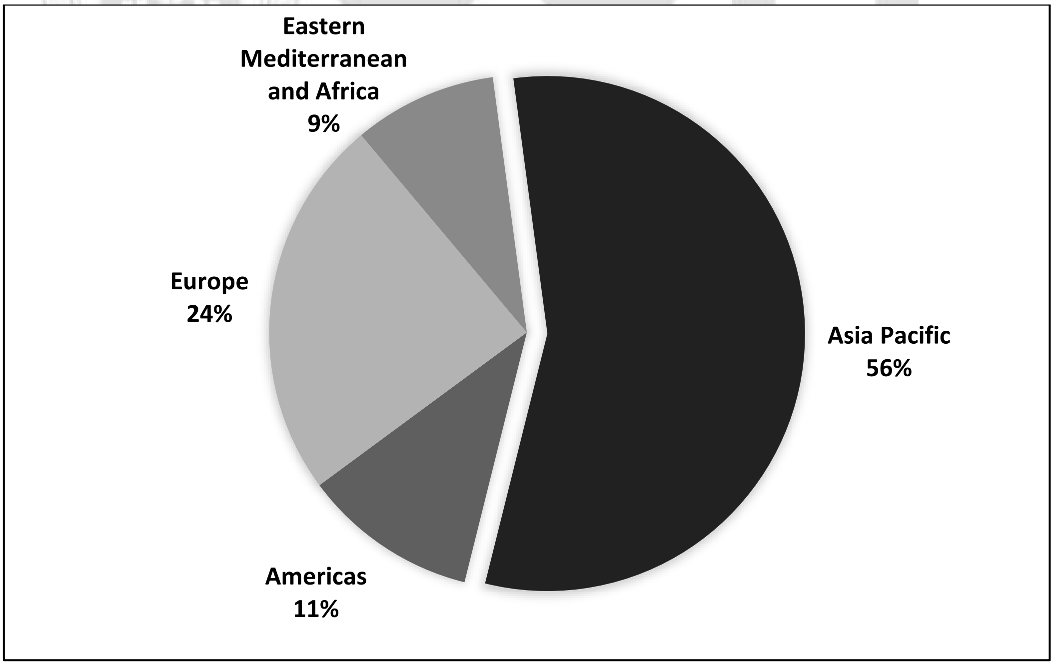


Figure 1.1 World cigarette consumption by region

Note: Adopted from Tan and Dorotheo (2014)

The ASEAN member countries comprise Indonesia, Malaysia, Philippines, Thailand, Vietnam, Singapore, Myanmar, Cambodia, Brunei, and Laos. As of 2015, the total ASEAN population is 628,937,000, including 122.4 million adult smokers (Tan & Dorotheo, 2016). The percentage of total smokers in ASEAN countries is illustrated in Figure 1.2. Indonesia scored the highest rate, with 53.3% of total adult smokers followed by the Philippines (13.5%) and Vietnam (12.7%). The remaining seven ASEAN countries, such as Thailand, Myanmar, Malaysia, Laos, Cambodia, Brunei, and Singapore depict less than 10% of total adult smokers.

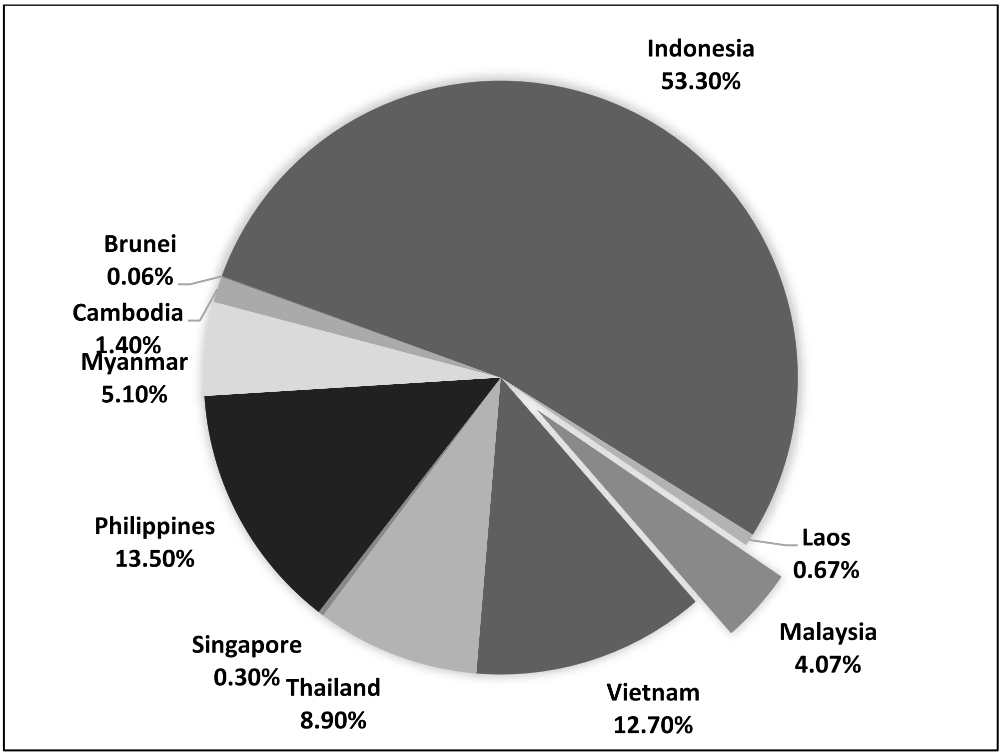


Figure 1.2 Percentage contribution of total adult smokers in ASEAN countries

Note: Adopted from Tan and Dorotheo (2016)

According to the WHO Global Report on Trend in Prevalence of Tobacco Smoking 2000-2025 (World Health Organisation, 2018), the report revealed that the real global reduction is still far-fetched from the worldwide reduction target of less than 0.05 smoking prevalence. Due to the global population growth and rapid economic development, the number of smokers is projected to rise and hit at least 2 billion by 2030, particularly in the ASEAN region (Tan & Dorotheo, 2016). Thus, all countries need to work together to curb the problem of tobacco use so that this problem can be controlled as a whole. For instance, in Malaysia, despite the percentage of smokers contributing less than 10%, several researchers found that smoking trend in Malaysia is expected to rise (Parkinson et al., 2009). Furthermore, the WHO also stated that based on the current trend of cigarette consumption, Malaysia is one of the countries that are expected not to be able to achieve the targetted endgame by 2045 (World Health Organisation, 2018).

1.2 Tobacco Epidemic in Malaysia

Tobacco use in Malaysia is evident and undeniable as the tobacco studies have been addressed from many perspectives. For instance, perspective on the factors influencing smoking habit (Chean et al., 2019; Lim, Kee, Mohamad Ghazali, & Lim, 2020; Lim et al., 2018), the effects of smoking on individuals, communities and nations (ITC Project, 2012; Ministry of Health Malaysia, 2016), and subsequently the impacts of anti-smoking strategies that have been implemented (Abd Rani et al., 2012; Elton-Marshall et al., 2015; Hock et al., 2019; Pei et al., 2020; Zainol Abidin, Zulkifli, & Zainal Abidin, 2016). In a Malaysian context, approximately 10,000 deaths yearly have been reported to be associated with smoking-related diseases since the 1980s (ITC Project, 2012; K.

H. Lim et al., 2009). Thus, it becomes one of the critical factors of death in this nation. The growth in the number of smokers in Malaysia is published by WHO Global Report on Trend in Prevalence of Tobacco Smoking (World Health Organisation, 2015), as shown in Figure 1.3.

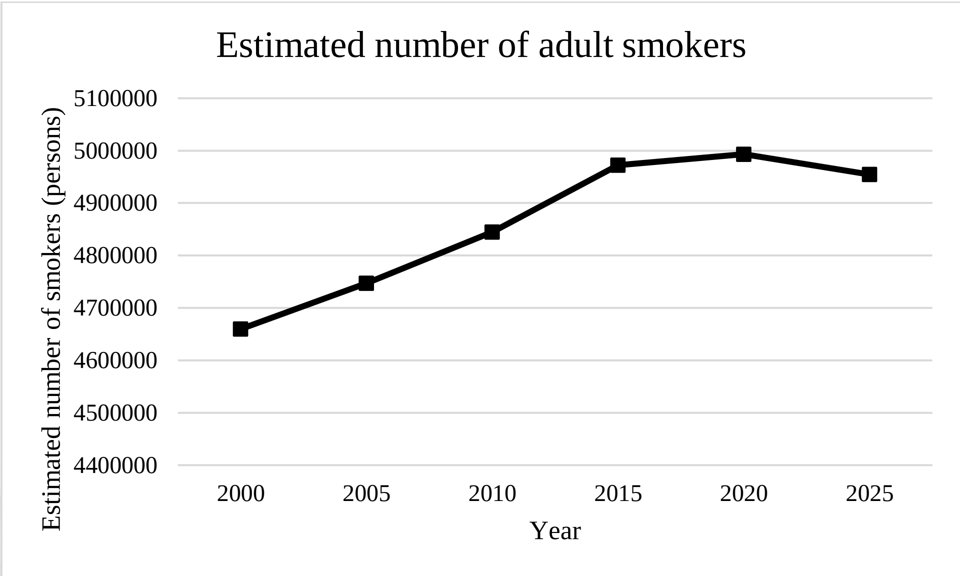


Figure 1.3 Estimated number of adult smokers in Malaysia

Note: Adopted from World Health Organisation (2015)

Locally, the National Health and Morbidity Surveys (NHMS) have been conducted starting from 1986 to 2015 (Institute of Public Health, 2015). Table 1.1 shows that the smoking prevalence in Malaysia remains more than 20%, with slight changes from 1986 to 2015. Although the pattern is a stagnant increase, in the long run, it can turn to vibrant growth if no action is taken.

Table 1.1

Smoking prevalence in National and Health Morbidity Survey Malaysia

	NHMS 1986	NHMS 1996	NHMS 2006	NHMS 2011	NHMS 2015
Smoking prevalence (%)	21.5	24.8	21.5	21.5	22.8

The increase in tobacco use will have an adverse effect on the public health of the country. Previous studies showed that cigarette smoking is the primary cause of premature mortality. They include the increased risk of smoking-related diseases, such as lung cancer, stroke, cardiovascular, respiratory, and other related illnesses (Al-Naggar, Al-Dubai, Hamoud, Chen, & Al-Jashamy, 2011). However, despite the proven hazardous effect, progress in meeting the global target set by WHO to reduce the prevalence of smoking remains off track. Hence, a promising solution could be developed by identifying the challenges in controlling tobacco use.

1.2.1 Challenges in Controlling Tobacco Epidemic

The key challenges in controlling the tobacco epidemic worldwide are the influence of addictive substances in tobacco products, the continuous conflict between public health authorities and the tobacco industry, and the ineffectiveness of anti-smoking strategies. Tobacco experts have iterated the same challenges in tobacco conferences like the Kuala Lumpur Nicotine Addiction Conference 2015 in April 2015 organised by Universiti Malaya. The explanations of these challenges are presented in Section 1.2.1.1 until Section 1.2.1.3.

1.2.1.1 The Influence of Addictive Substance in Tobacco Products

Typically, tobacco products are consumed by combustion, where the leaves of tobacco are burned at high temperatures, and the smokers inhale the resulting smoke. Combustion is the most efficient way of delivering nicotine to the brain. According to Eriksen et al. (2012), in Tobacco Atlas, nicotine is one of the thousands of hazardous compounds in tobacco smoke, and it is highly addictive. It can be argued that nicotine can have adverse effects on cognitive functions and can even cause nerve damage. Nevertheless, tobacco is legally sold worldwide, and after decades of knowing its harm, it remains not only legal but highly accessible and profitable. High profits arise because the consumer is dependent on the product due to nicotine addictivity (Tiffin, 2015). Therefore, to reduce the prevalence of smoking, one way that seems to be best implemented until now is to control tobacco use.

1.2.1.2 The Continuous Conflict Between Public Health Authorities and Tobacco Industry

There is a continuous conflict between those committed to reducing the tobacco market (public health authorities and tobacco control organisations) and those interested in developing the tobacco market (tobacco industry). Therefore, public health authorities with the tobacco control organisations have been opposing any step made by the tobacco industry. However, based on the current trends of tobacco use, there is still no effective mechanism on how and what combination of anti-smoking strategies that should be implemented to reduce the prevalence of smoking, particularly in Malaysia.

1.2.1.3 The Ineffectiveness of Anti-smoking Strategies

Despite the fact that various anti-smoking strategies have been implemented, tobacco use is still deemed the most preventable cause of death, leading to premature mortality. Therefore, growing studies have been conducted to find the most impactful strategy to be implemented to reduce smoking prevalence. However, most of the studies have been solely focused on the implementation of anti-smoking strategies. Less is explored on the root of the problem, which is factors influencing smoking habits, where they are the driving forces of the smoking habit. Moreover, existing strategies focused only on a specific part of the problem and are not holistic.

1.2.2 Future Direction of Tobacco Epidemic in Malaysia

The rising number of adult smokers and the smoking prevalence highlighted require immediate actions by the government to avoid an unfavourable outcome in the future, if no proper action is taken. To prevent these trends from becoming a public health reality, the World Health Organisation (WHO) has enacted a treaty, namely the Framework Convention on Tobacco Control (FCTC). This treaty represents a set of strategies for controlling tobacco use and reducing smoking prevalence, which covers packaging and labelling, pricing and taxation, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education, communication, and public awareness (World Health Organisation, 2003). Thus, Malaysia signed up to be one of the WHO members and ratified in 2005 (ITC Project, 2012) as the possible resolving measures for the challenges mentioned.

As a member of the WHO FCTC, Malaysia is obligated to implement all the tobacco measures agreed on the convention. The treaty demand reduced smoking prevalence with the practical guidance related to the implementation of FCTC known as MPOWER (World Health Organisation, 2003). The six MPOWER policies include the following:

- **M**ONITOR tobacco use and prevention policies
- **P**ROTECT people from tobacco smoke
- **O**FFER help to quit tobacco use
- **W**ARN about the dangers of tobacco
- **E**NFORCE bans on tobacco advertising, promotion, and sponsorship
- **R**AISE taxes on tobacco

Through these policies, Malaysia set a target to achieve tobacco endgame by 2045, with a smoking prevalence of less than 0.05. Conclusively, WHO FCTC through the MPOWER, translates the Malaysian government's high commitment to reducing the number of smokers as well as the smoking prevalence.

1.3 Issues Related to Modelling Approaches in Tobacco Control Studies

In the context of tobacco control domain, previous studies had been applying various modelling approaches such as statistical (Hong et al., 2013; Hunt et al., 2017; Teh, Ooi, Tam, Kadirvelu, & Sadasivan, 2014; Zawahir et al., 2013; Zhang, Vuong, Andersen-Rodgers, & Roeseler, 2018), mathematical (Castillo-Garsow, Jordan-Salivia, & Rodriguez-Herrera, 1997; Feirman et al., 2015; Goyal, 2014; Pang, Liu, Zhang, & Tian, 2019; Pang, Zhao, Liu, & Zhang, 2015; Pulecio-Montoya, Luis Eduardo, & Benavides, 2019), and simulation (Chao, Hashimoto, & Kondo, 2015; Luke et al., 2017; Rigotti &

Wallace, 2015). From the review, the strength of statistical modelling lies in the ability to extract collected data and easy-to-comprehend method. However, this approach fails to capture the feedback process exhibit in the research problem. Meanwhile, mathematical modelling has its robust theoretical model in modelling the tobacco system, particularly its ability to examine the research problem from multiple angles using mathematical formulation and equations. Despite these advantages, a non-mathematical expert may find it challenging to comprehend the mathematical analysis process.

Due to the complexity of the tobacco system, simulation modelling like Agent-Based Modelling (ABM), Discrete-Event Simulation (DES), and System Dynamics (SD) have their potential to overcome the challenges. All three types of simulation have their strengths and limitations. Nevertheless, most of the studies using ABM and DES do not capture the system behaviour holistically, but only focus on specific components of the system. On the other hand, SD offers its capability to incorporate feedback processes and was found effective for policy evaluation in the long run. The effectiveness can be seen in the previous studies by Ahmad (2005), Levy et al. (2010), Richardson (2007), Roberts, Homer, Kasabian, and Varrell, (1982), and Zagonel et al. (2011). Even though all these studies were able to incorporate the feedback mechanism needed, their contributions were limited to only evaluating the anti-smoking strategies and less attention were given on finding the dominant root causes and correctors in a tobacco system. Little attention was given to synthesise and combine information from the dominant component to assist the decision-maker to make more objective and strategic planning in decision making. Due to the highlighted issues, the prioritisation method may be needed as offered by Multi-Criteria Decision-Making family.

1.4 Problem Statement

There is a growing concern related to the high number of premature mortality cases in Malaysia (World Health Organisation, 2018). The leading cause of this issue is the drastic increase in smoking-related diseases, which originated from high smoking prevalence (Melson, 2014; World Health Organisation, 2013). The efforts in reducing smoking prevalence have been debated since 1965 (Roberts et al., 1982). Previous studies have elaborated on various interventions that focus on the result of the anti-smoking implementation to reduce the prevalence of smoking, such as packaging and labelling tobacco products, pricing and taxation, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education and cessation support (Atusingwize, Lewis, & Langley, 2015; Hock et al., 2019; Pei et al., 2020; Ratih & Susanna, 2018; Yang, 2018). However, with the lack of driving forces element explored in existing tobacco control studies, the impact of the implemented anti-strategy is disputed. The lacking is believed to be one of the reasons behind the endless fight against tobacco. As a result, tobacco use is deemed the most preventable cause of death (Near, Blackman, Currie, & Levy, 2014; Tan & Dorotheo, 2016; World Health Organisation, 2013). Based on this reason, in an effort to solve the problem, factors influencing smoking were considered for reducing smoking prevalence, particularly in Malaysia.

However, among the factors influencing smoking, the most influential factor needs to be identified to examine the dominant cause and effect, then only the cause and corrector relationship to reduce smoking prevalence is captured effectively. Therefore, modelling is used to understand better how the tobacco system works and to assess the causes and effects of anti-smoking strategy implementation other than because it can capture the relationship between the essential components in the tobacco system. Many modelling studies have investigated the impact of anti-smoking strategies implemented (Ahmad, 2005; Ahmad & Billimek, 2005; Al-Naggar et al., 2011; Cheah & Naidu, 2012; K. H. Lim et al., 2014; Near et al., 2014; Roberts et al., 1982). However, the literature is yet to reveal any attempt to structure the tobacco control system model by considering the factors influencing smoking habit and anti-smoking strategies simultaneously. Furthermore, it has been acknowledged that there is limited tobacco-related literature that integrates the elements of prioritisation and simulation in a single study. This limitation calls for a better solution. Thus, a study that is capable of prioritising the influential factors of smoking and the anti-smoking strategies, simulating the long-term effects of smoking prevalence, and producing the best solution of smoking prevalence rate in a single study is necessary. By taking into account the limitation of the discussed methods, this research proposed an Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) integration model to determine the dominant factors influencing smoking and anti-smoking strategies towards achieving tobacco endgame in Malaysia. By integrating both methods, the dominance of the root causes and its corrector can be determined to assist policymakers to make better and informed decisions. Also, the EAHP will assist in tackling the difficulties of embedding qualitative variables in modelling. Subsequently, the proposed model is deemed comprehensive to provide information to policymakers for better decision-making towards reducing smoking prevalence.

1.5 Research Questions

i. What is the dominant factor contributing to smoking habits?
ii. How to quantify the parameters of the contributing factors which is not in numerical in nature?
iii. How can the tobacco epidemic be assessed in a dynamic environment considering its influential factors?
iv. What is the intervention strategy that gives the minimum value of smoking prevalence by the year 2045?

1.6 Research Aim and Objectives

The aim of this study is to evaluate the anti-smoking strategies towards achieving tobacco endgame in Malaysia. In order to achieve the aim of this research, five sub-objectives are determined as follows:

i. To identify factors that influence smoking habits.
ii. To determine the weights of the contributing factor using EAHP.
iii. To prioritise the anti-smoking strategies using EAHP.
iv. To simulate the tobacco control system using an integrated EAHPSD model.
v. Evaluate the integrated EAHPSD model to achieve the minimum value of smoking prevalence by the year 2045.

1.7 Scope of the Research

The scope of the research includes:

i. This study will only focus on the policies that have already been implemented in Malaysia, including health warning labels and pack descriptors, pricing and taxation of tobacco products, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education, communication, and public awareness. Hence, this study will not consider any other policies outlined in the Framework Convention on Tobacco Control (FCTC) if it is not implemented in Malaysia.

ii. This study will only focus on cigarette smoking. Therefore, this study will not consider the perspectives of other types of tobacco usage, such as chewing tobacco, cigars, and smokeless tobacco. Cigarette smoking is chosen because it is widely used compared to different kinds of tobacco usage (Eriksen et al., 2012).

iii. A first-hand smoker is defined as the person who inhales the smoke from the burning cigarette. The person who did not smoke but inhales the smoke from a first-hand smoker is defined as a second-hand smoker. Meanwhile, third-hand smokers are the ones who did not smoke but inhaled the smoke from the tobacco smoke residues left after the cigarette was burnt. In this study, first-hand smokers are chosen due to the dominating effects of decreasing the number of first-hand smokers consequently reducing the numbers of second-hand and third-hand smokers.

iv. The historical data used in this research were based on sixteen years period, from 2000 to 2016, due to data availability. As to date, 2016 is the latest data published by the Ministry of Health Malaysia.

1.8 Summary of Research Contributions

This research presents six contributions as the outcomes from the research objectives, where the first four are related to the body of knowledge, while the following two contributions are related to the managerial aspects. The details of these contributions are elaborated in Section 6.2 of Chapter Six. The summary of these contributions is as stated below.

i. The development of the integrated Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) model proposed in this research offers an alternative approach in evaluating the impact of anti-smoking strategies with the inclusion of factors influencing smoking which has not been featured in the previous tobacco-SD studies by Ahmad (2005), Cavana and Tobias (2007), Levy et al., (2010), Richardson (2007), Roberts et al., (1982) and Zagonel et al., (2011). Thus, the developed EAHPSD model resembling the real tobacco system is an improved decision-making tool with prioritisation capability for evaluating the impact of anti-smoking strategies in reducing the prevalence of smoking.

ii. This research provides a transparent formulation of the prioritisation to identify the most influential factors of smoking and the most impactful anti-smoking strategies in Malaysia. Hence, the targetted approach of the EAHPSD process contributes to more objective and strategic planning in decision making.

iii. This research enhances the existing system dynamics modelling process by providing step-by-step process of capturing the qualitative and quantitative variables related to this research. Therefore, the integration of EAHP and SD is capable of capturing the qualitative variables as well as providing parameter values for better simulation results.

iv. The developed EAHPSD model in this research offers various combinations of parameters to be tested in policy evaluation. Hence, the combination allows sensitivity analysis to simulate how a change in the control variables causes a change in the tobacco system's dynamic behaviour. Therefore, the developed EAHPSD offers a flexible capability to evaluate the impact of anti-smoking strategies and suggest the best strategy for reducing the smoking prevalence.

v. The proposed EAHPSD model could be potentially utilised by policymakers and practitioners in the Ministry of Health (MOH) and the World Health Organisation (WHO) to provide information and recommendations on the most impactful intervention strategies in reducing smoking prevalence.

vi. The developed model could help the policymaker safely evaluate the impact of anti-smoking strategies on reducing smoking prevalence through risk-free experimentation via various scenario strategies. Thus, the actual system is not interrupted and cost consequences can be avoided. Furthermore, with appropriate modification this research design can be generalised to assess the intervention strategies in other substance use problems such as e-cigarettes, drugs, and alcohol.

1.9 Outline of the Thesis

This thesis is organised into five chapters. Chapter 1 describes the background of the study, problem statement, research questions and research objectives, scope of the research and contributions of this research. The review of the related literature as well as the concept of EAHP and SD will be presented in Chapter 2. Chapter 3 will present the methodology used in this research followed by results and discussions in Chapter 4. Finally, the conclusion and recommendations are presented in Chapter 5 Figure 1.4 describes the summary of the thesis.

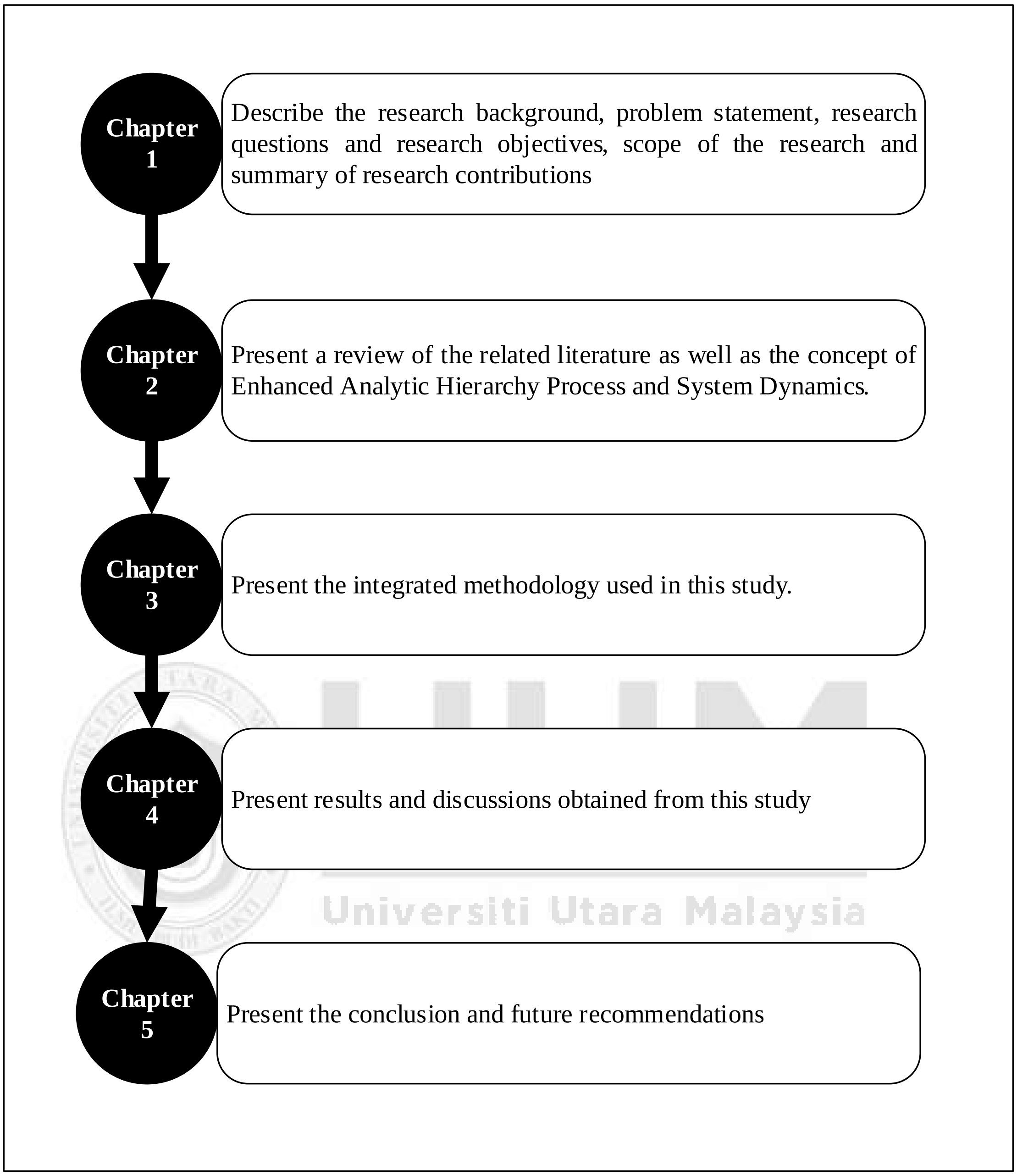


Figure 1.4 Outline of the thesis

CHAPTER TWO
LITERATURE REVIEW

Chapter Two presents the review of the literature on the key components in the tobacco epidemic, modelling approaches that have been applied in solving the tobacco epidemic issues as well as the basic concepts and theories. This chapter starts with the introduction of the tobacco epidemic, presented in Section 2.1. This is followed by the discussions on the factors influencing smoking habits in Section 2.2. Further, the type of anti-smoking strategies was reviewed in Section 2.3. Next, works of literature discussed on the modelling methods consisting of statistical, mathematical and simulation in tobacco control studies are presented in Section 2.4. Then, several methods of Multi-Criteria Decision Making were discussed and compared in Section 2.5. Research gaps identified through the literature review process that resulted in contributing to the body of knowledge in the relevant field are highlighted in Section 2.6. This chapter continues with the discussion on the concepts and theories of Enhanced Analytic Hierarchy Process (EAHP) and System Dynamics (SD) in Section 2.7. Finally, a summary of the contents closes this chapter.

2.1 Introduction to the Tobacco Epidemic

The term epidemic can be defined as a condition where an infectious disease spreads extensively to many people over a certain period. The term was derived from the Greek word ‘*epi demos’* with the meaning ‘who in his country’ since the 6^{th} century BC (Jaafar, 2019; Martin & Martin-Granel, 2006). From the perspective of the tobacco problem, the rampant tobacco use and continuous increasing trends of smoking-related morbidity and mortality had been addressed as an epidemic worldwide (Drope et al., 2018; Eriksen, Mackay, Schluger, Islami, & Drope, 2015).

2.1.1 Types of Tobacco Used

Generally, tobacco use can be divided into two distinct categories which are smoking tobacco and smokeless tobacco. Tobacco smoking is the practice of burning the dried leaves of the tobacco plant and breathing in the smoke. This process uses heat to make new chemicals that are not found in unburned tobacco and permits them to be ingested through the lungs. There are several types of smoking tobacco, such as manufactured cigarettes, e-cigarettes, cigars, roll-your-own tobacco, pipes, and water pipes (Drope et al., 2018; Eriksen et al., 2012). On the other hand, smokeless tobacco is usually consumed orally without burning. Smokeless tobacco increases the risk of tumour and stimulates nicotine dependence like cigarette smoking. Examples of smokeless tobacco are chewing tobacco, snuff tobacco, and plunging tobacco (Drope et al., 2018; Eriksen et al., 2012). Manufactured cigarettes, or widely known as cigarettes, are the most commonly consumed tobacco products worldwide. It consists of shredded tobacco which is processed with various chemicals and flavours (Drope et al., 2018; Eriksen et al., 2012).

2.1.2 The Cycle of Smoking Addiction

According to Eriksen et al., (2012), nicotine is addictive, similar to heroin and cocaine. When a smoker inhales the smoke from a cigarette, the nicotine penetrates deep into the lungs. From the lungs, it will infiltrate the blood circulation, which is carried to the heart and then to the brain. It takes only six seconds for nicotine to penetrate and reach the brain. Nicotine is a stimulant that increases speed. When a person smokes, the nicotine stimulates the heart to beat faster and increases blood pressure. Nicotine makes smokers feel more alert and awake. After thirty minutes, the level of nicotine in the blood decreases, smokers begin to experience withdrawal manifestations. Withdrawal is characterised as the predisposition that a smoker feels when the nicotine is taken away (Faulkner et al., 2018; Reidpath, Davey, Kadirvelu, Soyiri, & Allotey, 2014).

The cycle of becoming a smoker begins with a never smoker's first trial due to various influential factors (Flay, Petraitis, & Hu, 1995). Along this initiation stage, if the individual continues to smoke repeatedly on a regular or non-regular basis, then they are called regular smokers. A regular smoker will smoke regularly, either daily, weekly, or monthly. While, non-regular smokers or social smokers will smoke only during specific situations or events. If the regular smoker quits smoking, then the individual is called ex-smoker. Along this cessation stage, it depends on the ex-smoker either to resume smoking or to stop it. Any initiatives that aim to discourage the smoking initiation process are considered as smoking prevention (Flay et al., 1995).

2.2 Factors Influencing Smoking

From the literature, the process of becoming a smoker can be influenced by various factors. According to the Theory of Triadic Influence, which was outlined by Flay, Petraitis and Hu (1994), the influential factors of smoking are personal beliefs and values, personal physiological, family influence, psychosocial influence, cultural influence, and legislative influence. This theory illustrates the predictors of smoking from the perspective of personal, social, and environmental aspects. Personal factors encompass the individual's sense of self, categorised into personal beliefs and values, and personal physiological. Social factors are related to the influence of an individual's surroundings through their smoking behaviour such as family and psychosocial impact. Environmental factors consist of the culture of society and legislation related to tobacco. This includes exposure to cigarette marketing and its availability. Further explanations of these factors are discussed in Section 2.2.1 until Section 2.2.6.

2.2.1 Personal Beliefs and Values

Personal beliefs and values can be defined as the ideal ideas one individual holds. These ideas include an individual's sense of curiosity and perception about smoking and what initiates them to smoke. With that in mind, smoking may give them a desirable social image such as 'being cool' and 'being mature'. Moreover, the perceived social benefits gained from smoking may boost their self-esteem and outweigh the health risks (Barton, Chassin, Presson, & Sherman, 1982). Previous studies show a relation between smoking habits and social benefits (Hu, Rich, Luo, & Xiao, 2012; Ma et al., 2008; Sheer & Mao, 2018). The researchers found that offering cigarettes is perceived as a sense of welcomed friendliness or brotherhood and offering good brands of cigarettes may also give the impression of better economic status and being generous.

2.2.2 Personal Physiological

Referring to the biological definition, physiological relates to how individual functions as a living organism genetically. Specifically, in this context, it refers to the influence of brain development during adolescence that may contribute to the individual's vulnerability to smoking addiction. The inheritability of smoking addiction during maturation processes has triggered medical researchers to investigate genetic linkages that cause nicotine dependence and how to intervene. The researchers found that for some people, personal physiological might influence individual towards specific problem behaviour (Bisol, Soldado, Albuquerque, Lorenzi, & Lara, 2010; Chambers, Taylor, & Potenza, 2003; Giedd & Rapoport, 2010; Lebel & Beaulieu, 2011; Steinberg, 2007; Wills, Sandy, & Yaeger, 2000; Windle et al., 2008; Zhai et al., 2019). Also, an exploration of physiological influence is needed as substance use during adolescence has adverse effects on the body, and this has the likelihood to increase the risk of nicotine dependence later in life (Windle et al., 2008). The findings revealed that substance use, such as nicotine dependence due to physiological influence helps to explain why specific interventions implemented to reduce smoking habit ineffective (Steinberg, 2007).

2.2.3 Family Influence

Family plays a central role in people's lives. Therefore, exposure to smoking by parents or older siblings in a family can initiate people to smoke, especially young people (Chassin et al., 2008; Gilman et al., 2009; Khan, Karim, Alam, Ali, & Masud, 2018). However, previous studies revealed that older siblings' smoking exposure has a strong influence on young people compared to exposure by smoking parents (Avenevoli & Merikangas, 2003; Rajan et al., 2003). Other than that, higher quality of parents-children relationships in terms of closeness, supportiveness, and involvement in a family can protect young people from smoking (Mahabee-Gittens et al., 2011). In contrast, a crisis that occurs in a family has the potential for young people to initiate smoking. Additionally, young people who perceive the disapproval of smoking from their parents are found to be less likely to smoke (Simons-Morton & Haynie, 2003). In a nutshell, the influence of family on smoking habits can be classified into four groups: smoking exposure by parents or older siblings, parenting behaviour, the relationship among family members, and parental reaction towards smoking habits.

2.2.4 Psychosocial Influence

Psychosocial may be defined as the combined influence of psychological and social factors. Psychological factor relates to the psychology that involves individual mental states while social factor refers to the surrounding environment that has the potential to influence people to initiate particular behaviour. The initiation of smoking which occurs in the presence of peers is prompted by psychosocial influence (Arnett, 2007; Bauman & Ennett, 1996; Khan et al., 2018; Kobus, 2003; H. L. Lim et al., 2020; Poulin, Kiesner, Pedersen, & Dishion, 2011; Scalici & Schulz, 2017; U.S. Department of Health and Human Services, 2012). In a comprehensive health report by a group of prominent health officers, peers' smoking behaviour and individual's perceptions of their peers' smoking behaviour are associated with the development of smoking initiation (U.S. Department of Health and Human Services, 2012). Notably, individuals may learn about tobacco use by observing their peers using tobacco to gain peers acceptance or establishing social identity.

2.2.5 Cultural Influence

Another factor influencing smoking is culture (Chean et al., 2019; Kuang H. Lim et al., 2018). The cultural norm is typically thought as social behaviour of members in a community that gives them a sense of acceptance to the community (Nichter, 2003).

For instance, in Malaysia, smokers would choose to dine at open-air eateries, hawker stalls, coffee shops, and Indian restaurants (‘*mamak-style*’ restaurants), where they would spend hours to chat with their friends and smoke cigarettes while sipping their drinks. Another example as in China, men and adolescent boys will smoke together after meals as a way of social bonds and offering cigarettes as gifts to guests is typical, and refusing the offer will be viewed as impolite (Pan, 2004).

2.2.6 Legislative Influence

Generally, legislative influence includes government policies that affect the price and availability as well as accessibility of tobacco in a country. Despite various interventions implemented to curb tobacco issues, the situation emerged the availability of illegal cigarettes (The New Straits Times, 2020; The Star, 2019). The illegal cigarettes are usually sold at a lower price compared to legal cigarettes, which attracts smokers, especially adolescents to smoke with cheap illegal cigarettes without considering the hazardous effects.

2.3 Anti-smoking Strategies

The World Health Organisation (WHO) Framework Convention on Tobacco Control (FCTC) was developed with the purpose to protect the present and future generations from the hazardous effects of tobacco use (World Health Organisation, 2003, 2015, 2018). The WHO FCTC is the world’s first public health treaty that addresses the global tobacco epidemic issues through a variety of measures and anti-smoking strategies. The convention is one of the most prominent treaties ever established, with 174 members as of January 2012. To diminish the burden of tobacco-related illness and death, Malaysia has resolved to actualise tobacco control approaches as outlined by the convention. Malaysia joined the convention on 23 September 2003 and was endorsed on 16 September 2005. In 2005, Malaysia established the basis for executing more grounded and more exhaustive tobacco control methodologies. The following sub-sections describe anti-smoking strategies that have been implemented in Malaysia.

2.3.1 Packaging and Labelling Tobacco Products

Health warning labels and pack descriptors have been implemented in Malaysia over the past 35 years. From 1976 to 2009, health warning labels had one text-only message in Malay and English written on the pack that read: "*Amaran Kerajaan Malaysia: Merokok Membahayakan Kesihatan*" in Malay and "Warning by the Malaysian Government: Smoking is hazardous to health". When Malaysia has become one of the signatories to WHO FCTC, the pictorial health warnings were improvised. The labels consist of graphics health warnings printed in Malay and English which covers 40% of the front and 60% of the back of all cigarette packs, as shown in Figure 2.1 below.

Figure 2.1 Examples of pictorial health warnings labels

Several researchers found that the implementation of packaging and labelling as outlined by the WHO FCTC appear to have a significant impact in reducing tobacco usage (Agaku, Filippidis, & Vardavas, 2014; Elton-Marshall et al., 2015; Germain, Wakefield, & Durkin, 2010; Hammond, 2010; Kees, Burton, Andrews, & Kozup, 2010; Mir et al., 2011). The findings show that pictorial warning labels provide greater impacts on smokers' cognitive and behavioural factors than warning in text form (Agaku et al., 2014). This view is also supported by Ratih and Susanna (2018), who conducted a comprehensive review on measuring the effectiveness of packaging and labelling of tobacco products in Asia. On the other hand, Fathelrahman et al., (2013) and Yong et al., (2013), examine the impact of cigarette pack warning labels on interest in quitting and subsequent quit attempts among adult smokers in Malaysia and Thailand. In contrast, both findings show that Malaysian's warning labels have a weaker impact compared to Thailand's warning labels.

2.3.2 Pricing and Taxation of Tobacco Products

Pricing and taxation of tobacco products emphasise on controlling demand and supply, by increasing prices and taxes on tobacco products (ITC Project, 2012). Considerable amounts of literature have been published on pricing and taxation of tobacco products (Abd Rani et al., 2012; Cavazos-Rehg et al., 2014; Gigliotti et al., 2014; Kostova et al., 2012; Pei et al., 2020). The studies revealed that tax increased, and the consequent price increased contributes significantly towards reducing tobacco usage, increases the number of attempts to quit, promotes cessation, and prevents initiation. In Malaysia, stringent tobacco taxation has been imposed on tobacco products over the past decade. Specifically, current tobacco taxes constitute 41.7% up to 80% of the retail cigarettes depending on the various cigarettes' types. Nevertheless, the best practice of the WHO FCTC suggested raising tobacco tax at least 75% to ensure its impact on reducing tobacco use. Therefore, it is believed that Malaysia should fully comply with the WHO FCTC suggestions to boost the cessation rate (Pei et al., 2020).

2.3.3 Tobacco Advertising, Promotion, and Sponsorship

This policy involves the prohibition to the most forms of direct or indirect tobacco advertising, promotion, and sponsorship. Among the recommended measures for tobacco advertising, promotion, and sponsorship is ban on cross-border advertising, promotion and sponsorship, display of tobacco products at the point-of-sale, tobacco product vending machines, internet sales, and attractive packaging and product features (ITC Project, 2012; Yang, 2018). In line with the mission to curb smoking habits, Malaysia has also banned the offer of advertising, promotion, and sponsorship related to any tobacco products (ITC Project, 2012).

2.3.4 Smoke-free Legislation

Smoke-free legislation is the act of banning smoking in public places to reduce tobacco consumption and protect non-smoker from environmental tobacco smoke. In 1993, following the outline by WHO FCTC regulations, the Malaysian government banned smoking indoors in open spaces such as public lifts, toilets, theatres, and air-conditioned restaurants. Subsequently, in 2004, the regulations were revised to be more comprehensive, by adopting full smoking bans in additional public spaces such as shopping centres, airports, petrol stations, stadiums, and fitness centres. Smoking areas can occupy one-third of a premise. However, smoking in pubs, night clubs, and casinos is still permitted. Malaysia further revised the regulations in 2008 to include smoking bans in National Service Training Centres, and in all air-conditioned workplaces in 2011 (ITC Project, 2012). Finally, as of January 2019, Malaysia has extended more of its smoke-free area, which prohibits smoking in all restaurants, open-air eateries, and hawkers stall (Abidin et al., 2020). According to the comprehensive review by Zainol Abidin, Zulkifli, and Zainal Abidin (2016), it has conclusively been shown that Malaysia has taken pro-active steps by implementing the smoke-free legislation as suggested by WHO FCTC to protect its citizens from adverse effects of smoking and second-hand smoke exposure. In addition, the smoke-free legislation was also supported by most of the Malaysians (Hock et al., 2019). Therefore, a broader expansion of smoking ban is strongly suggested for reducing exposure to second-hand smoke and denormalising smoking at public places. The implementation year of the various smoke-free policies in certain places is summarised in Table 2.1.

Table 2.1

Smoke-free public places and workplaces policy timeline

Locations	**Regulation Year**				
	1993	**2004**	**2008**	**2010**	**2020**
Entertainment centres or theatres	/	/	/	/	/
Hospitals and clinics	/	/	/	/	/
Public lifts	/	/	/	/	/
Public toilets	/	/	/	/	/
Public transportation	/	/	/	/	/
Air-conditioned eating places	/	/	/	/	/
Air-conditioned shops		/	/	/	/
Public transport terminals		/	/	/	/
Airports		/	/	/	/
Government premises		/	/	/	/
Places of public assembly		/	/	/	/
Educational institutions		/	/	/	/
Nurseries		/	/	/	/
School buses		/	/	/	/
Floor with service counters		/	/	/	/
Shopping complexes		/	/	/	/
Petrol stations		/	/	/	/
Stadiums, sports complexes, fitness centres or gymnasiums		/	/	/	/
Religious institutions		/	/	/	/
Libraries		/	/	/	/
Internet cafes		/	/	/	/
National Services Training Centre			/	/	/
Air-conditioned workplaces				/	/
Restaurants					/
Coffee shops					/
Hawker stalls					/
Open-air eateries					/

Note: Adopted from the Ministry of Health Malaysia (2008)

2.3.5 Education, Communication, and Public Awareness

Article 12 of the WHO FCTC defines that each party is obligated to promote and strengthen public awareness of tobacco control issues through education and public awareness programs. The primary purpose of the measure is to boost the denormalisation of smoking habit by raising public awareness in the community (World Health Organisation, 2020). In conjunction with this, WHO FCTC initiated a World No Tobacco Day in 1987 to increase international public awareness of the negative and dangerous consequences of tobacco use and exposure to second-hand smoke and prevent tobacco use in any way. The World No Tobacco Day is celebrated by WHO and regional partners on 31 May every year. Other than that, the most common ways to educate and create awareness are through cigarette packs, posters, televisions, billboards, and cinemas (ITC Project, 2012). These programs should cover topics including health risks of tobacco consumption, benefits of cessation, and enable public access to information about the tobacco industries.

As one of the WHO FCTC representatives, Malaysia is obligated to bring public attention to this crisis. From 2004 to 2010, the Malaysian government launched "*Tak Nak*" or "Say No", a nationwide anti-smoking campaign to reduce the smoking prevalence by influencing current smokers to quit and deterring young people from starting. The campaign used mass media and print media channels to promote accurate information about the dangers of smoking. The general outcome from the evaluation made in March 2012 shows that the "*Tak Nak"* mass media campaign is highly successful in reaching smokers. It reported that at least 93% of the smokers are aware of the campaign, and the majority of the smokers recognised the benefits of reliable, well-funded anti-smoking campaigns (ITC Project, 2012). The example of print "*Tak Nak*" campaign posters promoting smoking denormalisation is shown in Figure 2.2.

Figure 2.2 “Tak Nak” campaign posters

Note: Adopted from ITC Project & International Tobacco Control (2012)

To date, there is no consensus has been reached regarding the anti-smoking strategies that can be most impactful implemented to control tobacco use towards achieving tobacco endgame. For the past decade, various profound literature studied on factors influential smoking and anti-smoking strategies separately. However, these studies only focused on the impact of the implementation of anti-smoking strategies without considering the driving forces of the problem, which are the factors influencing smoking habits. Therefore, there is a lack of study which focuses on the causes of the issue along with the correctors of the problem. This information is essential to allow early preparedness and timely preventive measures that give vital advantages in preventing and controlling smoking initiation.

2.4 Review of Modelling Approaches in Tobacco Studies

This section presents review of past studies that have been conducted relevant to tobacco control, focusing on modelling approaches in tobacco control studies. A modelling process can be described as a tool for imitating the operations of real-world systems (Law & Kelton, 1991; M Faeid, 2018; Maidstone, 2012). There is an abundance of modelling approaches available from various disciplines depending on the objectives of a particular study. In regard to tobacco control modelling, statistics, mathematics and simulation models have been widely used to study the impact of the anti-smoking strategies implemented. The discussions on these approaches are explained in Section 2.4.1 to Section 2.4.3.

2.4.1 Statistical Modelling

Researchers have extensively used statistical modelling to analyse tobacco control issues worldwide as well as in Malaysia. By definition, statistics is a discipline that deals with the collection and interpretation of data. In the application of statistical modelling, statistical methods were used to extract information from collected data and provide ways to assess the desired research output. Generally, researchers adopt various statistical methods in their analysis, which include the Chi-Square test and Regression Analysis to evaluate the anti-smoking strategies implemented and its impacts.

Statistical modelling by Teh, Ooi, Tam, Kadirvelu, and Sadasivan (2014) applied the Chi-Square test to assess the perceived effectiveness of tobacco control in Malaysia. In this study, the effectiveness of policy and legislation implemented were measured from two specific areas which are public perception related to prohibition of tobacco products sales and advertisements, as well as the banning of smoking in particular areas. The results show a positive outcome with 66.5% indicating that people felt that restricting under age group (below 18 years old) was found to be very effective. On top of that, Teh et al., (2014) also found that 61.2% indicated that people felt that displaying pictorial warnings at point-of-sale and banning tobacco advertisements, promotion, and sponsorship were effective. In another study, Zawahir et al., (2013) used a Chi-Square test and regression model to measure the effectiveness of anti-smoking strategies involving media messages and education in Malaysia and Thailand. The data were obtained from the International Tobacco Control Southeast Asia Project (ITC-SEA) survey, which revealed that educating students in schools appears to the most impactful strategy for both countries. This finding has contributed to a better understanding of determining the association of reported exposure to anti-smoking media messages and education with knowledge, health risk, and susceptibility.

Other than that, Hunt et al., (2017) and Zhang, Vuong, Andersen-Rodgers, and Roeseler (2018) has incorporated multivariate regression in their tobacco control model. In the study by Hunt et al., (2017), health and economic impacts of achieving tobacco endgame (less than 5% of smoking prevalence) in the United Kingdom were evaluated by extrapolating the data obtained to fit the population estimates in order to create projections until 2035. If the current practice and trend continues, the projected smoking prevalence is 10%, which is above the target in achieving tobacco endgame. However, the finding revealed if tobacco endgame were achieved, more than 5000 new cases of smoking-related diseases and £8 million of healthcare costs could be avoided in 2035 alone. In another study, Zhang et al., (2018) studied the impact of raising the minimum tobacco sale age from 18 to 21 years old using multivariate models. In this study, the retailer violation rate (RVR) was estimated and the finding showed that the

RVR is 4.6% decreased after the intervention is made. The finding indicated that more than 50% of tobacco retailers aware of the law and supported the law.

From the reviews, it shows that statistical models can test the effectiveness of anti-smoking strategies implemented. The strength of statistical modelling lies in the ability to extract information from collected data and provides statistical analysis to interpret the desired research output. A large amount of historical data is essential to allow precise evaluation. Therefore, statistical modelling is least applicable to research problems with limited data available. Other than that, the variables and equations used was straight forward relationship and did not capture the interrelationship and feedback process exist in the tobacco system. Thus, this kind of relationship defeats the dynamicity of the tobacco system.

2.4.2 Mathematical Modelling

Mathematical modelling can be described as the process of translating real-world problems into formulations using mathematical concepts and theories, which will provide useful guidance and insights for solving the problem under study. In the context of mathematical modelling involving tobacco studies, it can be categorised into two types of study objectives, which are (i) to project changes in tobacco use behaviour over time (trend study) and (ii) to evaluate the impact of anti-smoking strategies implemented (policy study). Further, from the study objectives, the study outcome can be classified into three types which are (i) outcome involving changes in tobacco use behaviours such as smoking prevalence, (ii) outcome involving tobacco-related morbidity and mortality, and (iii) outcome involving economical cost related to tobacco use (Feirman et al., 2015). In general, researchers used various mathematical methods in their studies depending on their desired objectives.

Several trend studies have been found in the literature using mathematical models. For instance, Castillo-Garsow & Rodriguez-Herrera (1997) introduced a basic model to analyse the behaviour and the dynamicity of tobacco use, recovery, and relapse. In their study, it was found that peer pressure is one of the key influences in initiating young people to smoke and leading to drug use. This is among the earliest tobacco studies using nonlinear differential equations that formulate the population into three groups: potential smokers, current smokers, and former smokers. In another study, Pulecio-Montoya, Luis Eduardo, & Benavides (2019) used nonlinear differential equations to analyse tobacco users' population growth dynamics. In this study, it was found that the current smokers will disappear over time, provided that the average number of new smokers that a single current smoker produced is less than one; otherwise, the smoking population continues.

Policy studies by Goyal (2014) developed a nonlinear SIRS mathematical model and found that awareness programs through media campaigning help reduce the smoking habit. This study found that targeting tobacco users with constant media awareness programs is the best strategy for reducing smoking. Furthermore, it is interesting to note that strategies focusing on non-tobacco users need to be applied much higher intensity than strategies focusing on tobacco users, assuming the same effectiveness in both cases. Meanwhile, Pang, Zhao, Liu and Zhang (2015) proposed a mathematical model described by ordinary differential equations for controlling tobacco in China by raising the price of the tobacco products besides setting up a smoking areas. From different perspectives, the latest study by Pang, Liu, Zhang, and Tian (2019) suggested that the combination of media coverage and smoking cessation treatment appears to be effective in controlling tobacco use in China.

In a nutshell, the strength of mathematical modelling lies in its ability to examine the research problems from multiple angles (Feirman et al., 2015). However, the analysis process may be limited within the person that professes with the method itself, which is too technical. Non-expert may find it challenging to comprehend the mathematical analysis process.

2.4.3 Simulation Modelling

According to Mat Tahar (2006), simulation modelling refers to the process of mimicking the complex operation that occurs in the real-world system. Simulation can be used for performance evaluation, system design, decision making, and policy planning. It is widely used due to its capability to test the policy prior to implementation, and it is risk-free experimentation. It is also a preferable approach to represent the problem under study due to its ability to deal with variability and graphical interfaces to facilitate understanding of the problem (Brailsford & Hilton, 2001). There are three types of simulation models usually used by researchers, which are Agent-Based Modelling (ABM), Discrete-Event Simulation (DES), and System Dynamics (SD) which are discussed in the next sections.

2.4.3.1 Agent-Based Modelling

Agent-Based Modelling (ABM) is a simulation method that deals with individual elements of a system which is called the agents. Generally, ABM has been used in various fields of study. In tobacco studies, a review of the literature found several studies that employed ABM such as a study by Luke et al. (2017) that found the reduction of retailer density may lead to a reduction in the accessibility of tobacco products in urban environments. In the study, the researchers modelled a tobacco system using ABM which the model is referred as 'Tobacco Town' to test four retailer reduction policies such as random retailer reduction, restriction by type of retailer, limiting the proximity of retailers to schools, and limiting the proximity of retailers to each other. Another study by Chao, Hashimoto and Kondo (2015) employed ABM to model the dynamic impact of social stratification and social influence on smoking prevalence. The study concludes that socioeconomic status differences between and within genders, and susceptibility to social influence are crucial factors behind gender differences in smoking prevalence trends. From their studies, ABM has shown its ability to solely focused on individual agents as well as considering multiple dimension of interactions to depict the behavioural rules. However, these advantages lead to the use of overly complex functions. For this reason, ABM is less practical to be used in solving highly complex problem that focus on holistic view (Ahmarofi, 2019; Jaafar, 2019)

2.4.3.2 Discrete-Event Simulation

Discrete-Event Simulation (DES) deals with operational activities and modelling a system that focuses on the network at discrete points of time (Rosetti, 2010). Regarding tobacco, Getsios et al., (2013) have conducted an example of DES research. The researchers proposed a framework to evaluate the potential health and economic impacts of smoking cessation interventions. Meanwhile, Xenakis et al., (2011) focus on simulating a DES model to investigate the outcome of varenicline medication. However, Mayorga, Reifsnider, Wheeler, & Kohler (2014) used DES to estimate the impacts of various tobacco control strategies for the decision maker to decide which is the best strategy for smoking cessation. The estimation includes the number of quality life years gained from smoking cessation and the costs of treatments that could be avoided. Conclusively, DES has shown its ability to be used in operational level involving process in a system. However, this advantage leads to the impracticality to model the complex system at strategic level which does not involve process or queue in a system.

2.4.3.3 System Dynamics Modelling

On the other hand, System Dynamics (SD) is used in many studies to gain insights about the interrelations between different parts in a complex system and modelled it as a whole. SD is growing at an impressive exponential rate due to its unique ability to deal with the real world's complexity. It successfully integrates the nonlinearity and feedback loop structures that are inherent in real complex problems (Forrester, 1994; Sterman, 2000). SD modelling is also used to understand the behaviour of complex systems over time.

To date, seven SD studies have been found in the works of literature relevant to various tobacco issues. The earliest study is initiated in 1979 by Roberts et al., (1982). They modelled the complex interactions that affect the initiation to smoke and motivation to quit. The initiation factors include societal approval, tobacco industry lobbying, and promotional expenditures. Accordingly, Ahmad (2005) developed a model to evaluate the cost-effectiveness of adjusting the state's legal smoking age to 21. This study focuses more on medical care cost. However, this study's remarkable notion is the measurement of health gains by calculating quality-adjusted life years (QALYS) as the outcome. The QALYS concept combines improvements in length of life and health-related quality of life into a single measure, as recommended by the US Task Force on cost-effectiveness in health and medicine.

However, Richardson (2007) takes the initiative to develop a tobacco model that provides insights into the overall tobacco control system. This study extends the previous ones, which focused only on separated components that contribute to more effective tobacco control and public health. Details of sectors of the model are further described in Table 2.5.

In New Zealand, Cavana & Tobias (2007) develop an SD model to study the consequences of tobacco control policies. In assessing the best strategies to implement the policies, four scenarios are simulated. These scenarios are business as usual, fiscal strategies which include less affordable cigarettes, harm minimisation that includes fewer addictive cigarettes and less toxic cigarettes, and a combination of all three scenarios.

On the other hand, Hirsch et al., (2010) explore the potential impacts of various intervention strategies to reduce the country's cardiovascular burden that is incorporated and track the effects of those risk factors overtime on both first-time and recurrent events. This is due to the strenuous efforts to plan and select the programs for the prevention and treatment of cardiovascular disease. It becomes a challenge for every community to fully-utilised their limited resources.

Studies on tobacco are further explored by Levy et al., (2010). The developed *SimSmoke* model simulates the dynamics consequences of smoking, smoking-related mortality, and the effects of those policies. The work by Levy et al, (2010) is interesting since the model is applied and tested to incorporate almost thirty-three countries.

Finally, Zagonel et al., (2011) proposed a novel contribution by introducing a losing awareness loop to the dynamic tobacco epidemic model. They attempt to develop a theory of the societal lifecycle of smoking by using a parsimonious set of feedback loops to capture historical trends and explore future scenarios. In this study, peer pressure, social norm formation, and role models are the factors examined in the model. However, similar to the study by Ahmad (2005), Cavana & Tobias (2007), Levy et al. (2010), Richardson (2007), and Roberts et al. (1982), the smoking factors are not explored in detail. In their research, Zagonel et al., (2011) expand the time horizon to be 110 years (1900 and 2010). Previous studies by Ahmad (2005), Cavana & Tobias (2007), Levy et al. (2010), Richardson (2007), and Roberts et al. (1982) used a maximum of 35 years observation. This attempt provides confirmatory evidence to support the claim by Forrester (1994) and Sterman (2000). They claimed that in order to get the best imitation in the SD model, the time horizon should be extended backward, far enough to capture the real behaviour of the problem.

All of the SD-based tobacco epidemic studies discussed above are summarised in Table 2.2.

Table 2.2

Review of tobacco epidemic modelling using system dynamics

Author(s)	**Model Name**	**Location**	**Time Horizon**	**Research Description**	**Main Variables**
Roberts et al. (1982)	MIT Model	United States	Hindsight (1965-1974) Foresight (until 2010)	The model focuses on the complex interactions which affect the initiation and quitting of smoking	1. Population 2. Contaminants and their effects 3. Factors affecting initiation (societal approval, tobacco industry lobbying and promotional expenditures)
Ahmad (2005)	Tobacco Policy Model (TPM)	United States	Hindsight (1995-2003) Foresight (until 2051+)	The model evaluates the cost-effectiveness of raising the state's legal smoking age	1. Cost of enforcement 2. Cost of checking purchaser identification 3. Cost of medical care

Table 2.2 (continued)

Richardson (2007)	Initiative on the Study and Implementation of Systems (ISIS)	United States	Hindsight (1965-2000) Foresight (until 2010)	To develop clearer ideas about the range of approaches that can contribute to more effective tobacco control	1. Smokers population 2. Smoking as a social norm 3. Tobacco growers 4. Awareness of tobacco health risk 5. Anti-tobacco constituencies 6. Pro-tobacco constituencies 7. Willingness to legislate tobacco control
Cavana and Tobias (2007)	New Zealand Tobacco Control Model	New Zealand	Hindsight (2001-2004) Foresight (until 2051+)	The developed model is used to evaluate the dynamic consequences of tobacco control policies in New Zealand	1. Population 2. Smoking prevalence 3. Tobacco-related deaths 4. Second-hand smoke
Hirsch et al. (2010)	Preventive Impacts Simulation Model (PRISM)	United States	Hindsight (1995-2003) Foresight (until 2040)	To evaluate the impacts of various interventions strategies for reducing the cardiovascular burden	Lifestyle and environment

Table 2.2 (continued)

Levy (2011)	*SimSmoke*	33 countries	Hindsight (2003-2007) Foresight (until 2020)	To simulate the effects of policies on smoking and smoking smoking-attributed deaths	1. Population 2. Smoking-related deaths 3. Tobacco control policies
Zagonel et al. (2011)	Societal Lifecycle of Cigarette Smoking	United States	Hindsight (1900-2010) Foresight (2051+)	To capture historical trends, explore future scenarios, and develop a theory of the societal lifecycle of smoking using a parsimonious set of feedback loops	Losing smoking awareness

2.4.4 Summary of Modelling Approaches in Tobacco Control Studies

To sum up, statistics, mathematics and simulation modelling have benefits and drawbacks that are applicable in various scenarios. From the reviewed tobacco studies, it can be inferred that while all the studies examined are able to solve the problems, it is found that the majority of studies using statistical and mathematical methods does not capture the system behaviour holistically, but only focus on specific components of the system. Besides that, these methods have omitted the interrelations and feedback mechanism that are inherent in real complex problems like tobacco control system. Hence, a simulation model that does not involve in-depth knowledge of mathematical formulations, does not rely heavily on data, and can capture the holistic view of the complexity in a tobacco control system, is considered suitable for modelling the tobacco control system.

Simulation modelling is a widely used instrument in operational research for several reasons. One notably reason for using simulation is it provides a valuable tool for approximating real-life behaviour. This allows the modeller to test and experiment with the developed model prior to any policy implementation, and it is risk-free experimentation. There are three commonly used models when it comes to simulations, which are Agent-Based Modelling (ABM), Discrete-Event Simulation (DES), and System Dynamics (SD), depending on the problem under analysis. All three types of simulation have their strengths and limitations.

In this research context, SD has shown potential as the most suitable method in mimicking the tobacco system and evaluating the anti-smoking strategies. Therefore, the justification for choosing SD lies in two aspects. First, the complex nature of tobacco epidemic which involves feedback interactions and nonlinearity which can be catered by using SD, as previous tobacco studies had supported it (Ahmad, 2005; Cavana & Tobias, 2007; Levy et al., 2010; Richardson, 2007; Roberts et al., 1982; Zagonel et al., 2011). Second, this study intends to analyse the feedback process between the multiple components of tobacco control system, such as influential factors of smoking and anti-smoking strategies. Therefore, a simulation study, particularly an SD model is very useful in this type of study in the case where it is impractical to carry out experiments in practice (Brailsford, Sykes, & Harper, 2006; Zainal Abidin, 2012).

However, despite the extensive use of SD in solving the complexity of the tobacco control system, it has limited ability to address a prioritization element that appears in the process of identifying the dominant effect of anti-smoking strategies and the factors influencing smoking habit. For this reason, Multi-criteria Decision Making (MCDM) approach is brought into the picture based on its characteristics that suitable to be applied to the problem. The MCDM is very likely to provide a ranking of factors based on its weight values. The two widely used MCDM methods are the Analytic Hierarchy Process and Technique of Order Preference Similarity to the Ideal Solution. The explanation for tobacco control studies using MCDM is discussed in Section 2.5.

2.5 Review of Multi-Criteria Decision-Making Approach

By definition, Multi-Criteria Decision Making (MCDM) is a part of operational research which deals with conflicting multiple criteria to find the best alternative (Mardani et al., 2015). Decision-making involving choices and sorting problems as well as prioritisation are complex due to the existence of multiple criteria. For precisely these reasons, MCDM has been developed to support decision-makers to make a better and informed decision.

In the application of MCDM, there are several numbers of methods have been developed to solve multi-criteria problems such as the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Analytic Hierarchy Process (AHP). These methods are widely used worldwide in their attempts to determine the degree of importance of each factor in various fields. MCDM is widely used due to its systematic decision making in analysing the multiple criteria in highly complex problems (Aruldoss, Lakshmi, & Ventakesan, 2013). However, despite the widely used of MCDM methods and a steadily increasing number of academic MCDM-related publications in various vectors, limited studies have been found in the literature using MCDM methods in the context of tobacco control.

2.5.1 Technique for Order of Preference by Similarity to Ideal Solution

In general, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) works by determining the best alternative based on the concept of compromise solution. This method has been used in the operational research field for over thirty years. The first work on TOPSIS was introduced in 1981 by Hwang and Yoon (Tzeng & Huang, 2011). Typically, TOPSIS use distance principle. By definition, the principle behind TOPSIS is that the selected alternative should have the shortest Euclidean distance from the ideal solution and the longest Euclidean distance from the anti-ideal solution (Papathanasiou & Ploskas, 2018). In regard to tobacco, there is one relevant study that employed TOPSIS to identify the key factors of smoking behaviours in Jordan. The result from the study by Zamri, Khaleel, and Ibrahim (2019) shows that the key factor contributing to smoking behaviour among Jordanian is to lose weight. In the study, four criteria and six alternatives were used. Although the TOPSIS method is straightforward and easy to understand, concerns arise where the TOPSIS is highly dependent on the use of Euclidean Distance and omitted the correlation and interrelationship of the attributes (Jaafar, 2019).

2.5.2 Analytic Hierarchy Process

The concept of the Analytic Hierarchy Process (AHP) was first introduced by Saaty in the 1970s (R. W. Saaty, 1987). Typically, the AHP method uses a hierarchical principle where the problem is decomposed into goal, criteria, and decision alternatives and thought of as a hierarchy. The AHP has generally been proposed to derive relative weights in accordance with the problem presented in a hierarchical form. To the best of the researcher's knowledge, few studies are being conducted using AHP in the tobacco control literature. In a study by Matsuda (1998), AHP is used to evaluate the effectiveness of anti-smoking strategies in Japan. This is among the earliest tobacco study that assessed the key factors influencing smoking habits and anti-smoking strategies using AHP. The result shows that higher pricing of tobacco was considered to be the most effective strategy. In another study, Song et al., (2018) had evaluated strategic priorities to improve the effectiveness of anti-smoking interventions in Korea. In this study, AHP is used to prioritise the anti-smoking strategies to improve the existing anti-smoking interventions. The study found that the most important strategy was to improve the perception of and strengthen the reward for smoking cessation.

Although AHP is effective for analysing multiple criteria, concerns arise when it is generally acknowledged that the major drawback of using AHP is inconsistency issues, where the consistency ratio (CR) is more than 0.1. If the CR value is more than 0.1, then the decision-maker needs to revise the pairwise comparison. Several studies are being conducted to overcome the consistency issues in AHP. This includes a study by Balhuwaisl (2013) that introduced a new approach in making the pairwise comparison that can guarantee the consistency all the time using an Enhanced Analytic Hierarchy Process (EAHP). The suggested approach by Balhuwaisl, (2013) is believed to produce a CR value of less than 0.1.

2.5.3 Summary of Multi-Criteria Decision-Making Approach in Tobacco Studies

In modelling tobacco using Multi-Criteria Decision Making (MCDM), both methods which are Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) had their strengths and limitations. Based on the above discussion, both methods are built on different principles. The AHP method is based on the use of the hierarchical principle. The AHP compares the criteria and decision alternatives to form a comparison matrix to determine the criteria weights and decision alternatives ranks. Meanwhile, TOPSIS is based on the distance principle. The TOPSIS set the criteria values and determine the decision alternatives ranks. Simply put, AHP can be used in weighting and ranking criteria and decision alternatives. However, TOPSIS can be used in ranking decision alternatives. Therefore, a comparison of the two methods reveals the suitability of the AHP method for solving the prioritisation problem and the computation of weight values for each criterion and decision alternatives. Meanwhile, the AHP may have a problem in terms of consistency in pairwise comparisons done by evaluators. The issues have been solved and debated by various researchers that proposed the alternatives. On that account, an alternative method like Enhanced Analytic Hierarchy Process (EAHP) offers the capability to prioritise the decision alternatives as well as the criteria, and at the same time provides the weight values for each criterion and decision alternatives.

2.6 Integration of SD and EAHP in this Research Context

To the best of our knowledge, there are limited studies that integrate the System Dynamics (SD) and Analytic Hierarchy Process (AHP) methods, and no attempt has been made to integrate SD and Enhanced Analytic Hierarchy Process (EAHP). Since using SD alone is not capable to prioritise the variables, prioritisation and simulation approaches should be combined to simulate the tobacco control system. In this study, the dominant effect of the influential factors and anti-smoking strategies will be analysed using prioritisation approach. The suitable prioritisation technique is the EAHP since the technique is able to model the relationships with simplicity. In addition, the guaranteed consistency offered by the EAHP is in line with the needs of decision-makers who require uncomplicated and less time-consuming instruments.

In addition to prioritisation, the EAHP can complement SD by providing parameter values to the factors influencing smoking habits which are qualitative variables. The integration of SD and EAHP seems to provide an effective base for prioritising and simulating a complex scenario of tobacco epidemic simultaneously. SD is a dynamic-based simulation modelling method, whereas EAHP is a multi-criteria decision-making method. Both SD and EAHP have many advantages and disadvantages, which are complementary. Therefore, it seems logical to combine the two methods to produce an all-inclusive integration-method.

The combination of these two aspects should be further explored in order to better simulate the tobacco control system. Therefore, in this study, the concept of simulation and prioritisation will be synergized using EAHP and SD. The integration model of EAHPSD is not a substitution to older modelling paradigms, but as a useful integration that can be efficiently combine EAHP and SD to capture much more complicated scenarios, thus providing for deeper insight in the system being modelled. Besides, the synergy helps to develop a unified consensus of the knowledge domain.

2.7 Concept and Theories of Enhanced Analytic Hierarchy Process and System Dynamics

This section focuses on the concepts and theories of Enhanced Analytic Hierarchy Process (EAHP) and System Dynamics (SD) in two sub-sections in order to understand how the integration of these methods assist in solving the problem under study. The integration of EAHP and SD as a new multi-method is found as a promising method for evaluating the impact of anti-smoking strategies. This section starts with a discussion on the concepts and theories of EAHP as a prioritisation method in Section 2.7.1. Then, the concepts and theories of SD as a simulation method will be discussed in Section 2.7.2.

2.7.1 Enhanced Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a mathematical method developed by Thomas L. Saaty in the 1970s. The AHP is a basic decision-making approach designed to solve problems involving multiple complex criteria in achieving the overall best decision (Anderson, Sweeney, & Williams, 2008; T. L. Saaty & Vargas, 2001). There are four basic steps involved in conducting AHP which are (1) problem decomposition, (2) pairwise comparison, (3) consistency check for the comparative judgements, and (4) priorities computation.

Saaty (2010) highlights the essence of using AHP is the complexity of the problem can be decomposed into a hierarchical structure, and this will assist decision-makers to visualise and organise their thoughts and judgements for effective decision making. Moreover, apart from the AHP's ability to quantify subjective factors in the decision-making problem, the judgement process is easy to be understood by non-mathematicians. In its simplest form, the hierarchy is made up of three levels: overall goal, criteria and alternatives. The AHP requires the decision-maker to provide pairwise comparison judgements which are then used to develop overall priorities for the decision alternatives. In the same way, priorities in each level of the hierarchy are also derived.

However, the drawback of using AHP is consistency issues. The idea of consistency is deemed important because inconsistent pairwise comparison reflects poor judgment process and the pairwise comparison process might have to redo. Therefore, realising the difficulty in ensuring consistency when dealing with pairwise comparison, several researchers have suggested some alternatives. One of the alternatives to overcome inconsistency issues is as suggested in the Enhanced Analytic Hierarchy Process (EAHP) by Balhuwaisl (2013).

In the work done by Balhuwaisl (2013), a pre-evaluation step is conducted prior to conducting the pairwise comparison. The pre-evaluation step requires the evaluator to rate the importance criteria using a scale 1 to 9, whereby 1 represents the least important, while 9 represents extremely important. The ratings obtained are then evaluated using a simple mathematical algorithm to form a pairwise comparison matrix. Then, the weights for each criterion are calculated using the existing AHP method to determine the priorities. The modelling process in developing EAHP model is illustrated in Figure 2.3 and the detailed explanations of the EAHP are described in the following sub-sections.

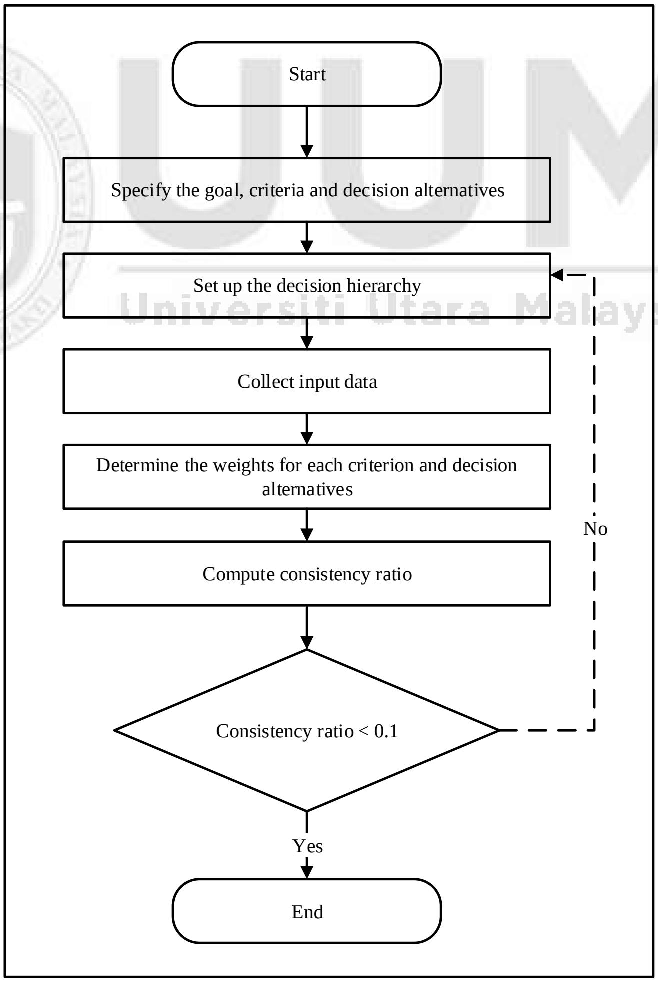


Figure 2.3 Modelling process in developing EAHP model

2.7.1.1 Specify the goal, criteria and decision alternatives

The first step in developing the model is by decomposing the decision problem into three important elements which are defined in Table 2.3 (Saaty, 2010).

Table 2.3

Basic elements in AHP model development

Element	Description
i. Goal	Objective to be achieved
ii. Criteria/sub-criteria	A measure of attributes or characteristics related to the goal
iii. Decision alternatives	Desired options or choices available to achieve the goal

2.7.1.2 Set up the decision hierarchy

Next, the goal, criteria, and decision alternatives are structured into a hierarchy. As suggested by Saaty (2010), the simplest form of AHP-hierarchy consists of three basic levels, which are the overall goal, criteria, and decision alternatives. For easy understanding, criteria are labelled as C_1 to C_m, and decision alternatives are labelled as DA_1 to DA_n. The hierarchy of the problem is illustrated in Figure 2.4 (Saaty, 2010).

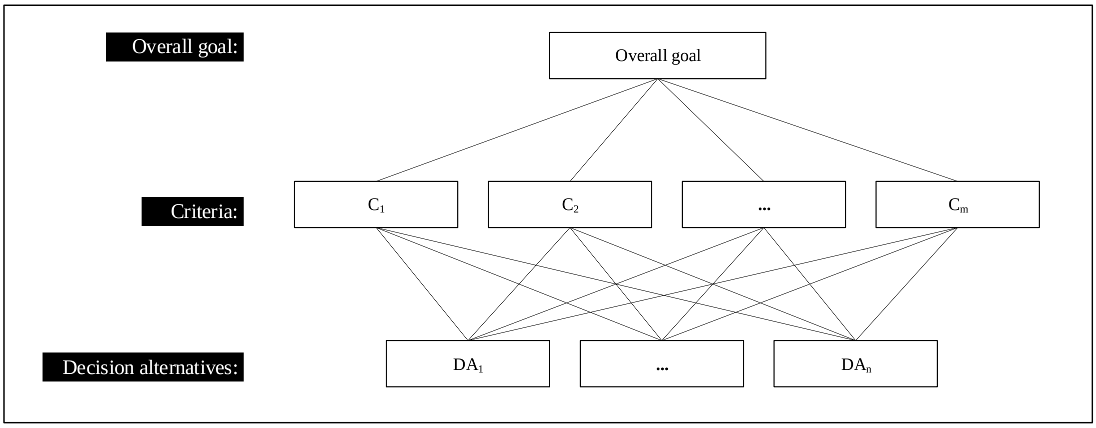


Figure 2.4 Hierarchical representation of the problem

2.7.1.3 Collect input data

In this third step, a set of questionnaires is used to obtain the input data (see Appendix B). The questionnaire is specifically designed to simplify the tedious pairwise comparison and overcome inconsistency issues (Balhuwaisl, 2013). Using the existing AHP method, the respondent is required to make comparative judgements using a scale with values from 1 to 9, whereby 1 represents equally important while 9 represents extremely important. However, instead of asking the respondent to make the comparative judgements, by using EAHP, the specially designed questionnaire enables the respondent to simply rate the level of importance of the criteria towards the overall goal by utilising the values between 1 and 9 with interpretations listed in Table 2.4 (Balhuwaisl, 2013). This is to gauge the respondent's logical thinking in assessing the level of importance towards the overall goal (Balhuwaisl, 2013; Engku Abu Bakar, Balhuwaisl, & M.Kasim, 2016).

Table 2.4

Interpretation of the values used in pairwise comparison

Importance level	Numerical value
Equally important	1
Equally to moderately important	2
Moderately important	3
Moderately to strongly important	4
Strongly important	5
Strongly to very strongly important	6
Very strongly important	7
Very strongly to extremely important	8
Extremely important	9

Next, the feedback received from the respondents will be utilised to form rating tables. The example of rating tables for criteria and decision alternatives used in this research is illustrated in Table 2.5 and Table 2.6. The ‘x’ sign in Table 2.5 and Table 2.6 represents the level of importance of each criterion towards the goal, rated by the respondents.

Table 2.5

Rating table for criteria

Criteria	**Rating**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
C_1	x								
C_2		x							
C_3		x							
C_4								x	
C_5							x		
C_6						x			

Table 2.6

Rating table for decision alternatives

Criteria	**Rating**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
DA_1	x								
DA_2		x							
DA_3		x							
DA_4								x	
DA_5							x		

2.7.1.4 Determine the weights for each criterion and decision alternatives

Next, the rating tables obtained are transformed into a pairwise comparison matrix to obtain the weights for the criteria. Suppose the respondent rates the criterion i as a_i and criterion m as a_m. Then, y_{im} which is the pairwise comparison value between criterion i and criterion m will be determined using the mathematical algorithm in Equation 2.1 to Equation 2.5.

if $i \leq m$ (2.1)

let $b = a_i - a_m$ (2.2)

if $b < 0$, then $y_{im} = \frac{1}{1-b}$ (2.3)

if $b = 0$, then $y_{im} = 1$ (2.4)

if $b > 0$, then $y_{im} = b + 1$ (2.5)

where, y_{im}, is the entry in the matrix.

Then, all the data collected are transformed into a pairwise comparison matrix, assigned as matrix A.

$$A = \begin{bmatrix} 1 & y_{12} & y_{13} & y_{14} & \cdots & y_{1m} \\ \frac{1}{y_{12}} & 1 & y_{23} & y_{24} & \cdots & y_{2m} \\ \frac{1}{y_{13}} & \frac{1}{y_{23}} & 1 & y_{34} & \cdots & y_{3m} \\ \frac{1}{y_{14}} & \frac{1}{y_{24}} & \frac{1}{y_{24}} & 1 & \cdots & y_{4m} \\ \cdots & \cdots & \cdots & \cdots & 1 & \cdots \\ \frac{1}{y_{1m}} & \frac{1}{y_{2m}} & \frac{1}{y_{3m}} & \frac{1}{y_{4m}} & \cdots & 1 \end{bmatrix}$$

The matrix should be in the following form as shown in Table 2.7.

Table 2.7

The pairwise comparison matrix

	C_1	C_2	C_3	C_4	…	C_m
C_1	1	y_{12}	y_{13}	y_{14}	…	y_{1m}
C_2	$\frac{1}{y_{12}}$	1	y_{23}	y_{24}	…	y_{2m}
C_3	$\frac{1}{y_{13}}$	$\frac{1}{y_{23}}$	1	y_{34}	y_{14}	y_{3m}
C_4	$\frac{1}{y_{14}}$	$\frac{1}{y_{24}}$	$\frac{1}{y_{34}}$	1	…	y_{4m}
	…	…	…	…	1	…
C_m	$\frac{1}{y_{1m}}$	$\frac{1}{y_{2m}}$	$\frac{1}{y_{3m}}$	$\frac{1}{y_{4m}}$	…	1

Once the pairwise comparison matrix is obtained, each criterion's weight is calculated using the existing AHP method. The principal eigenvalue and the corresponding normalised right eigenvector of the comparison tables will give the relative importance of the criteria being compared. The normalised eigenvector elements are termed weights with respect to the criteria and rating with respect to the alternatives.

2.7.1.5 Compute consistency ratio

Next, the EAHP provides a measure of consistency for the pairwise comparisons by computing a consistency ratio (CR). This is a crucial process as this will measure the degree of consistency of the pairwise comparison judgments provided by the decision-maker. The values of CR is determined as follows:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)}$$

$$CR = \frac{CI}{RI}$$

where CI is the consistency index, λ_{max} is the maximum eigenvalue of the judgement matrix, and RI is the random index. The CR should be less than 0.1 for a reliable result. However, CR exceeding 0.1 indicates that the pairwise judgments are just about random and are completely untrustworthy (Tzeng & Huang, 2011).

CR > 0.10	inconsistent
CR < 0.10	consistent

2.7.2 System Dynamics

System Dynamics (SD) is a simulation technique founded by Jay W. Forrester at the Massachusetts Institute of Technology in the 1960s (Sterman, 2000). It is an approach to understand complex systems over time (Sterman, 2000). The behaviour of a complex system over time represents the variations and trends regarding the variable of interest. García (2006) defines SD as the technique that aims to understand the behaviour of a system in terms of its structure. Nonlinear dynamics and feedback controls developed in mathematics, physics, and engineering are the building blocks in SD. Previous literature highlight that SD technique helps to improve the decision making process and policy formation through its characteristics of incorporating all the relevant cause-effect relationships, time delays, and feedback loops in a dynamics behaviour mode of systems (Sterman, 2000).

There are five basic steps involved in developing the SD model, which are model conceptualisation, development of dynamic hypothesis, development of stock and flow model, model validation, and policy design and evaluation (Sterman, 2000). As shown in Figure 2.5, the modelling process is an iterative procedure and the iteration is represented in dashed line. The iteration in any of the modelling steps will be repeated until the model's behaviour closely replicates the actual behaviour.

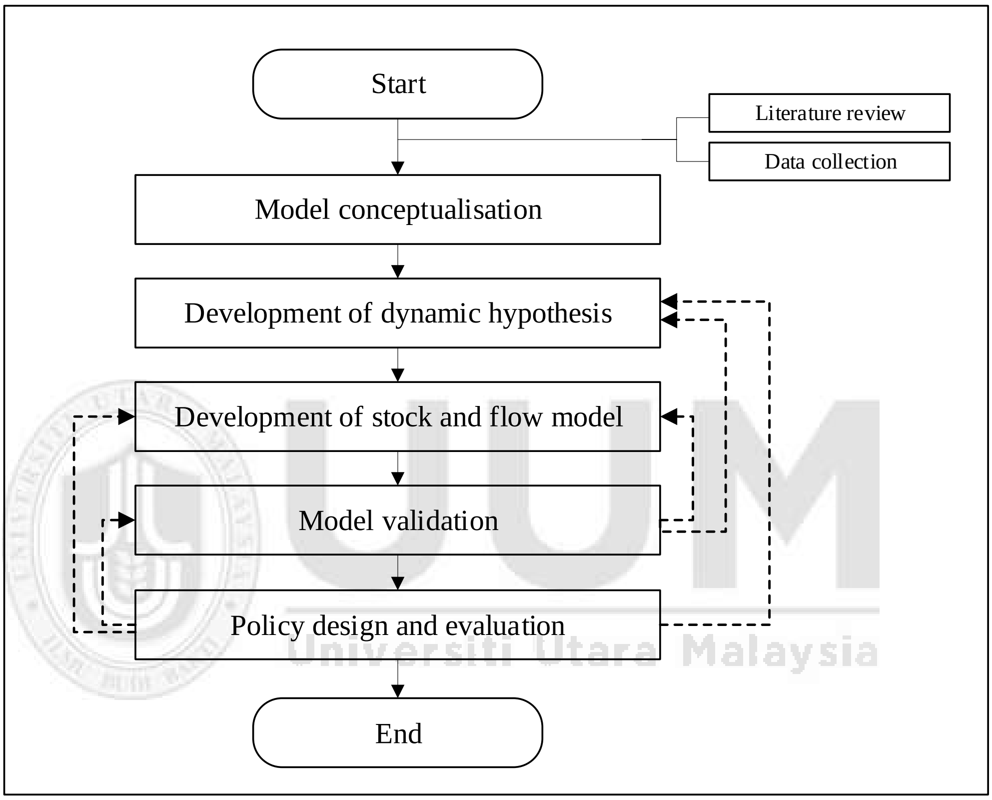


Figure 2.5 Modelling process in developing SD model

Note: Adopted from (Sterman, 2000)

The detailed explanations of each step related to this study are described as follows:

2.7.2.1 Model Conceptualisation

Model conceptualisation is the most crucial step in the overall modelling process. This step starts with a discussion, data collection, interviews, and observation in order to obtain an initial characterisation of the problem (Sterman, 2000). The important aspects to be identified at this stage are the purpose of the model, reference modes, and time horizon.

A clear purpose of the model is the most crucial step in addressing the problem. The clarity of the purpose relates to the research questions to be answered, and its objectives to be achieved, which will determine the usefulness of the developed model (García, 2006; Sterman, 2000). Reference modes are defined as any descriptive data or set of graphs showing the problem's behaviour over time (Sterman, 2000). The modeller will refer to the reference modes as guidance throughout the modelling process in order to determine how the problem arose and how it might evolve in the future. Time horizon and key variables considered to be important for understanding the problem are also identified through report review, expert interview, or literature review. In order to show the development of the problem, the time horizon should extend far enough back in history. The selection of the time horizon should be able to capture the behaviour of the problem (Sterman, 2000).

2.7.2.2 Development of Dynamic Hypothesis

Once the problem has been identified, the modellers need to formulate a dynamic hypothesis or working theory describing how the problem developed (Sapiri, Zulkepli, Ahmad, Zainal Abidin, & Hawari, 2015; Sterman, 2000). The hypothesis explains the dynamics of behaviour and the underlying feedback process of the system. There are various mapping tools used to represent the dynamic hypothesis of the model as well as to show the model boundary. For example, model boundary chart, subsystem diagram, causal loop diagram, stock and flow maps, and policy structure diagram are used to hypothesise the structural explanation of observed behaviour (Sterman, 2000).

Causal loop diagram (CLD) is one of the mapping tools to present the overall architecture of the problem (Sterman, 2000). It can reveal the causal structure of a system holistically. The basic structures of CLD are variables (represents factors) and arrows (represents links), as shown in Figure 2.6. The nature of the variables can be quantitative or qualitative, and it is one of the CLD strength as it can incorporate qualitative variables into the system thinking approach (Maani & Cavana, 2007). Other than that, the connecting arrows illustrate the causal relationship and changes between and within the variables. Each causal relationship or link is assigned to indicate the direction of influence. Referring to Figure 2.6, a plus sign (+) indicates a change in Variable 1 will produce a change of the same direction in Variable 2. Meanwhile, a minus sign (-) indicates a change in Variable 2 will produce a change of the opposite direction in Variable 1.

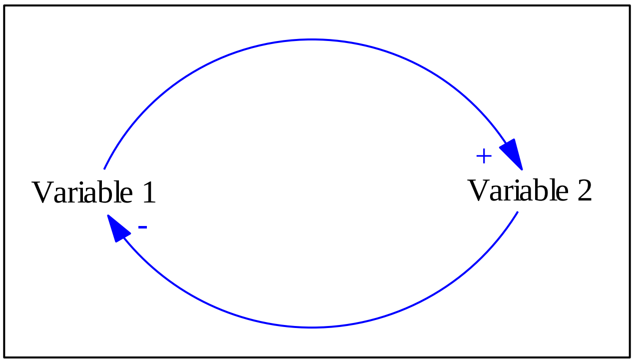


Figure 2.6 Basic structure of a causal loop diagram

Note: Adopted from (Sterman, 2000)

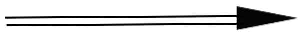
In this mapping stage, the modeller also must carefully identify which variables are influencing the problem. The variables are classified either by endogenous or exogenous explanation. The term “endogenous” means “arising from within”, while “exogenous” means “arising from without” (Sterman, 2000). This implies an endogenous variable interacts within the boundary of the model, while an exogenous variable is generated from outside the boundary of the model. The endogenous variables should be carefully identified in order to explore the patterns of the problem behaviour. On the other hand, exogenous variables should not be neglected. The interaction of the exogenous and endogenous variables should be carefully considered in order to determine the model boundary (Sterman, 2000).

2.7.2.3 Development of Stock and Flow Model

Stock and flow model development begins after the conceptual model has been developed. The dynamic hypotheses are transformed into stock and flow in the SD model. The SD model is made by stocks, inflows, outflows, valves, and clouds, as shown in Table 2.8, and the general structure in SD modelling is depicted in Figure 2.7.

Table 2.8

Elements in the system dynamics model

Elements	**Diagram notation**	**Functions**
Stock		Reservoir
Flow (inflow or outflow)		Channel/connector

Valve		Flow regulator
Clouds (source or sink)		Stocks outside of the model boundary

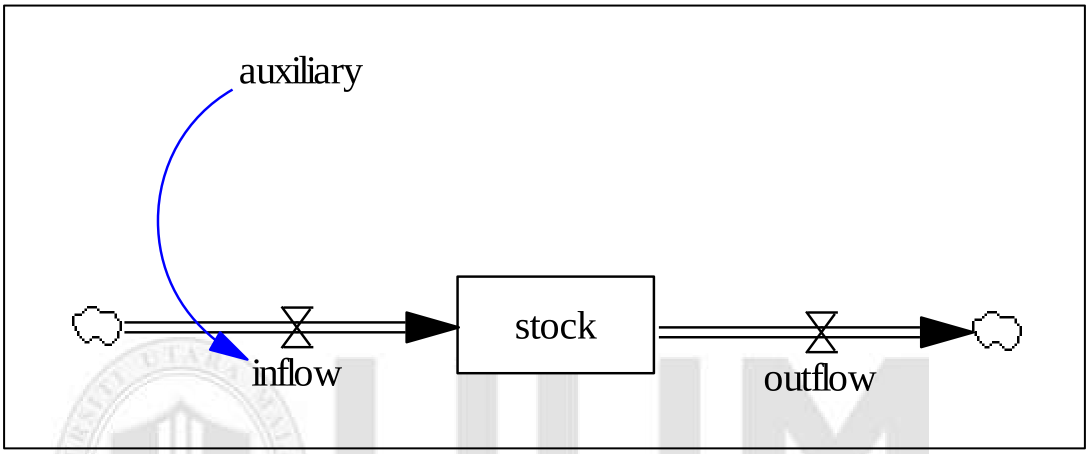


Figure 2.7 General structure in system dynamics model

Note: Adopted from (Sterman, 2000)

A rectangle represents stock. It acts as the reservoir to accumulate the elements, while flows act as channels for transferring the flow of things into and out of stocks. Inflow occurs when the flow increases, and outflow occurs when the flow decreases. Valves act as the flow regulator. Clouds represent the sources and sinks for the flows. A source represents flows originated from outside the model boundary. In contrast, a sink represents flows terminating and leaving the model boundary. However, these clouds are assumed to have the infinite capacity (Sterman, 2000).

Furthermore, the idea of stocks and flow diagram is best illustrated using a bathtub of water metaphor, as illustrated in Figure 2.8. The tub acts as a stock. The water flowing in through the tap acts as inflows, while the water flowing out acts as outflows. The water taps control the quantity of water flowing into the bathtub, while the tub hole channelled the water flowing outside of the tub.

Figure 2.8 Bathtub metaphor of stocks and flows

Generally, the net change in the flow of the stock is the inflows minus outflows, which corresponds precisely to the following equation:

$$Net\ change\ in\ stock = Inflow - Outflow$$

As explained earlier, stocks function to accumulate or integrate their flows. Therefore, the mathematical representation of the net change of flow in any stocks from initial time, t_0 to the current time, t correspond to the integral equations as follows:

Integral equation: $$Stock(t) = \int_{t_0}^{t} [Inflows(s) - Outflows(s)]ds + Stock(t_0)$$

Equivalently, the net rate of change in stock corresponds to the differential equation as follows:

Differential equation: $$\frac{d}{dt} Stock = Net\ Change\ in\ Stock = Inflow(t) - Outflow(t)$$

As well as stock and flow, auxiliary variables are another element used in model development. It acts as the intermediate variable for model clarity. For a clear presentation of the model, auxiliary variables help break the complex equation into smaller parts. By using auxiliary variables, the complex equations are split into smaller and clearer parts (García, 2006; Sterman, 2000).

2.7.2.4 Model Validation

The model validation process starts as soon as the SD model has been developed. It is a process to establish the model's robustness, uncover the model's flaws, and increase model confidence (Barlas, 1994b, 1994a; Forrester & Senge, 1980; Sterman, 2000). Generally, model validation process is grouped into structure and behaviour validity tests.

2.7.2.5 Policy Design and Evaluation

Policy design and evaluation are conducted to attempt model improvement after the robustness of the model is validated (Sterman, 2000). Generally, model improvement can be categorised into sensitivity test and policy optimisation. In the sensitivity test, changes are made in parameter values, taking into account both worst-case and best-case scenarios. Policy optimisation is the process of improving the model's results either in terms of its performance or by calibrating it to suit into reported time series data.

In SD, optimisation is twofold. First, one may wish to improve the developed model in term of its performance. For example, it is desired to minimise the overall cost of production. So, the focus here is cost, and it would be minimised after seeking the related parameter. This type of optimisation is called policy optimisation. Second, a modeller may wish to determine the optimal parameters that fit the model based on historical data. The focus is to determine how well the model fits the data pertaining to an important model variable. This type of optimisation is called calibration optimisation.

2.8 Summary

This chapter presents a review of previous studies related to the research topic: tobacco epidemic, enhanced analytic hierarchy process (EAHP) and system dynamics (SD) as well as the fundamental concept of EAHP and SD. These reviews lead to the identification of the research gaps. Conclusively, this research differs from previous studies in four aspects:

i. This research offers a targetted approach in evaluating anti-smoking strategies by highlighting the causes and correctors of smoking habit which has not been featured in the previous tobacco control studies.

ii. To the best of researcher's knowledge, there are very limited studies on the applications of EAHP and SD in tobacco studies. Hence, this research intends to demonstrate the strength of the integrated model and its capability in addressing research problems.

iii. The integration of EAHP and SD in this research allows a prioritisation capability to rank anti-smoking strategies and factors influencing smoking habits.

iv. The integrated EAHPSD model developed in this research permeates the use of qualitative variables through the weight values obtained using EAHP.

The following chapter will discuss the overall research methodology process which starts from problem identification until the desired result obtained by integrating the concepts of EAHP and SD.

CHAPTER THREE
RESEARCH METHODOLOGY

This chapter discusses the methodology used in order to achieve research objectives. This chapter's essence is the step-by-step approach of integrated Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) model to evaluate anti-smoking strategies towards achieving tobacco endgame. It begins with the explanations on research design, research process, and research framework. Next, the development of the proposed integrated EAHPSD model is discussed. Finally, a summary of the content is provided at the end of the chapter.

3.1 Research Design

This research was designed to accomplish the research objectives. The main objective is to evaluate the anti-smoking strategies towards achieving tobacco endgame in Malaysia. It will be conducted through seven stages: problem definition, literature review, data collection, model development, model validation, model evaluation, and policy improvement.

In this research, the Malaysian tobacco epidemic has been chosen as the domain where the integrated model is adopted for strategic planning towards achieving tobacco endgame by the year 2045. The research data from this research is drawn from primary and secondary data. Primary data includes meeting and discussion with the expert on tobacco control in Malaysia. In contrast, secondary data were obtained from tobacco statistic reports and review of the literature. The integrated model of EAHPSD is then developed with the incorporation of the main components in the tobacco system. The main components are population, factors influencing smoking, and anti-smoking strategies. The integrated model is then evaluated through model validation and evaluation. Next, the best-so-far result of smoking prevalence obtained from the evaluation process will be interpreted for policy improvement.

3.2 Research Process

In order to obtain a clear understanding of the research process, the general flow of research activities is presented in Figure 3.1.

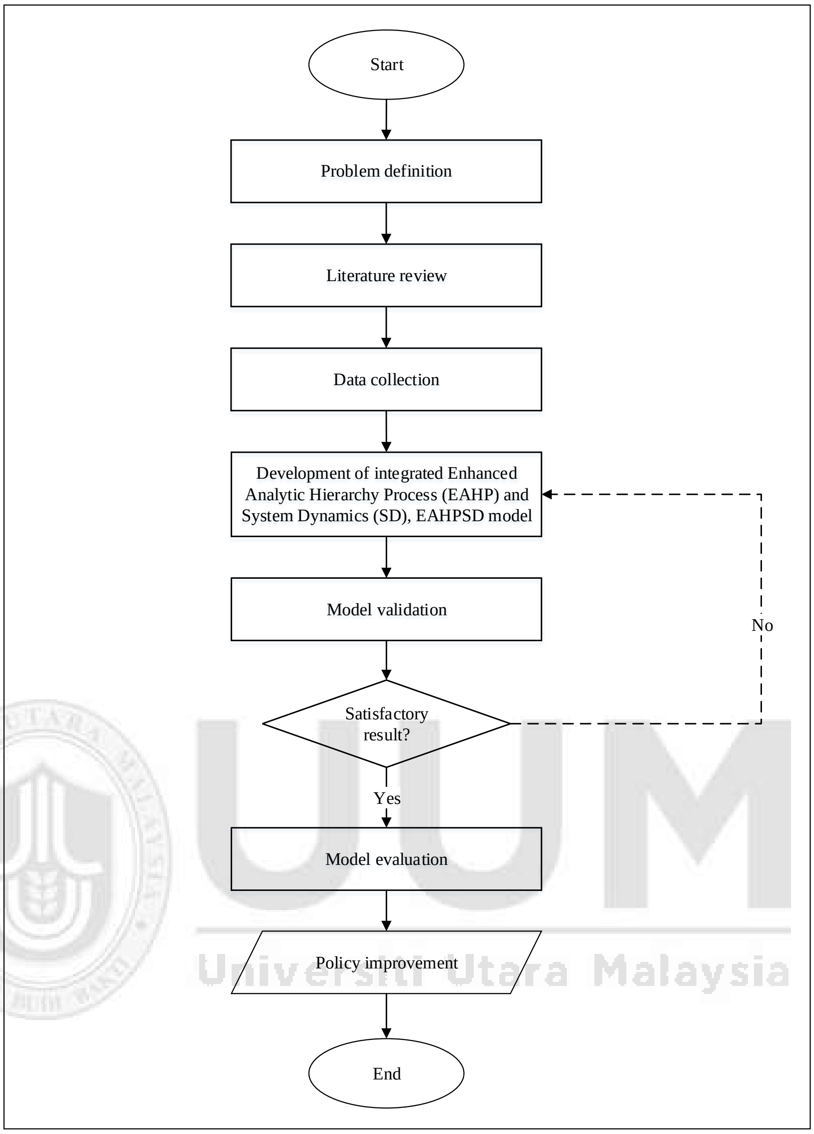
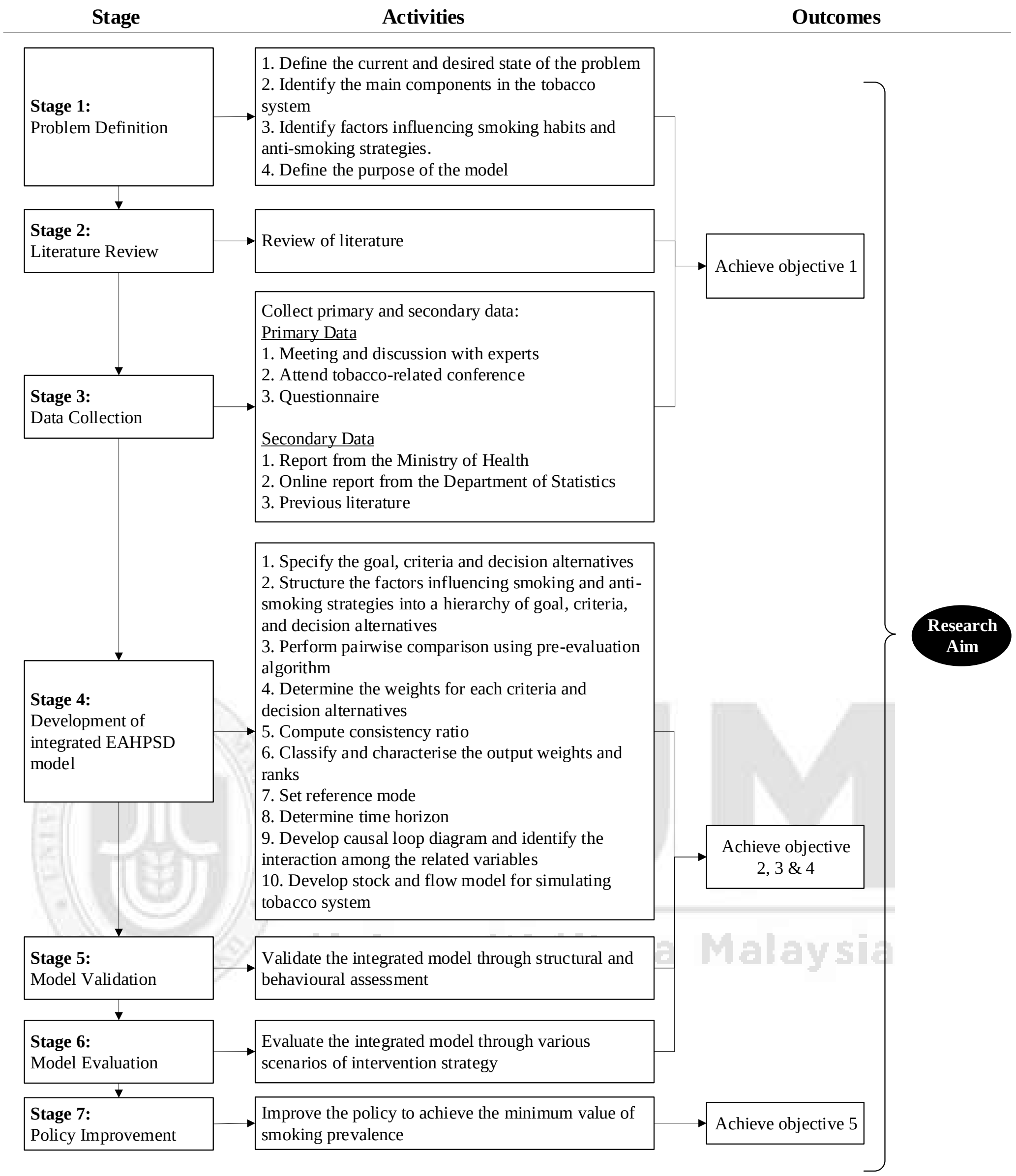


Figure 3.1 General flow of the research activities

The general flow shows the research activities' levels, namely problem definition, literature review, data collection, model development, model validation, model evaluation, and policy improvement. Each level in the general flow is specified as stages of research activities carried out to achieve research objectives (see Figure 3.2). A detailed discussion of model development is explained in Section 3.6.



RESEARCH AIM AND OBJECTIVES:

The aim of this study is to evaluate the anti-smoking strategies towards achieving tobacco endgame in Malaysia. In order to achieve the aim of this research, five sub-objectives are determined as follows:

1. To identify factors that influence smoking habits.
2. To determine the weights of the contributing factor using EAHP.
3. To prioritise the anti-smoking strategies using EAHP.
4. To simulate the tobacco control system using an integrated EAHPSD model.
5. Evaluate the integrated EAHPSD model to achieve the minimum value of smoking prevalence by the year 2045.

Figure 3.2 Details of research activities

3.3 Research Framework

Based on the problem statement, research objectives, and research activities, a research framework was proposed, as shown in Figure 3.3. It expands the research activities' structure with the related methods on how to accomplish each particular objective. In this framework, Stage 1 (Problem Definition) is further discussed in Section 3.4, while Stage 2 (Literature Review) was discussed in Chapter 2. In this section, Stage 3 (Data Collection), Stage 4 (Model Development), Stage 5 (Model Validation), Stage 6 (Model Evaluation), and Stage 7 (Policy Improvement) are discussed to show a more systematic approach in achieving the research objectives. Overall, the framework highlights the stage's linkages in achieving research objectives, data used, and policy improvement as the final outcome.

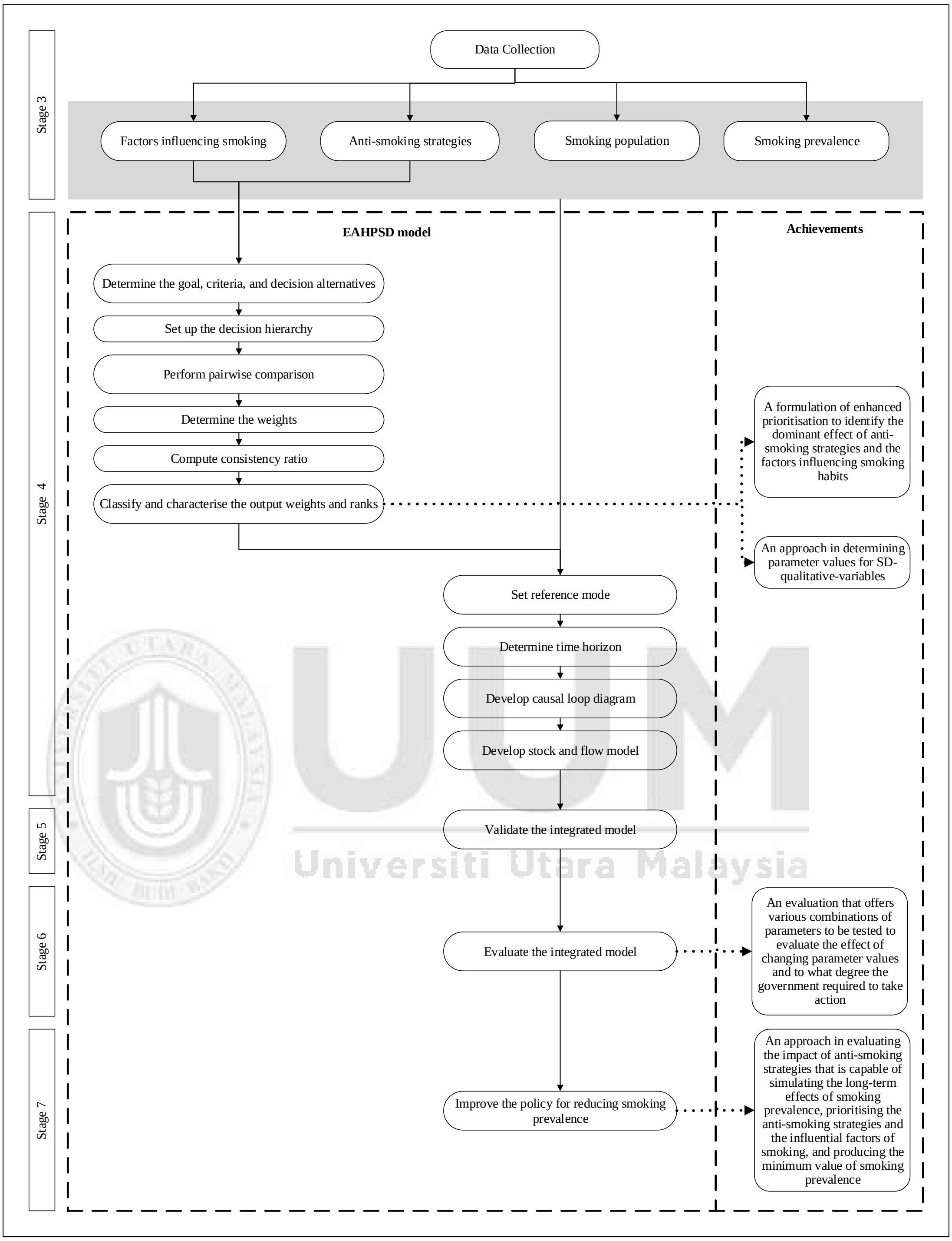


Figure 3.3 Framework of the research

3.4 Problem Definition

In order to develop the proposed integrated EAHPSD model, the Malaysian tobacco epidemic has been considered as the domain where the integrated model is adopted for strategic planning towards achieving tobacco endgame by the year 2045. However, the action plan to achieve tobacco endgame is impossible to accomplish since there is a growing concern related to the high number of premature mortality cases in Malaysia (World Health Organisation, 2018).

Referring to the standard practice by previous tobacco-SD researchers such as Ahmad (2005), Cavana & Tobias (2007), Levy et al. (2010), Richardson (2007), and Roberts et al. (1982), tobacco system is modelled into several basic components. These components are population, smoking-related morbidity and mortality, and anti-smoking strategies. However, in tobacco system modelling, little attention was given to the factors influencing smoking. These factors are deemed important as they are the driving forces of the smoking habit, which need to be considered for better decision making. Due to that, in this research, the researcher explores the dynamic and feedback process in the tobacco system by considering three components, which are population, causes, and correctors of smoking. The causes of smoking are the factors influencing smoking, and the correctors are the anti-smoking strategies. It is undeniable that the tobacco system is a substantial multidisciplinary interrelated component. However, for a model to be useful, it must address a specific problem and portray the simplification of the problem rather than mirroring the whole system in detail (Sterman, 2000).

Next, after identifying and defining the current and desired state of the problem as well as the main components involved, the purpose of the model is defined. According to García (2006) and Sterman (2000), the initial step in model development is to identify and focus on the problem under study and define its purpose. In this research, the general objective is to develop the dynamics of the tobacco control model in evaluating the impact of anti-smoking strategy that resulted in solutions towards reducing the smoking prevalence. In order to achieve the aim of this research, five sub-objectives need to be answered, as stated in Chapter 1 (Section 1.6). In a nutshell, this research focus on the feedback process involved in simulating the causes and correctors of smoking in a population. The population, factors influencing smoking, and anti-smoking strategies are used as input, whereas smoking prevalence value as the output of the research. One of the purposes of this research is to identify the driving forces that cause smoking habits and suggest the most relevant corrector for achieving tobacco endgame.

3.5 Data Source and Collection

There are two types of data needed for this research, which are primary and secondary data. Figure 3.4 shows the graphical representation of the data source and collection.

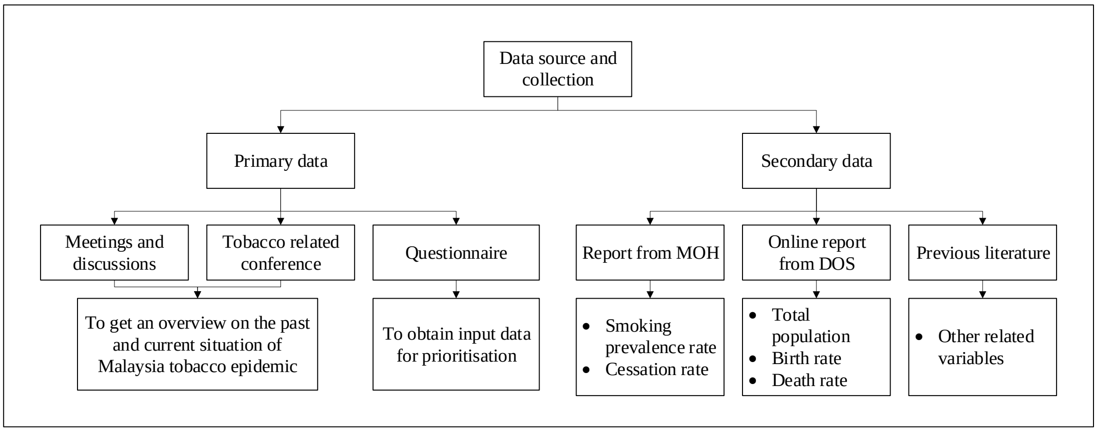


Figure 3.4 Data source and collection

Primary data can be defined as an original data source collected for specific research problem at hand using specific procedures that best fit the research problem. It can be collected in a number of ways. According to Kim and Ahn (1999), primary data can be collected through observations, discussions, or interviews made with one or more experts, depending on the expert constraint. For this research, data are collected from meetings and discussions with the tobacco-related officials, who have been assigned by WHO as the FCTC Secretariat in Malaysia. Hence, their on-the-field experience regarding the current situation of the tobacco epidemic in Malaysia is deemed essential to obtain a clearer picture of the problem undertaken. In addition, the data is also obtained from the prominent tobacco-related conference, Kuala Lumpur Nicotine Addiction Conference 2015, in April 2015. During this conference, the current scenario in the tobacco epidemic, the strategies implemented as well as the challenges to smoking cessation are discussed by the world tobacco experts. The participants are from various parts of the world, such as New Zealand, Thailand, and the United States.

Apart from meeting with experts and attending the tobacco-related conference, a set of questionnaires (refer Appendix B) is also used to obtain the input data to prioritise smoking causes and correctors. The respondents are the medical doctors as well as the FCTC secretariat, and the data was collected in November 2016. They are Dr. Noraryana Hassan (Respondent 1), Dr. Norliana Ismail (Respondent 2), and Dr. Netty Darwina Mohd Dawam (Respondent 3).

On the other hand, it is possible to use the data collected from second-hand sources, which is secondary data. In this research, secondary data are obtained from the reports from the Ministry of Health Malaysia. The approval for retrieving the data comes from the National Medical Research Register (NMRR) with NMRR ID of NMRR-14-1916-22969 (refer Appendix A). These data include time-series data of smoking prevalence and cessation rate from the year 2000 till 2016. These numerical data were obtained from the Institute of Public Health (IPH) Malaysia. Besides that, data are collected from the Department of Statistics Malaysia, which is publicly available online. These data include the total number of populations, birth rate, and death rate. Other than that, secondary data were also taken from Tobacco Atlas from the World Health Organisation (WHO). The list of secondary data and its source are compiled in Table 3.1 below.

Table 3.1

List of secondary data and its source

Data	**Source**
Smoking prevalence rate Smoking cessation rate	• National Health and Morbidity Survey Reports • Tobacco Atlas • World Health Organisation
Total number of populations Birth rate Death rate	Malaysia Department of Statistics

3.6 Development of Integrated EAHPSD Model

The development of a proposed integrated Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) model is elaborated in the following steps to meet the main objective of this research.

- Step 1: From the literature review and data collection, the problem is decomposed into goal, criteria, and decision alternatives.

- Step 2: The goal, criteria, and decision alternatives are presented in a hierarchical form.

- Step 3: Data collected from questionnaires are transferred into a rating table to utilise the feedback received from respondents. Next, from the rating table, a pairwise comparison matrix is constructed using a pre-evaluation algorithm.

- Step 4: The weights for criteria and decision alternatives are evaluated. From the weights obtained, the ranks for criteria and decision alternatives are determined.

- Step 5: The consistency ratio is computed to ensure that it is less than 0.1.

- Step 6: For each criterion, the weights obtained is used as the parameter values for factors influencing smoking. For decision alternatives, the highest rank is used as the anti-smoking strategy to be tested in the simulation model.

- Step 7: Graphs for key variables are constructed using historical data gathered during the data collection process.

- Step 8: Relevant time period and the units used is determined.

- Step 9: Population, factors influencing smoking and anti-smoking strategy (obtained from EAHP ranks) are conceptualised through the development of a causal loop diagram (CLD).

- Step 10: Stock and flow model is developed to simulate the impact of anti-smoking strategy with the inclusion of influential factors of smoking, which is the qualitative variables.

- Step 11: The integrated EAHPSD model is validated through structural and behavioural assessment.

- Step 12: The integrated EAHPSD model is evaluated through various scenarios of intervention strategies using sensitivity analysis series and EAHPSD optimisation. The best-so-far scenario obtained is recommended for policy improvement.

The steps for developing the integrated EAHPSD model for evaluating the impact of an anti-smoking strategy are illustrated in a flowchart, as shown in Figure 3.5. The following sub-sections further describe the steps for developing the integrated EAHPSD model.

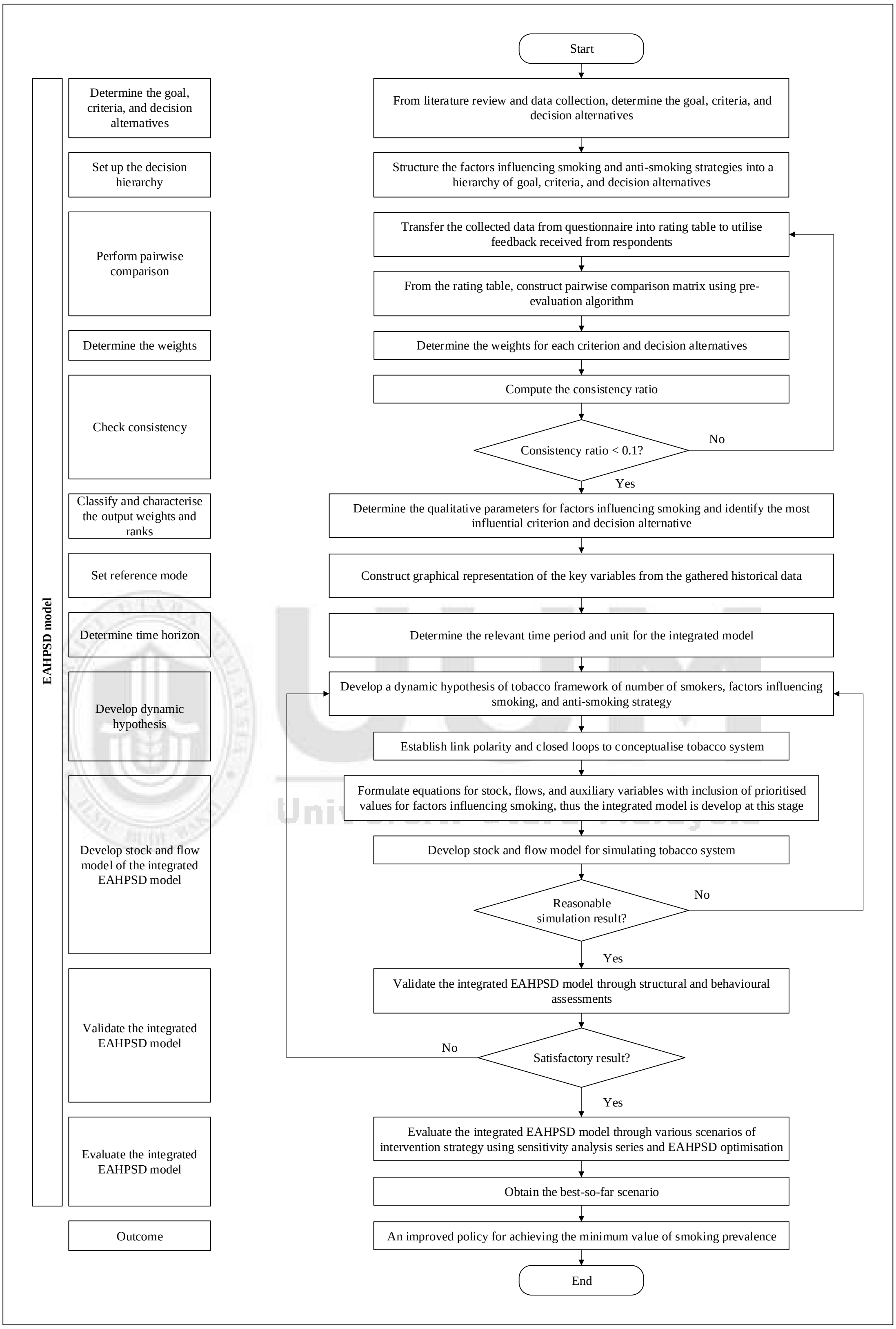


Figure 3.5 Flowchart for development of integrated EAHPSD model

3.6.1 Determine the goal, criteria and decision alternatives

In this step, the factors gathered from the literature review and data collection which are relevant to the goal are specified. The factors are assigned as criteria and decision alternatives. The gathered factors will be prioritised in order to determine the most impactful strategy to reduce smoking prevalence.

In this research, the criteria are personal beliefs and values, personal physiological, family influence, psychosocial influence, cultural influence, and legislative influence, adopted from the Theory of Triadic Influence (Flay et al., 1995). Meanwhile, decision alternatives are represented by packaging and labelling, pricing and taxation, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education, communication, and public awareness, which are adopted from the MPOWER strategy as stated in the World Health Organisation (WHO) reports and Tobacco Atlas. Detailed explanations for both criteria and alternatives are provided in Table 3.2.

Table 3.2

The description of the criteria and decision alternatives used in the model

		Label	**Description of the criteria/decision alternatives**
Criteria	Personal beliefs and values	C_1	This includes the sense of no risk in trying, curiosity, perception, risk-taking, self-esteem/self-image to portray.
	Personal physiological	C_2	This includes genetics, puberty, and adolescence.

Table 3.2 (continued)

	Family influence	C_3	This includes parental smoking, sibling smoking, parental values and attitudes towards smoking, and socioeconomic status.
	Psychosocial influence	C_4	This includes peer affiliation, connectedness to home or school, and sense of alienation.
	Cultural influence	C_5	This includes exposure to tobacco marketing, images of smoking in the popular media, and the tobacco industry.
	Legislative influence	C_6	This includes government legislative and policy issues that affect the price and the availability of tobacco.
Decision alternatives	Packaging and labelling	DA_1	This includes health warning labels and pack descriptors.
	Pricing and taxation	DA_2	This includes increasing or decreasing the prices and taxes on tobacco products.
	Education, communication, and public awareness	DA_3	This includes promoting and strengthening public awareness of tobacco control issues through social media and public awareness programs.
	Smoke-free legislation	DA_4	This includes banning smoking indoors in certain public spaces such as public lifts, toilets, theatres, and air-conditioned restaurants.
	Tobacco advertising, promotion, and sponsorship	DA_5	This policy involves the prohibition of most forms of direct or indirect tobacco advertising and promotion.

Next, the criteria and decision alternatives are structured to form a decision hierarchy.

3.6.2 Set up the decision hierarchy

The hierarchical representation in assessing the most impactful anti-smoking strategy is illustrated in Figure 3.6.

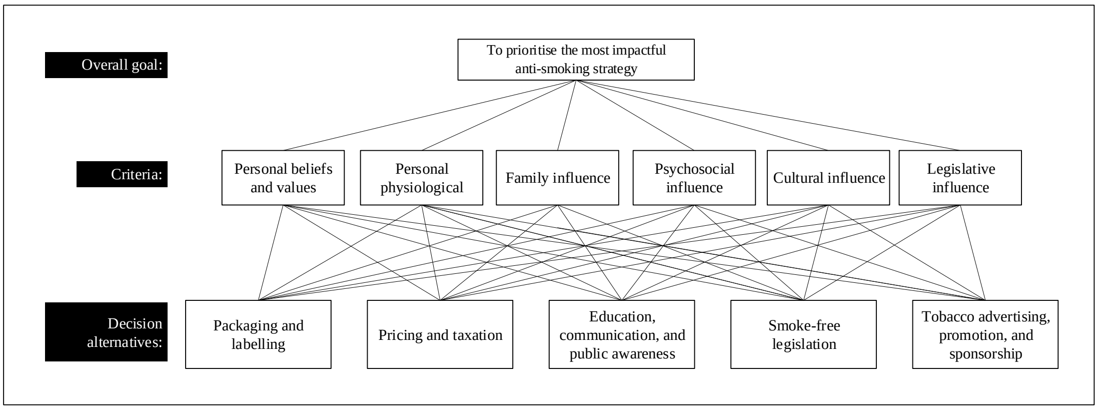


Figure 3.6 Hierarchical representation of the tobacco system

3.6.3 Perform pairwise comparison using the pre-evaluation algorithm

Each respondent was requested to rate each criterion according to each criterion's importance in reducing smoking prevalence. The respondent evaluated the criteria in prioritising the factors influencing smoking and anti-smoking strategies using a numerical rating of 1 (least important) to 9 (extremely important).

Table 3.3 and Table 3.4 show the ratings gathered from Respondent 1. The ratings obtained from Respondent 1 are presented here to illustrate the evaluation process. While, for the ratings gathered from Respondent 2 and Respondent 3 are in Appendix C. The 'x' represented the level of importance of each factor towards the goal.

Table 3.3

Rating table for factors influencing smoking for Respondent 1.

Criteria	Rating 1	2	3	4	5	6	7	8	9
C_1					x				
C_2						x			
C_3								x	
C_4								x	
C_5									x
C_6	x								

Table 3.4

Rating table for anti-smoking strategies for Respondent 1

i) Personal beliefs and values

Criteria	Rating 1	2	3	4	5	6	7	8	9
DA_1									x
DA_2									x
DA_3									x
DA_4									x
DA_5									x

ii) Personal physiological

Criteria	Rating 1	2	3	4	5	6	7	8	9
DA_1									x
DA_2									x
DA_3									x
DA_4									x
DA_5									x

iii) Family influence

Criteria	Rating 1	2	3	4	5	6	7	8	9
DA_1									x
DA_2									x
DA_3									x
DA_4									x
DA_5									x

iv) Psychosocial influence

Criteria	Rating								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
DA_1									x
DA_2									x
DA_3									x
DA_4									x
DA_5									x

v) Cultural influence

Criteria	Rating								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
DA_1									x
DA_2									x
DA_3									x
DA_4									x
DA_5									x

vi) Legislative influence

Criteria	Rating								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
DA_1									x
DA_2									x
DA_3									x
DA_4									x
DA_5									x

3.6.4 Determine the weights for each criterion and decision alternatives

Ratings from the respondents are transformed into a matrix format and later are manipulated mathematically to determine the weights. The ratings were evaluated using the formula explained in Chapter 2 (Section 2.7.1.4) and later transformed into a converted pairwise comparison table as shown in Table 3.5 and Table 3.6.

Table 3.5

Converted pairwise comparison table for factors influencing smoking

		Criteria					
		C_1	C_2	C_3	C_4	C_5	C_6
Criteria	C_1	**1**	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{5}$	5
	C_2	2	**1**	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{4}$	6
	C_3	4	3	**1**	1	$\frac{1}{2}$	8
	C_4	4	3	1	**1**	$\frac{1}{2}$	8
	C_5	5	4	2	2	**1**	9
	C_6	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{9}$	**1**

Table 3.6

Converted pairwise comparison tables for anti-smoking strategies for Respondent 1

i) Personal beliefs and values

		Decision alternatives				
		DA_1	DA_2	DA_3	DA_4	DA_5
Decision alternatives	DA_1	1	1	1	1	1
	DA_2	1	1	1	1	1
	DA_3	1	1	1	1	1
	DA_4	1	1	1	1	1
	DA_5	1	1	1	1	1

ii) Personal physiological

		Decision alternatives				
		DA_1	DA_2	DA_3	DA_4	DA_5
Decision alternatives	DA_1	1	1	1	1	1
	DA_2	1	1	1	1	1
	DA_3	1	1	1	1	1
	DA_4	1	1	1	1	1
	DA_5	1	1	1	1	1

iii) Family influence

		Decision alternatives				
		DA_1	DA_2	DA_3	DA_4	DA_5
Decision alternatives	DA_1	1	1	1	1	1
	DA_2	1	1	1	1	1
	DA_3	1	1	1	1	1
	DA_4	1	1	1	1	1
	DA_5	1	1	1	1	1

iv) Psychosocial influence

		Decision alternatives				
		DA_1	DA_2	DA_3	DA_4	DA_5
Decision alternatives	DA_1	1	1	1	1	1
	DA_2	1	1	1	1	1
	DA_3	1	1	1	1	1
	DA_4	1	1	1	1	1
	DA_5	1	1	1	1	1

v) Cultural influence

Decision alternatives		DA1	DA2	DA3	DA4	DA5
	DA1	1	1	1	1	1
	DA2	1	1	1	1	1
	DA3	1	1	1	1	1
	DA4	1	1	1	1	1
	DA5	1	1	1	1	1

vi) Legislative influence

Decision alternatives		DA1	DA2	DA3	DA4	DA5
	DA1	1	1	1	1	1
	DA2	1	1	1	1	1
	DA3	1	1	1	1	1
	DA4	1	1	1	1	1
	DA5	1	1	1	1	1

All the calculations to determine the weights and consistency ratios for the criteria and decision alternatives by the Respondent 1 are in Appendix D. The final weights for influential factors, and anti-smoking strategies are obtained using Microsoft Excel and presented in Chapter 4 and Appendix E.

3.6.5 Compute consistency ratio

The consistency ratio (CR) is evaluated using Microsoft Excel and presented in Chapter 2 Section 2.7.1.5 page 58.

3.6.6 Classify and characterise the output weights and ranks

Up to this step, there are two types of output from EAHP analysis. First, the prioritised output for criteria with weight values are interpreted as parameter values during the development of stock and flow model. The criteria in the EAHP analysis are represented by the factors influencing smoking, which is qualitative in nature. Second, the output with the highest rank for decision alternatives is selected as the policy to be tested during model evaluation. The process is illustrated in Figure 3.7.

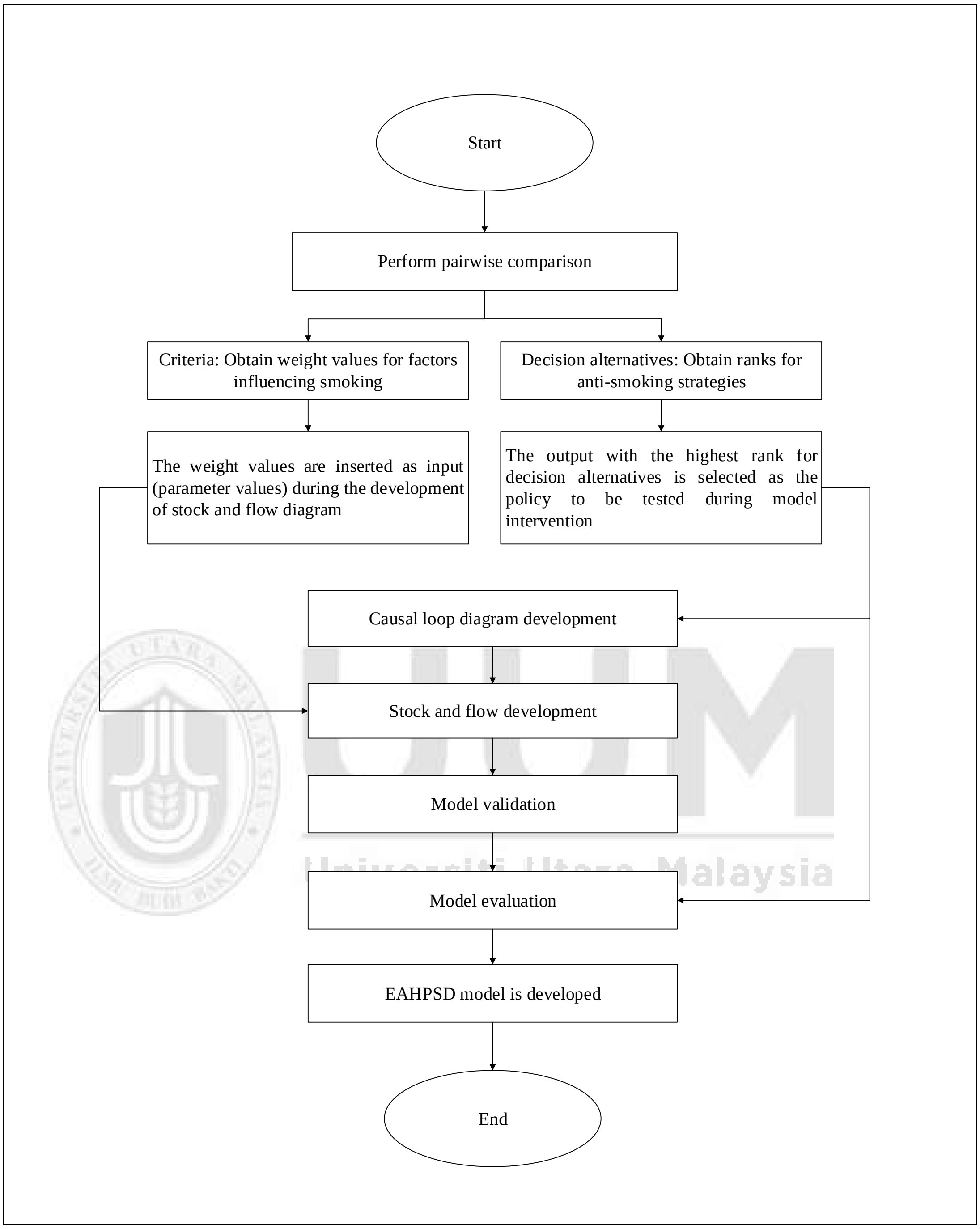


Figure 3.7 Classification of weights and ranks process

3.6.7 Set reference mode

In this step, a graph of the chosen key variable is plotted to portray the trend and behaviour over time. This graph will be referred to as reference mode throughout the modelling process. The reference mode represents time on the horizontal axis (*x*-axis) and key variable values on the vertical axis (*y*-axis).

In this research, the smoking prevalence rate in Malaysia between 2000 and 2016 was used as the reference mode. Referring to Figure 3.8, actual data is represented by a solid line, while a dotted line represents the trend line generated by Microsoft Excel. Based on the trend illustrated, it is predicted that the smoking prevalence values will continue to escalate over time. According to the World Health Organisation (WHO) and Ministry of Health (MOH) Malaysia, tobacco endgame is achieved when the smoking prevalence is less than 0.05 by 2045. Therefore, using this as the benchmark, this research will address the question of what is the best strategy that can be applied to assist in achieving the tobacco endgame target of less than 0.05 smoking prevalence by 2045.

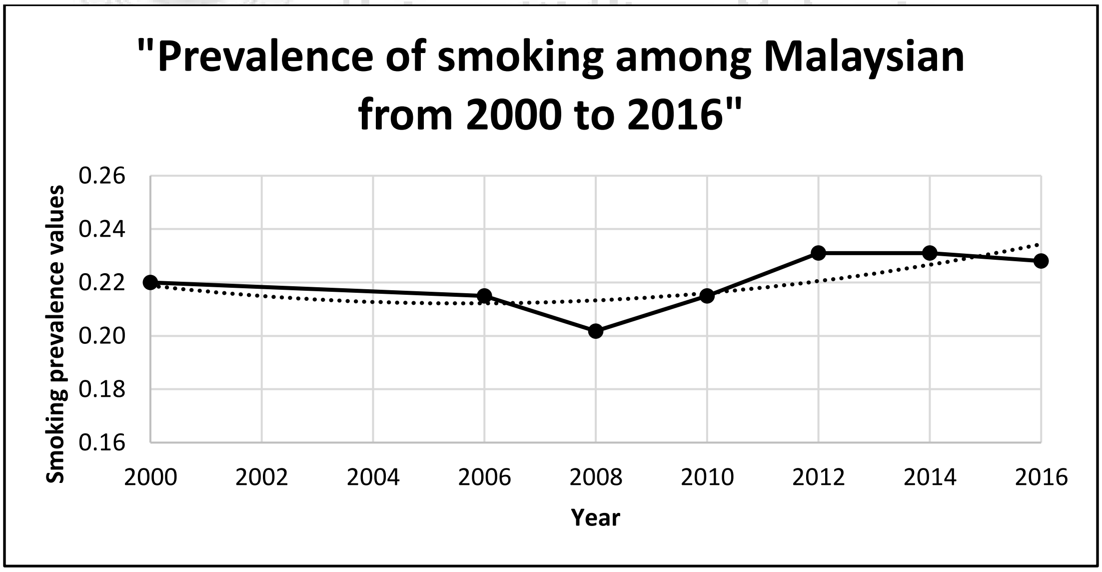


Figure 3.8 Changes in the prevalence of smoking for Malaysian from 2000 to 2016

3.6.8 Determine time horizon

In this research, the selected time horizon for model development is sixteen years, which is between 2000 until 2016. The sixteen years is considered sufficient relative to most previous tobacco studies. The main reason for the time horizon selection is data availability. This is because national health data, specifically tobacco data, were recorded in a survey by the MOH at intervals of five years approximately, and so far, 2016 is the latest data published. As for the simulation purpose, the model will be simulated until 2050. The projections to 2050 chime with a target year for government policy aimed at reversing the current trends. The stated target is to achieve the endgame of tobacco nationwide by 2045.

3.6.9 Development of dynamic hypothesis

In this research, the dynamic hypothesis is formulated using a causal loop diagram (CLD) since it is the most suitable mapping technique to visualise the dynamic of the tobacco problem. The behaviour of the tobacco control system depended on the complex interactions between several interrelated key variables. The interrelationships among the identified key variables and the causal effects across them are illustrated in Figure 3.9. The selection of the key variables was based on the flow of effect of tobacco consumption in a population. The arrow protruding from one variable to another represents the influence of that variable on the other variable. Further, the summary of the major feedback involved in the CLD is tabulated in Table 3.7. Referring to Table 3.7, two reinforcing loops and four balancing loops are captured, represented by the bold arrows. For example, the population loop, R1, captures the reinforcing effect of changes in the population due to birth.

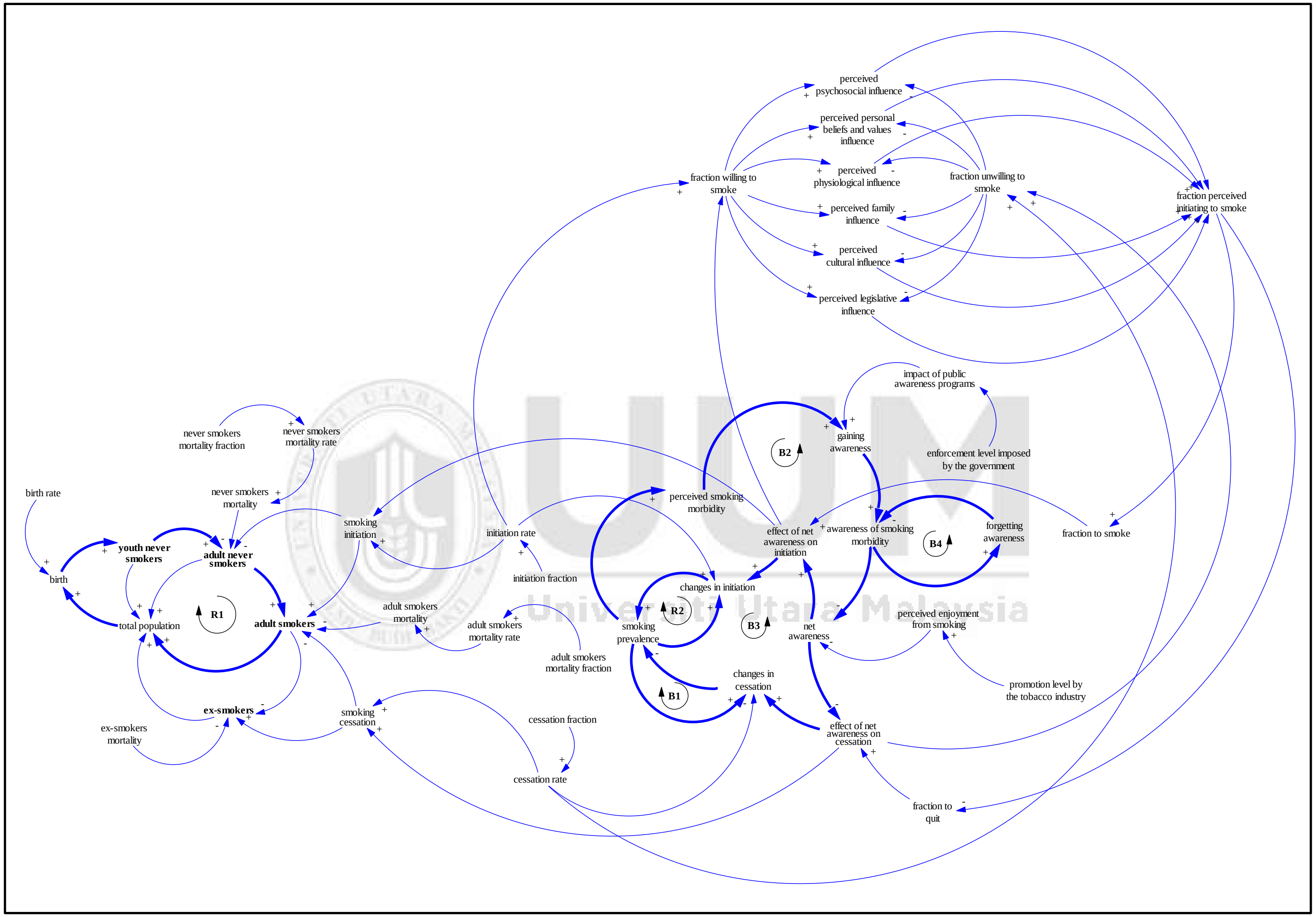


Figure 3.9 Causal loop diagram for the tobacco epidemic

Table 3.7

Major feedback loops

Feedback loop	Loop notation	Description
Population loop	R1	total population $\xrightarrow{+}$ birth $\xrightarrow{+}$ youth never smokers $\xrightarrow{+}$ adult never smokers $\xrightarrow{+}$ adult smokers $\xrightarrow{+}$ total population
Initiation loop	R2	smoking prevalence $\xrightarrow{+}$ changes in initiation $\xrightarrow{+}$ smoking prevalence
Cessation loop	B1	smoking prevalence $\xrightarrow{+}$ changes in cessation $\xrightarrow{-}$ smoking prevalence
Awareness reducing initiation loop	B2	smoking prevalence $\xrightarrow{+}$ perceived smoking morbidity $\xrightarrow{+}$ gaining awareness $\xrightarrow{+}$ awareness of smoking morbidity $\xrightarrow{-}$ net awareness $\xrightarrow{+}$ effect of net awareness on initiation $\xrightarrow{+}$ changes in initiation $\xrightarrow{+}$ smoking prevalence
Awareness increasing cessation loop	B3	smoking prevalence $\xrightarrow{+}$ perceived smoking morbidity $\xrightarrow{+}$ gaining awareness $\xrightarrow{+}$ awareness of smoking morbidity $\xrightarrow{-}$ net awareness $\xrightarrow{-}$ effect of net awareness on cessation $\xrightarrow{+}$ changes in cessation $\xrightarrow{-}$ smoking prevalence
Forgetting awareness loop	B4	awareness of smoking morbidity $\xrightarrow{+}$ forgetting awareness $\xrightarrow{-}$ awareness of smoking morbidity

There are three sub-models of the CLD are developed from different background sources of information related to tobacco, which is targetted better to explain the development of the overall causal structure. Each sub-model has a significant contribution to aid in the understanding of the tobacco epidemic. The whole system was linked together with three sub-models named population structure, factors influencing smoking structure, and anti-smoking strategy structure. The detailed explanations for each structure of sub-models are as follows:

i. Population sub-model

The CLD population sub-model is presented in Figure 3.10. The sub-model structure was divided into never smokers, smokers, and ex-smokers. Never smokers were people who never smoke. In this research, never smokers were sub-divided into youth never smokers and adult never smokers where youth never smokers consist of people aged 0 to 14 and adult never smokers consist of people aged between 15 to 64. Smokers were those who were currently smoking and ex-smokers were the ones who had already quit smoking. Never smokers were converted to smokers by the function describing the smoking initiation and current smokers were converted to ex-smokers by the function describing the smoking cessation. The population-level increases by the population birth rate. This structure's representation is chosen to better illustrate the smoker's population by initiation and cessation rate (Roberts et al., 1982).

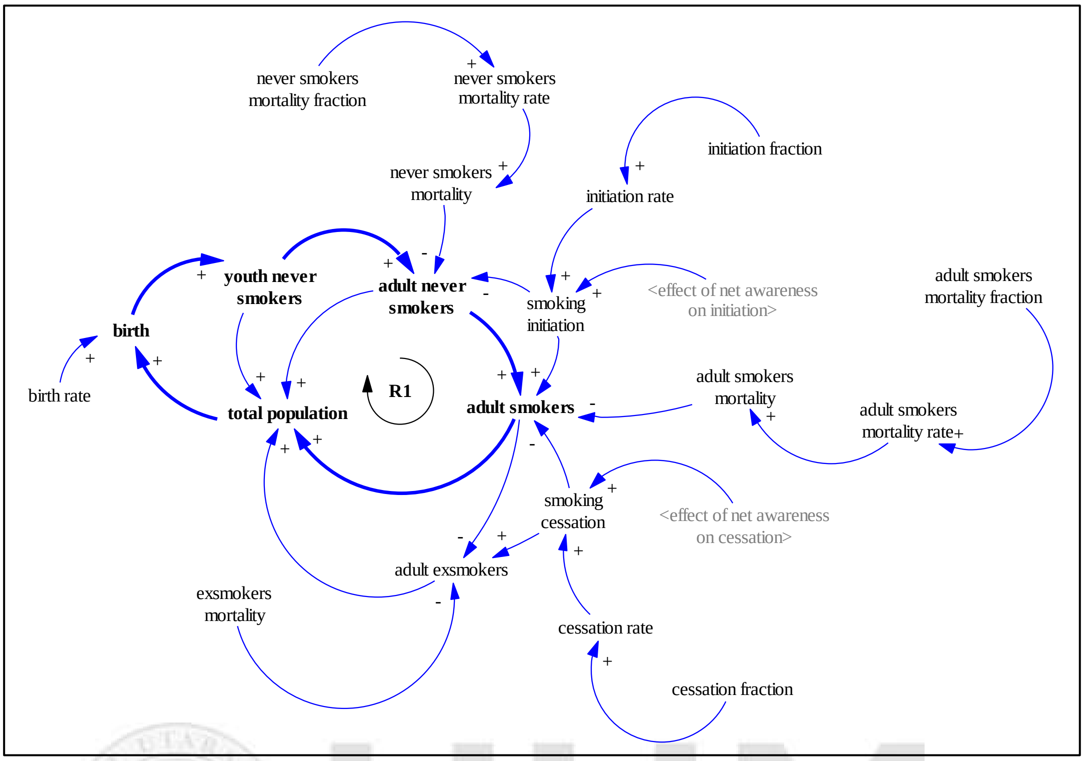


Figure 3.10 Causal loop diagram for population sub-model

ii. Factors influencing smoking sub-model

The CLD for factors influencing smoking sub-model is presented in Figure 3.11. From the weight values obtained, the values are then translated as parameter values for the variables in the SD model. The variables involved are the smoking factors, which are personal beliefs and values, personal physiological, psychosocial influence, family influence, cultural influence, and legislative influence. The smoking factors are influenced by the fraction willing to smoke and fraction unwilling to smoke. In this structure, the flow of effect of the variables are determined by a multiplicative formulation since any extreme value in each of the variable will reinforce one another (Ulli-Beer, 2004).

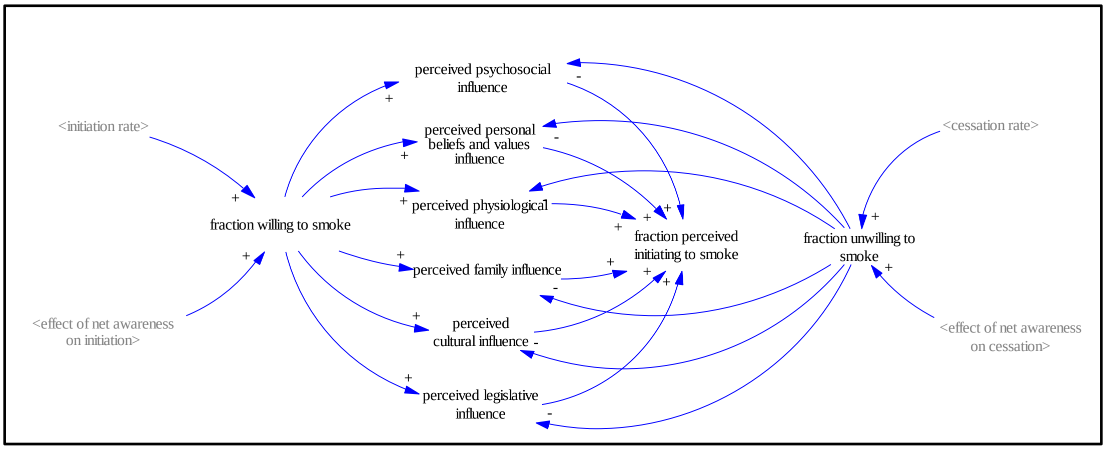


Figure 3.11 Causal loop diagram for factors influencing smoking sub-model

iii. Anti-smoking strategy sub-model

The CLD for anti-smoking strategy sub-model is presented in Figure 3.12. The sub-model structure is developed based on the highest rank obtained and by incorporating five main feedback loops. Reinforcing loop R2 represents the initiation loop indicating the feedback of influential factors and smoking prevalence. Balancing loop B1 represents the cessation loop which captures the balancing effect of cessation and smoking prevalence.

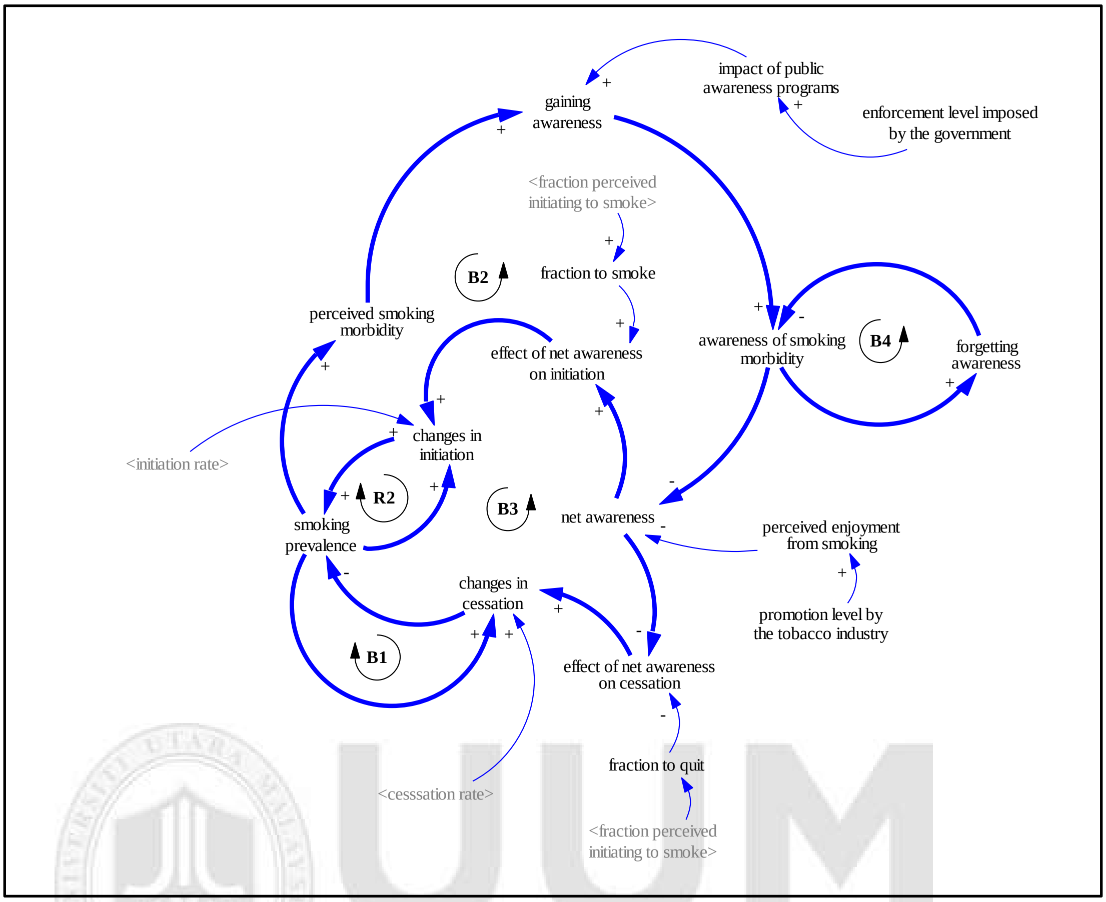


Figure 3.12 Causal loop diagram for anti-smoking strategies sub-model

3.6.10 Development of stock and flow model

Next, the stock and flow model is developed based on the causal loop diagram that has been developed. Three main sectors have been developed. The sectors are population, factors influencing smoking, and anti-smoking strategy. Initially, a simple model is developed, and then it is extended to include more related variables (Sterman, 2000). Then, all the sectors will be connected by arrow lines to representing cause and effect relationships within the model structure (Cavana & Maani, 2000).

There are several available options regarding software packages to assist SD modelling and analysis, such as Dysmap, Cosmic, Vensim, Stella, Powersim and i-

Think as shown in Table 3.8. In this study, the SD model will be constructed by using the Vensim software package. The Vensim software is deemed user-friendly, highly flexible and has a visual insight into the developed model (Vierhaus, Fügenschuh, Gottwald, & Grösser, 2014). The developed model can also be adjusted and re-run at numerous times. Thus, it provides an interactive process for model construction, and it can improve the simulated model.

Table 3.8

Evolution of software package

Software package	**Year**
Dynamo	1960
Dysmap	1970
Cosmic and Cosmos	1984
Stella/iThink	1985
Vensim	1990
Powersim	1992

i. Population Sector

As presented in Figure 3.13, the population sector illustrates the dynamic involved in various population categories to track the inflows and outflows of current smokers, ex-smokers, and people who never smoked, from birth to death. In this sector, the model divides the population into four stocks, which are youth never smokers, adult never smokers, adult smokers, and adult ex-smokers. The model is simulated for a 50-year simulated duration, beginning in 2000 until 2050.

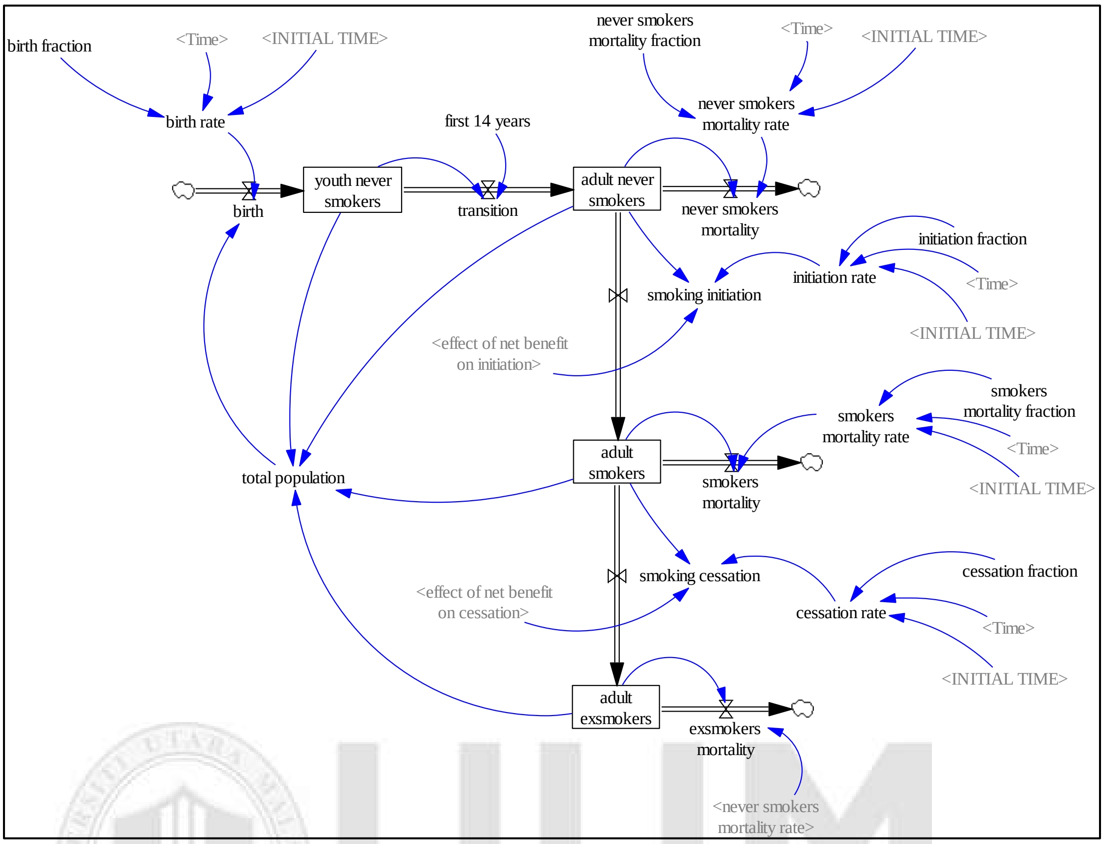


Figure 3.13 Population sector

Youth never smokers (YNS, persons) represents the number of people aged 0 to 14 years old in a population. It is assumed that all people are born never smoked and they are considered as potential smokers. This population increases by the population birth rate (BR, person/Year). BR is formulated using an exponential function to depict the historical data of birth rate in Malaysia. YNS either die never having smoked or are converted to smokers. Equations 3.1 until 3.11 show the mathematical equations involving never smoker's population.

$$\textbf{Stock:} \quad YNS\ (t) = \int_{t_0}^{t} (B - TR)dt + YNS\ (t_0) \tag{3.1}$$

$$\textbf{Flow:} \quad B = TP \times BR \tag{3.2}$$

$$\textbf{Flow :} \quad TR = \frac{YNS}{TRV} \tag{3.3}$$

$$\textbf{Converter :} \quad TP = YNS + NS + S + XS \tag{3.4}$$

$$\textbf{Converter :} \quad BR = 0.021 \times \exp(BF\,(t - t_0)) \tag{3.5}$$

$$\textbf{Converter :} \quad BF = -0.016 \tag{3.6}$$

$$\textbf{Converter :} \quad TRV = 14 \tag{3.7}$$

$$\textbf{Stock :} \quad NS = \int_{t_0}^{t} (TR - M_{NS})dt + NS\,(t_0) \tag{3.8}$$

$$\textbf{Flow :} \quad M_{NS} = NS \times MR_{NS} \tag{3.9}$$

$$\textbf{Converter :} \quad MR_{NS} = 0.0042 \times \exp(MF_{NS}\,(t - t_0)) \tag{3.10}$$

$$\textbf{Converter :} \quad MF_{NS} = 0.0099 \tag{3.11}$$

where **YNS** = youth never smokers, **NS** = adult never smokers, **S** = adult smokers, **XS** = adult ex-smokers, **TP** = total population, **B** = birth, **BR** = birth rate, **BF** = birth fraction, **TR** = transition, **TRV** = first 14 years, $\mathbf{M_{NS}}$ = never smokers mortality, $\mathbf{MR_{NS}}$ = never smokers mortality rate, $\mathbf{MF_{NS}}$ = never smokers mortality fraction.

Adult smokers are the population that is currently smoking. Adult never smokers are converted to adult smokers by the function describing the smoking initiation rate. These smokers either die at the rate of the smokers' death rate or quit smoking. Equations 3.12 until 3.23 show the mathematical equations involving current adult smokers and ex-smokers' population.

$$\textbf{Stock :} \quad S = \int_{t_0}^{t} (I - C - M_S)dt + S(t_0) \tag{3.12}$$

$$\textbf{Flow :} \quad I = IR \times NAI \tag{3.13}$$

Flow : $M_S = S \times MR_S$ (3.14)

Converter : $IR = 0.0123 \times \exp(IF(t - t_0))$ (3.15)

Converter : $IF = 0.0143$ (3.16)

Converter : $MR_S = 0.0054 \times \exp\,(MF_S(t - t_0))$ (3.17)

Converter : $MF_S = -0.021$ (3.18)

Stock : $XS(t) = \int_{t_0}^{t} (C - M_{XS})dt + XS(t_0)$ (3.19)

Flow : $C = CR \times NAC$ (3.20)

Flow : $M_{XS} = MR_{NS}$ (3.21)

Converter : $CR = 0.003 \times \exp(CF(t - t_0))$ (3.22)

Converter : $CF = -0.052$ (3.23)

where **S** = adult smokers, **I** = smoking initiation, **C** = smoking cessation, **M_S** = smokers mortality, **IR** = initiation rate, **NAI** = net awareness on initiation, **MR_S** = smokers mortality rate, **IF** = initiation fraction, **MF_S** = smokers mortality fraction, **XS** = adult ex-smokers, **M_{XS}** = ex-smokers mortality, **CR** = cessation rate, **NAC** = net awareness on cessation, **MR_{NS}** = never smokers mortality rate, **CF** = cessation fraction.

Apart from previous researchers' current practice, the population dynamic is represented as in Figure 3.13 based on two reasons. First, it is clear to examine the number of populations in each category; never smokers, smokers, and ex-smokers, which is the main interest in the model. Second, the smoking status can be distinguished clearly by the two rates which are initiation and cessation.

ii. Factors Influencing Smoking Sector

This sector illustrates the dynamic involves in the factors influencing smoking to capture the qualitative nature involved. In this sector, the model has six stocks representing personal beliefs and values, personal physiological, family influence, psychosocial influence, cultural influence, and legislative influence. The stock and flow model of this sector is presented in Figure 3.14.

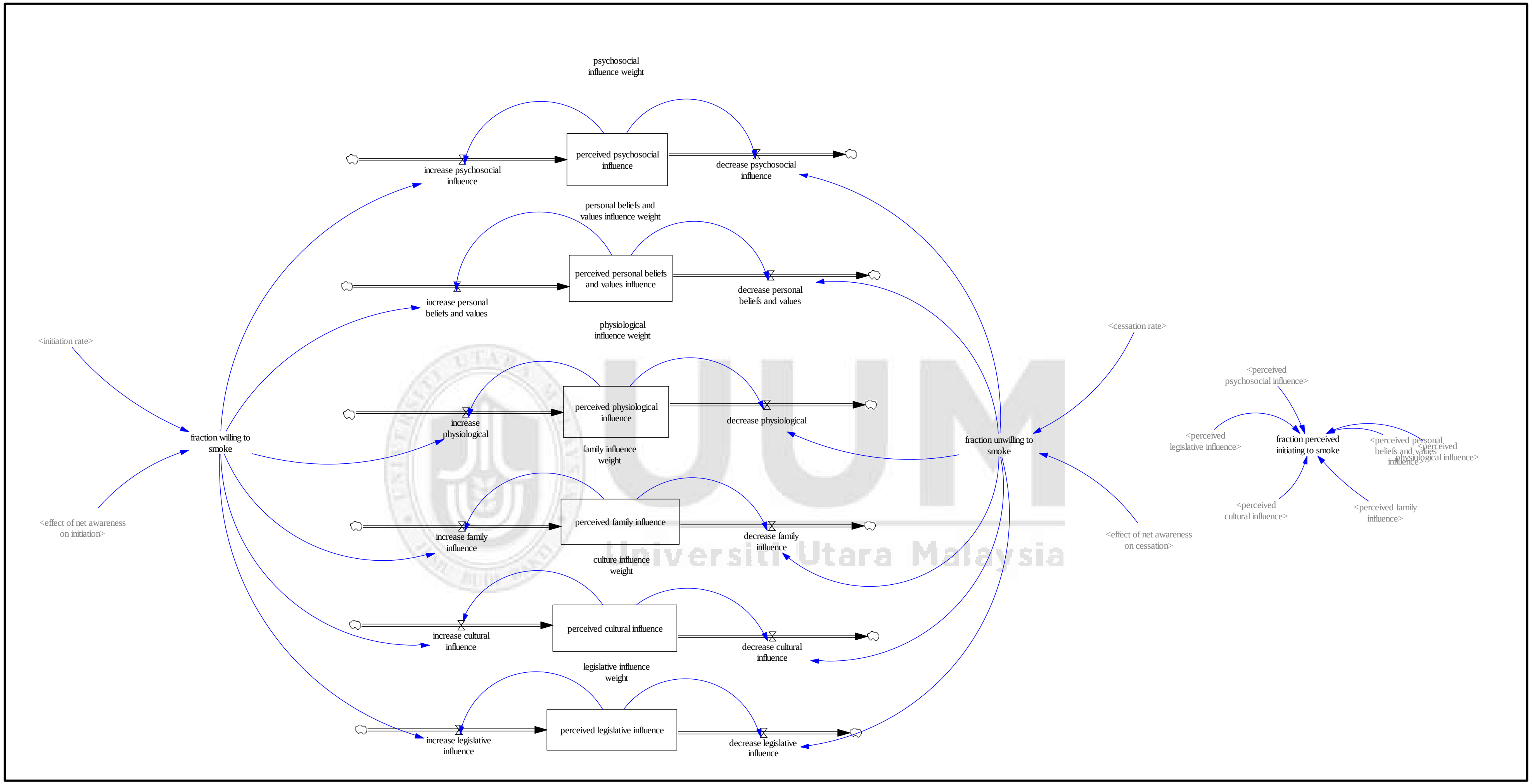


Figure 3.14 Factors influencing smoking sector

Equations 3.24 to 3.50 show the mathematical equations involved in this sector.

Stock : $SI(t) = \int_{t_0}^{t}(ISI - DSI)dt + SI\ (t_0)$ (3.24)

Stock : $BI(t) = \int_{t_0}^{t}(IBI - DBI)dt + BI\ (t_0)$ (3.25)

Stock : $PI(t) = \int_{t_0}^{t}(IPI - DPI)dt + PI\ (t_0)$ (3.26)

Stock : $FI(t) = \int_{t_0}^{t}(IFI - DFI)dt + FI\ (t_0)$ (3.27)

Stock : $CI(t) = \int_{t_0}^{t}(ICI - DCI)dt + CI\ (t_0)$ (3.28)

Stock : $LI(t) = \int_{t_0}^{t}(ILI - DLI)dt + LI\ (t_0)$ (3.29)

Converter : $FWS = IR \times NBI$ (3.30)

Flow : $ISI = SI \times FWS$ (3.31)

Flow : $IBI = BI \times FWS$ (3.32)

Flow : $IPI = PI \times FWS$ (3.33)

Flow : $IFI = FI \times FWS$ (3.34)

Flow : $ICI = CI \times FWS$ (3.35)

Flow : $ILI = LI \times FWS$ (3.36)

Converter : $FUS = CR \times NBC$ (3.37)

Flow : $DSI = SI \times FUS$ (3.38)

Flow : $DBI = BI \times FUS$ (3.39)

Flow : $DPI = PI \times FUS$ (3.40)

Flow : $DFI = FI \times FUS$ (3.41)

Flow : $DCI = CI \times FUS$ (3.42)

Flow : $DLI = LI \times FUS$ (3.43)

Converter : $SIW = 0.1903$ (3.44)

Converter : $BIW = 0.0759$ (3.45)

Converter : $PIW = 0.1845$ (3.46)

Converter : $FIW = 0.1403$ (3.47)

Converter : $CIW = 0.1638$ (3.48)

Converter : $LIW = 0.0917$ (3.49)

Converter : $FTS = SI \times BI \times PI \times FI \times CI \times LI$ (3.50)

where **SI**= perceived psychosocial influence, **BI** = perceived personal beliefs and values influence, **PI** = perceived physiological influence, **FI** = perceived family influence, **CI** = perceived cultural influence, **LI** = perceived legislative influence, **SIW** = psychosocial influence weight, **BIW** = personal beliefs and values influence weight, **PIW** = physiological influence weight, **FIW** = family influence weight, **CIW** = cultural influence weight, **LIW** = legislative influence weight, **ISI** = increase psychosocial influence, **IBI** = increase personal beliefs and values influence, **IPI** = increase physiological influence, **IFI** = increase family influence, **ICI** = increase cultural influence, **ILI** = increase legislative influence, **DSI** = decrease psychosocial influence, **DBI** = decrease personal beliefs and values influence, **DPI** = decrease physiological influence, **DFI** = decrease family influence, **DCI** = decrease cultural influence, **DLI** = decrease legislative influence, **FWS** = fraction willing to smoke, **FUS** = fraction unwilling to smoke, **S** = adult smokers, **TP** = total population, **FTS** = fraction perceived initiating to smoke.

iii. Anti-smoking Strategy Sector

As presented in Figure 3.15, the anti-smoking strategy sector illustrates the dynamic involved in the level of awareness for strategy involving education, communication, and public awareness to reduce the smoking habit. In this sector, the model is divided into a smoking prevalence part and public awareness part.

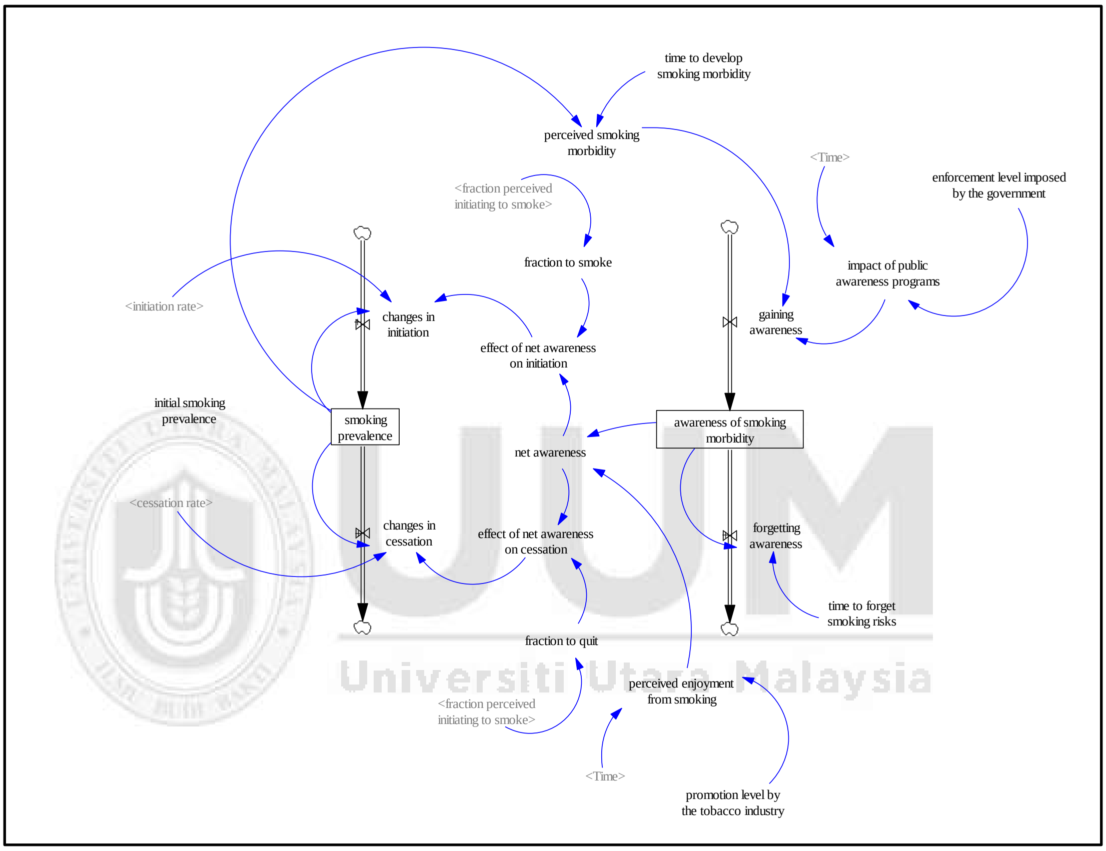


Figure 3.15 Anti-smoking strategy sector

Equations 3.51 to 3.66 show the mathematical equations involved in this sector.

Stock : $SmokePrev(t) = \int_{t_0}^{t} (CI - CC)dt + SmokePrev(t_0)$ (3.51)

Flow : $CI = IR \times NAI \times SmokePrev$ (3.52)

Flow : $CC = CR \times NAC \times SmokePrev$ (3.53)

Converter : $NA = PES - Awareness$ (3.54)

Converter : $NAI = NB^{(1-FIS)}$ (3.55)

Converter : $NAC = NB^{(-FUS)}$ (3.56)

Stock : $Awareness = \int_{t_0}^{t} (GAR - FAR)dt + Awareness(t_0)$ (3.57)

Flow : $GAR = PSM \times enforcementLevel$ (3.58)

Flow : $FAR = \frac{Awareness}{TF}$ (3.59)

Converter : $enforcementLevel = 1$ (3.60)

Converter : $TF = 35$ (3.61)

Converter : $PSM = \frac{SmokePrev}{TM}$ (3.62)

Converter : $TSM = 25$ (3.63)

Converter : $PBS = promotionLevel$ (3.64)

Converter : $FUS = FIS$ (3.65)

Converter : $promotionLevel = 1$ (3.66)

where **SmokePrev** = smoking prevalence, **CI** = changes in initiation, **CC** = changes in cessation, **IR** = initiation rate, **NAI** = effect of net awareness on initiation, **CR** = cessation rate, **NAC** = effect of net awareness on cessation, **NA** = net awareness, **PES** = perceived enjoyment from smoking, **Awareness** = awareness of smoking morbidity, **FIS** = fraction willing to initiate smoking, **FUS** = fraction unwilling to initiate smoking, **GAR** = gaining awareness, **FAR** = forgetting awareness, **enforcementLevel** = enforcement level imposed by the government, **PSM** = perceived smoking morbidity, **TF** = time to forget smoking risks, **TSM** = time to develop smoking morbidity, **promotionLevel** = promotion level by the tobacco industry.

3.7 Validation of the Integrated EAHPSD Model's Structure and Behaviour

Once the stock and flow model of the integrated EAHPSD model is developed, the model is subject to the validation process. The flowchart for validating the model is illustrated in Figure 3.16. The purpose of the process is to establish the robustness of the developed model, uncover the model's flaws, and increase model confidence. Thus, the model is tested on its structure and behaviour. The structural validity test aims to compare the structure of the real system with the structure of the developed model - without examining the developed model's relationships and behaviour. At the same time, the behavioural validity test aims to measure the accuracy of the developed model in terms of its ability to replicate the major behaviour of the real system (Barlas, 1994a).

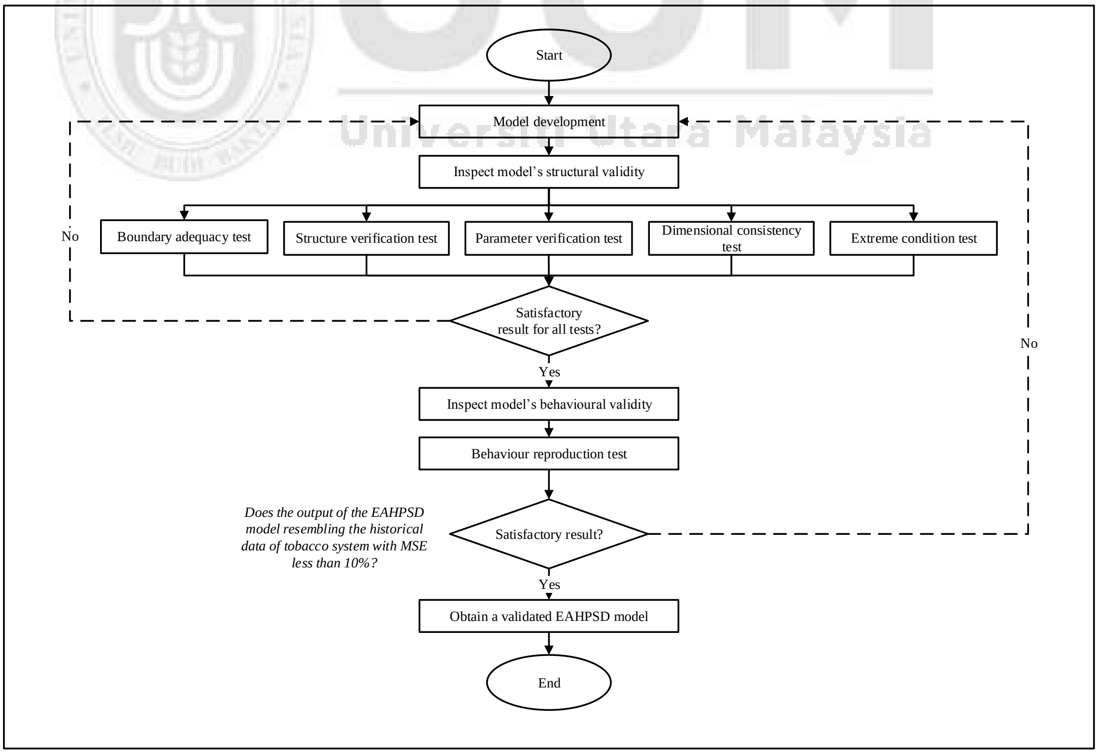


Figure 3.16 Flowchart for validating the integrated EAHPSD model

In this study, six tests were conducted to test the developed model: boundary adequacy test, structure verification test, parameter verification test, dimensional consistency test, extreme condition test, and behaviour reproduction test. The summary of each test and its purpose are tabulated in Table 3.9 as suggested by Sterman (2000).

Table 3.9

Types of model verification and validation

Test		**Purpose**	**Procedures**
Structure validity test	Boundary adequacy test	To ensure important components are captured in the developed model.	Use archival materials, review of literature, interviews, or direct inspection.
	Structure verification test	To ensure the decision rules are structurally captured in the developed model.	Use the causal loop diagram and stock and flow model.
	Parameter verification test	To ensure the decision rules are numerically captured in the developed model.	Use expert opinion and previous literature.
	Dimensional consistency test	To ensure that units for all variables are consistent.	Use built-in dimensional analysis in Vensim software.
	Extreme condition test	To test whether the model runs normally under extreme conditions.	Test response to extreme values.
Behaviour validity test	Behaviour reproduction test	To test whether the model simulates the real pattern and behaviour of the real system.	Compute statistical measure of correspondence between simulation run and historical data.

3.8 Evaluation of the Integrated EAHPSD Model

Once the integrated EAHPSD model had been validated, a series of interventions will be conducted to identify the minimum values of smoking prevalence towards achieving tobacco endgame by the year 2045. There are two intervention experiments conducted to complete this stage. Firstly, the integrated EAHPSD model was evaluated using a sensitivity analysis series. Secondly, the model was evaluated using EAHPSD optimisation. Both experiments are conducted to see how the smoking prevalence behaves through the variation of input parameters, i.e., *enforcement level imposed by the government, promotion level by the tobacco industry*. In a nutshell, the experiments are used to observe model responsiveness towards changes in parameter values of the determined variables without involving serious post-policy implementation cost. The overview structure of the experiments is shown in Figure 3.17.

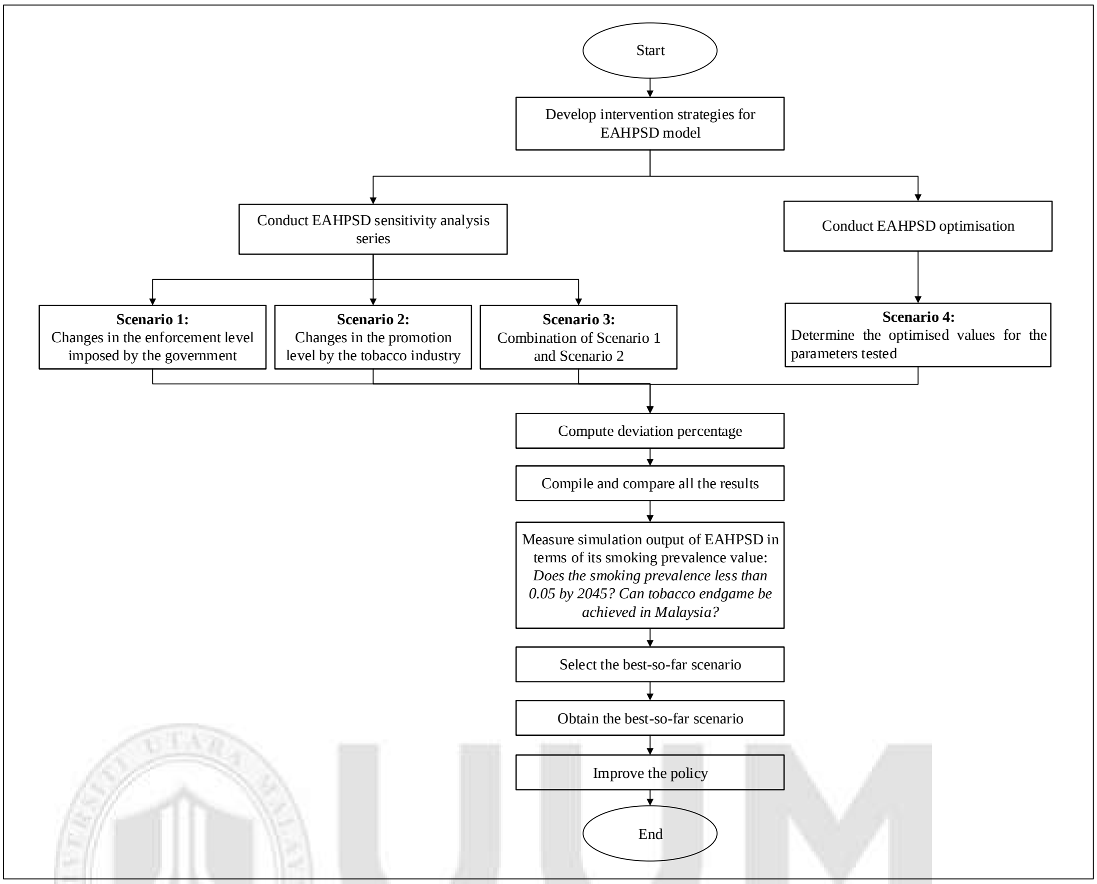


Figure 3.17 Flowchart for evaluating the integrated EAHPSD model

Referring to Figure 3.17, there are four intervention scenarios performed in the evaluation stage. These interventions focus on the minimum values of smoking prevalence that can be achieved towards tobacco endgame. The simulation's output is measured with the questions; *Does the smoking prevalence less than 0.05 by 2045? Can tobacco endgame be achieved in Malaysia?* By answering the questions, all the simulation results are compiled and compared, and the best-so far scenario is selected for policy improvement based on the highest deviation percentage of smoking prevalence from the base run. The highest deviation percentage (DP) of smoking prevalence is calculated by subtracting the smoking prevalence values by the base run ($SP_{baserun}$) from the experimented smoking prevalence values ($SP_{experimented}$). Next, the difference is divided by smoking prevalence by base run multiplied by hundreds. Thus, the calculation is as follows:

$$DP_n = \left(\frac{SP_{\text{experimented}} - SP_{baserun}}{SP_{baserun}} \right) \times 100 \quad (3.61)$$

Further explanation of model evaluation starts with a base run scenario in Section 3.8.1. Then, the explanation of intervention strategies is discussed in Section 3.8.2 and Section 3.8.3.

3.8.1 EAHPSD Base Run Scenario Setting

The first run presented is a base run representing the 'business as usual' or current practice of the tobacco epidemic in Malaysia. In other words, all the anti-smoking strategies in effect remain with the assumption that no change occurs in the future. The *enforcement level imposed by the government* with low national campaign and *promotion level by the tobacco industry* with high promotion levels by tobacco manufacturers were set as the control variables. Table 3.10 presents the parameter values used for the base run experiment.

Table 3.10

Control variables used in the base run setting

Variables	Initial value	Description
1. Enforcement level imposed by the government	0	Low national campaign conducted
2. Promotion level by the tobacco industry	1	High promotion level by tobacco manufacturers

3.8.2 EAHPSD Sensitivity Analysis Series

In this section, the EAHPSD model is evaluated based on three scenarios which are (i) changes in *enforcement level imposed by the government* while maintaining the *promotion level by the tobacco industry* as its initial value set during the base run, (ii) changes in *promotion level by the tobacco industry* while maintaining the *enforcement level imposed by the government* as its initial value set during base run, and (iii) changes in both *enforcement level imposed by the government* and *promotion level by the tobacco industry*.

In each scenario, several strategies were evaluated which made up to ten strategies to evaluate the sensitiveness of smoking prevalence values through the variation of the input parameters, i.e., *enforcement level imposed by the government* and *promotion level by the tobacco industry*. The evaluation strategies were conducted based on ten levels of changes with 0.25 increments for *enforcement level imposed by the government* and 0.25 reductions for *promotion level by the tobacco industry*, ranging from 0 to 1, where the intervention intervals were made as suggested in work by Ahmad (2005).

3.8.3 EAHPSD Optimisation

By using dynamic optimisation as the principle, an optimisation experiment is conducted with the aim to identify the possible minimum value of smoking prevalence can be achieved for reversing the current trend in smoking prevalence in order to achieve tobacco endgame. The optimisation experiment was conducted using the built-in optimisation function in Vensim software. Similar to the previous evaluation process, two variables were selected to be tested, which are *enforcement level imposed by the government* and *promotion level by the tobacco industry*. In EAHPSD optimisation, there are five basic steps involved, as shown in Figure 3.18. The objective function for the optimisation is shown in Equation 3.62.

$$Objective\ function = Min\left|Smoking\ prevalence_{2045}\right| \qquad (3.62)$$

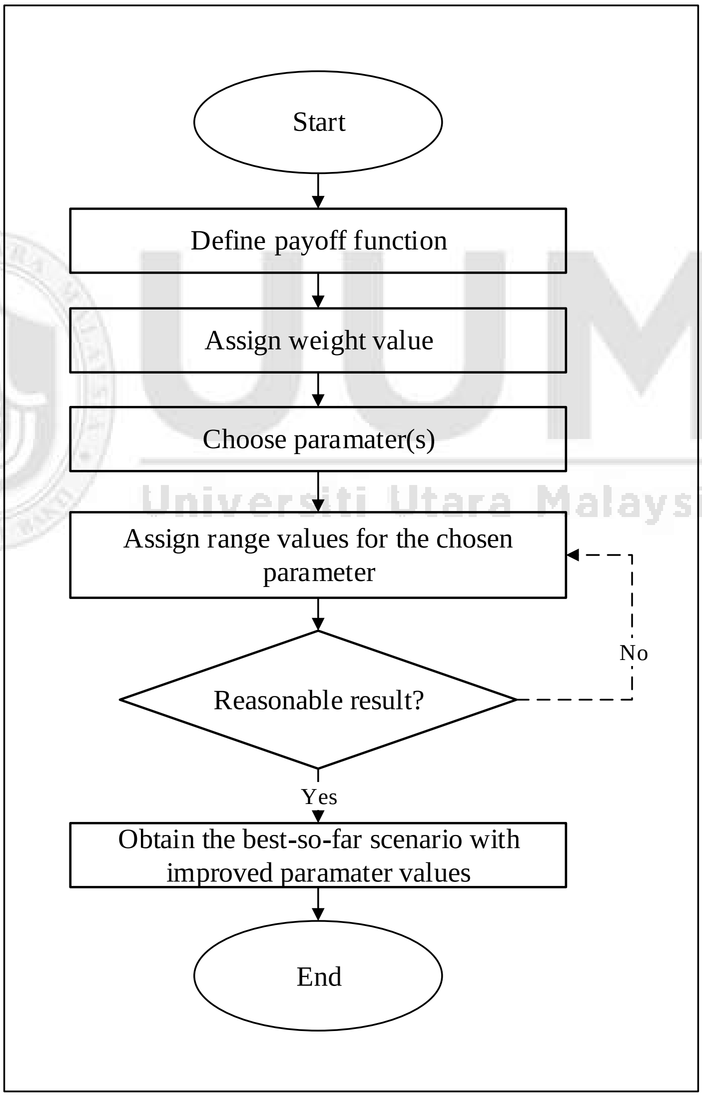


Figure 3.18 Flowchart for EAHPSD optimisation process

The EAHPSD optimisation model is set to start by the year 2019. The initial start is to define the payoff function and weight of the objective function. The weight value is assigned as 1 since the calibration optimisation is selected. Next, the model parameter(s) and range values are selected, which are *enforcement level imposed by the government* and *promotion level by the tobacco industry*. Later, the range for each parameter was defined.

Thus far, the EAHPSD integrated model's evaluation is the final step in developing the integrated model. All simulation strategies are compiled and compared based on the deviation percentage (DP). The highest DP is selected as the best-so-far scenario for policy improvement as discussed in the next section.

3.9 Policy Improvement Towards Achieving Tobacco Endgame

Based on the simulation results of the eleven strategies performed, the best-so-far scenario is obtained for policy improvement, as discussed in Section 2.7.2.5. As a result, the best-so-far scenario with smoking prevalence less than 0.05 with an acceptable values of *enforcement level imposed by the government* and *promotion level by the tobacco industry* is further explained in Section 4.4. Consequently, the best-so-far scenario is proposed to the Ministry of Health (MOH) Malaysia for improving the policy towards achieving tobacco endgame by 2045.

3.10 Summary

In this chapter, research design and a step-by-step process involved in the EAHPSD model development are explained. All the output from each run are compiled and compared at the end of the process for selection purposes. The next chapter presents the results of experimentation and analysis derived from this research using the developed EAHPSD model.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

This chapter presents the results and discussions of the integrated Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) model. It starts with the weights and ranks of the factors influencing smoking and anti-smoking strategies obtained, which is presented in Section 4.1. It is followed by the output from the validation assessments outlined in Section 4.2. Next, the EAHPSD base run's results, EAHPSD sensitivity analysis series, and EAHPSD optimisation are presented in Section 4.3. Further, the best-so-far scenario obtained for all experiments were then compared to selecting the most impactful anti-smoking strategy to reduce smoking prevalence is presented in Section 4.4. It is continued with the discussions on the results from the intervention in Section 4.5. Finally, Section 4.6 concludes the chapter.

4.1 Weights and Ranks Output

In the development of the integrated EAHPSD model, the weights and ranks output were evaluated, which was initially done by performing pairwise comparison using the pre-algorithm. The respondents were asked to rank the anti-smoking strategies as well as the factors influencing smoking habits among Malaysians. The data collected from the respondents were used to identify the ranks and to determine the weight values. The next process involved with the classification and characterisation of the results obtained. Hence, the results are presented in four parts as follows:

iv. The weight values for the criteria of personal beliefs and values, personal physiological, family influence, psychosocial influence, cultural influence, and legislative influence.

v. The rank values for the criteria of personal beliefs and values, personal physiological, family influence, psychosocial influence, cultural influence, and legislative influence.

vi. The weight values for the decision alternatives of packaging and labelling, pricing and taxation, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education, communication, and public awareness.

vii. The rank values for the decision alternatives of packaging and labelling, pricing and taxation, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education, communication, and public awareness.

The results of prioritised values for factors influencing smoking and anti-smoking strategies are presented in Table 4.1 and Table 4.2.

Table 4.1

The weights and ranks for factors influencing smoking

Criteria	**Weights**	**Ranks**
Personal beliefs and values	0.0759	6
Personal physiological	0.1845	2
Family influence	0.1403	4
Psychosocial influence	0.1903	1
Cultural influence	0.1638	3
Legislative influence	0.0917	5

Table 4.2

The weights and ranks for anti-smoking strategies

Criteria	Weights	Ranks
Packaging and labelling	0.1717	5
Pricing and taxation	0.1835	4
Education, communication, and public awareness	0.2269	1
Smoke-free legislation	0.1951	3
Tobacco advertising, promotion, and sponsorship	0.2142	2

From the results obtained in Table 4.1, the psychosocial influence was identified as the most important factor in influencing smoking among adults in Malaysia. The influential factors are followed by personal physiological (second place), cultural influence (third place), family influence (fourth place), legislative influence (fifth place), and personal beliefs and values (sixth place). By definition, psychosocial influence includes peer affiliation and connectedness to home, school, or workplace. A possible explanation for the finding might be that adults were initiated to smoke because they consider it sophisticated and socially acceptable, supported by their peers' smoking habits. This finding is consistent with the studies by Arnett (2007), Bauman and Ennett (1996), Kobus (2003), Poulin et al. (2011), and the U.S. Department of Health and Human Services (2012) who stated that psychosocial influence is the dominant factors of influencing an individual to smoke.

Table 4.2 on the other hand shows the final weights and ranks representing the relative importance of the five anti-smoking strategies to cope with smoking habits. The above results show that education, communication, and public awareness is the best anti-smoking strategies to be implemented for reducing smoking prevalence effectively in

Malaysia. This is followed by tobacco advertising, promotion, and sponsorship (second place), smoke-free legislation (third place), pricing and taxation (fourth place), and packaging and labelling (fifth place). The findings of this study are concordance with the report by ITC Project & International Tobacco Control in 2012, which suggested that the government should continue and strengthen mass media campaign strategy in order to cope with smoking habits, particularly among adults.

4.2 Validated Structure and Behaviour of the EAHPSD Model

The results of the EAHPSD model from the validation tests are presented in this section. In this research, the integrated EAHPSD model is validated structurally and behaviourally (see Section 3.7). The model's structure was validated through the boundary adequacy test, structure verification test, parameter verification test, dimensional consistency test, and extreme condition test, while the behavior of the model is validated through the behavior reproduction test. The explanation for each test's findings is further explained in Section 4.2.1 until Section 4.2.6 as follows:

4.2.1 Validated Boundary Adequacy

Boundary adequacy test assess the suitability of the model boundary based on the research objectives (Sterman, 2000). In this research, the boundary adequacy test was initially done by analysing the important components and feedbacks of the tobacco system. The process of identifying the main components was done by reviewing tobacco reports and tobacco-related literature, and interviewing respondents of the tobacco conference. From the review, all the components in the tobacco system were listed as in Table 4.3. Then, important components and feedbacks that are related to the research objectives were selected.

Referring to Table 4.3, there are three main components identified that are related to the research objectives, which are (1) population, (2) factors influencing smoking, and (3) anti-smoking strategies. Population and anti-smoking strategies are the fundamental components that are frequently studied, while little attention was given to the factors influencing smoking in the previous tobacco-SD studies.

Table 4.3

List of components from previous tobacco-SD literature

Sources	Model name	Main components/sectors in tobacco system	Description	Does the component involved in achieving research objectives?
Roberts et al., (1982)	MIT model	1. Population	The model is divided into three levels which are (1) potential smokers, (2) smokers, and (3) ex-smokers.	**Yes**
		2. Contaminants and their effects	Representing the effects of smoking and the contaminants absorbed by smokers.	No
		3. Factors affecting initiation	Describing the factors involved in converting potential smokers into smokers	**Yes**
		4. Factors affecting quits	Describing the factors involved in converting smokers into ex-smokers	No
		5. Factors affecting intensity	Representing the number of cigarettes smoked by smokers per year	No
		6. Factors affecting price	Examining the effects of price on smoking habit	No
		7. Restrictions on smoking	Representing the general societal level of smoking restrictions	No

Table 4.3 (continued)

		8. Perceived hazards	Representing the identified hazards due to smoking	No
		9. Societal approval of smoking	Representing the effects of societal approval or disapproval towards smoking	No
		10. Tobacco industry spending	Representing the industry revenue to increase smoking habit.	No
		11. Anti-smoking campaign	Representing the government efforts to reduce smoking habit	**Yes**
Cavana, Broatch, & Clifford (2003) and Cavana & Clifford, (2006)	New Zealand Tobacco Control Model	1. New Zealand tobacco industry	Representing tobacco manufacturing and duty collection for cigarettes.	No
		2. New Zealand customs	Representing air and marine processing activities for cigarettes	No
		3. New Zealand health	Estimating the cost of smoking-related illnesses.	No
Cavana & Tobias, (2007)		1. Population	The model is divided into three levels which are (1) never smokers, (2) youth smokers, and (3) adult smokers.	**Yes**
		2. Smoking prevalence	Calculating the ratio for smoking prevalence for each population level.	No

Table 4.3 (continued)

	3. Second-hand smoke	Representing the exposure and mortality associated with second-hand smokers (passive smokers).	No
	4. Tobacco attributable deaths	Calculating the mortality associated with current smokers and passive smokers.	No
Cavana & Tobias, (2008) and Tobias, Cavana, & Bloomfield (2010)	1. Population	The model is divided into three levels which are (1) never smokers, (2) youth smokers, and (3) adult smokers.	**Yes**
	2. Smoking prevalence	Calculating the ratio for smoking prevalence for each population level.	No
	3. Second-hand smoke	Representing the exposure and mortality associated with second-hand smokers (passive smokers).	No
	4. Tobacco consumption	Calculating the number of cigarette consumption for each population level.	No
	5. Tobacco attributable deaths	Calculating the mortality associated with current smokers and passive smokers.	No

Table 4.3 (continued)

Tengs, Osgood, & Lin (2001), Tengs, Ahmad, Moore, & Gage (2004), Tengs, Ahmad, Savage, Moore, & Gage (2005), Ahmad, (2005), Ahmad & Billimek (2005) and Ahmad & Franz, (2008)	Tobacco Policy Model (TPM)	1. Population	The model is divided into three levels which are (1) never smokers, (2) current smokers, and (3) former smokers.	**Yes**
		2. Health	Calculating Quality Adjusted Life Years (QALYs) to measure public health	No
Richardson (2007)	Initiative on the Study and Implementation of Systems (ISIS)	1. Population	The model is divided into three levels which are (1) non-smokers, (2) smokers, and (3) former smokers.	**Yes**
		2. Tobacco industry	Representing the industry efforts to increase smoking habit.	No
		3. Tobacco control and government intervention	Representing government intervention in tobacco sales and production	No

Further, the boundary adequacy of the model was also validated by expert opinion through the tobacco conference. The process was validated by the Malaysian secretariat of WHO FCTC which consider as the experts of tobacco. Thus, the model boundary is validated. Conclusively, it was found that the selected components were closely associated with the previous tobacco research, and in line with the experts' opinion. The process involved in the validation process with the experts is summarised in Table 4.4.

Table 4.4

Model validation process with the expert in the field

Date	**Expert rank and affiliation**	**Process**	**Action taken**
23-24 April 2015	FCTC Secretariat, MOH Malaysia	Structure and feedback checking for dynamic hypothesis and stock and flow model	Structure and feedback for dynamic hypothesis and stock and flow model were correctly accepted

4.2.2 Validated Structure

A structure verification test is conducted to ensure the decision rules are structurally captured and consistent with the real situation. Once the model boundary is validated, the conformance of the developed model to the real situation was done using a mapping tool called the causal loop diagram (CLD). The CLD illustrates the main component in the tobacco system: population sector, factors influencing smoking sector, and anti-smoking strategies sector. These sectors were modelled based on the previous study by past researchers. For the population sector, the model was developed based on the study by Cavana and Tobias (2007) and the anti-smoking strategies sector was developed by Zagonel et al. (2011). While, for factors influencing smoking sector, the model was developed based on the study by Ulli-beer (2004).

Next, the developed CLD was converted into a stock and flow model. In this process, the main component was initially modelled in an individual sub-model and finally expanded into the primary model. Again, the developed stock and flow model was referred from key papers, as were in Cavana and Tobias (2007), Zagonel et al. (2011), and Ulli-beer (2004). However, for CLD and stock and flow model, several modifications have been made to achieve the research objectives.

Then, the developed CLD and stock and flow model were validated by the experts. The validation process was conducted using the same experts with the process of model boundary adequacy test, as explained in Section 5.2.1 (refer Table 5.4). In a nutshell, after the validation process conducted, it was found that the fundamental structure and feedback process for both CLD and stock and flow model were closely conformed to the previous studies and in-line with expert opinion.

4.2.3 Validated Parameter

A parameter verification test is conducted to validate whether the developed model's parameters used are the correspondence to the real structure of the tobacco system. In this study, parameter values were taken from the published reports from the Department of Statistics Malaysia, Ministry of Health Malaysia and World Health Organisation between 2000 and 2017. The selected parameter values used in this study is shown in Table 4.5.

Table 4.5

List of parameters used in the EAHPSD model

Type of data	Period	Description/Source
Total population Birth rate Death rate	2000 - 2017	Department of Statistics Malaysia
Smoking prevalence	2000 - 2016	Institute of Public Health Malaysia World Health Organisation

4.2.4 Validated Dimensional Consistency

Dimensional consistency test is one of the most crucial and basic tests in SD modelling (Sterman, 2000). Each variable has been specified and subjected to suitable measurement units to ensure consistency. The test is performed by making sure the two-hand sides of the model equations are consistent. In this study, Table 4.6 presents an analysis of the dimensional consistency of several variables used in the model for better understanding. This test has been specified and checked from time to time throughout the modelling process. The test is carried out using the built-in feature in Vensim software, and the results show that all units are consistent, as shown in Figure 4.1.

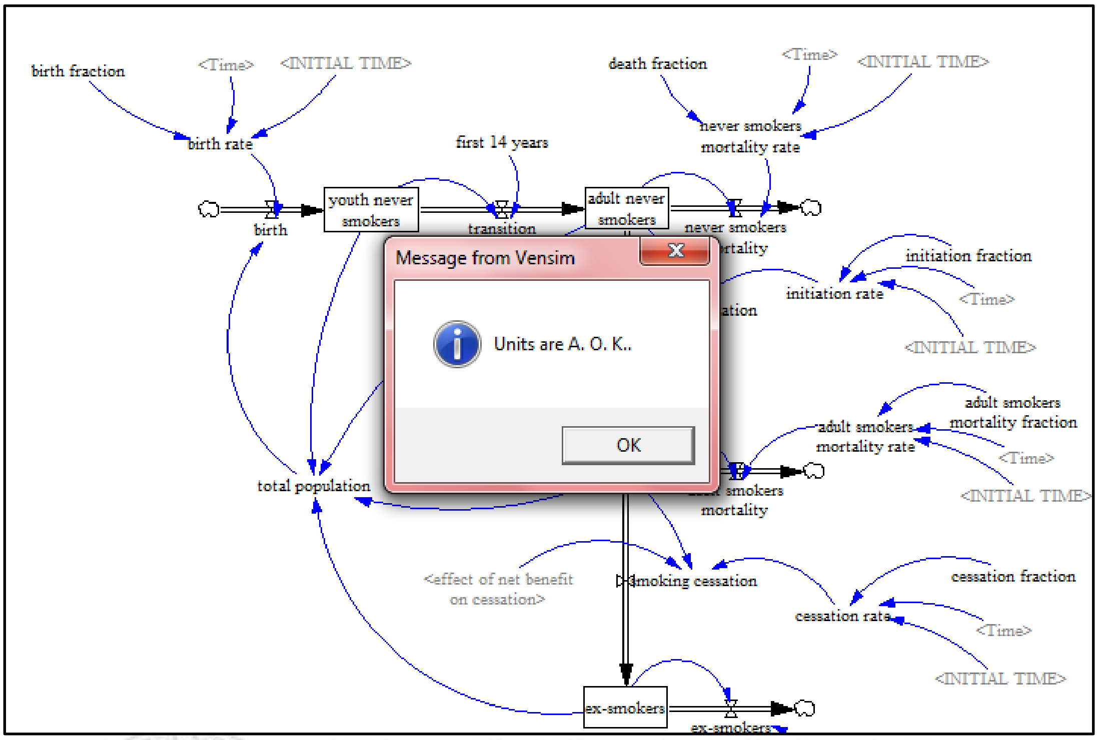


Figure 4.1 Successful units test performed in Vensim

Table 4.6

Dimensional consistency checking of selected equations

Variable name	**Equation**	**Dimensional analysis**
birth	birth=total population*birth rate	$\frac{person}{year} = person * \frac{1}{year}$
youth never smokers	youth never smokers = INTEG (birth-transition, 8M)	$persons = INTEG\left(\frac{person}{year} - \frac{person}{year}\right)$
adult never smokers	adult never smokers = INTEG (transition-never smokers mortality-smoking initiation, 15.5M)	$persons = INTEG\left(\frac{person}{year} - \frac{person}{year} - \frac{person}{year}\right)$
adult smokers	adult smokers = INTEG (smoking initiation-adult smokers mortality-smoking cessation, 3.84M)	$persons = INTEG\left(\frac{person}{year} - \frac{person}{year} - \frac{person}{year}\right)$

Table 4.6 (continued)

ex-smokers	ex- never smokers = INTEG (smoking cessation-ex-smokers mortality, 328929)	$persons = INTEG\left(\frac{person}{year} - \frac{person}{year}\right)$

4.2.5 Validated Behaviour Reproduction of EAHPSD Output

The testing process continues with the behaviour reproduction test. The primary purpose of this test is to assess the point-by-point fit (Sterman, 2000). This test is conducted to check whether the simulated behaviour is fitting closely to replicate real behaviour. In this study, the integrated EAHPSD model's behaviour is validated by comparing the simulated output with the real data. Hence, four simulated behaviours which are smoking prevalence, birth rate, number of adult smokers, and total population, are evaluated according to the current reference mode. The variables were chosen because they are in the population sector, which is the fundamental sector for simulating the model.

A baseline run with all the initial input parameters, as defined in Section 3.6.10, is simulated to obtain simulated smoking prevalence, birth rate, number of adult smokers, and total population. The result of the behaviour reproduction tests is presented in Figure 4.2 to Figure 4.5 based on historical data collected from 2000 to 2017. The historical data are regarded as the mode of reference. Based on the trends revealed in Figure 4.2 to Figure 4.5, it is shown that there is a good resemblance between historical and simulated data. In addition, the comparisons between historical and simulated data are measured in terms of Mean Square Error (MSE). It is a measurement of dispersion between the simulated values and actual values (Sterman, 2000). The calculation is as follows:

$$MSE = \frac{1}{n}\sum(\text{simulated output} - \text{historical data})^2 \qquad (4.1)$$

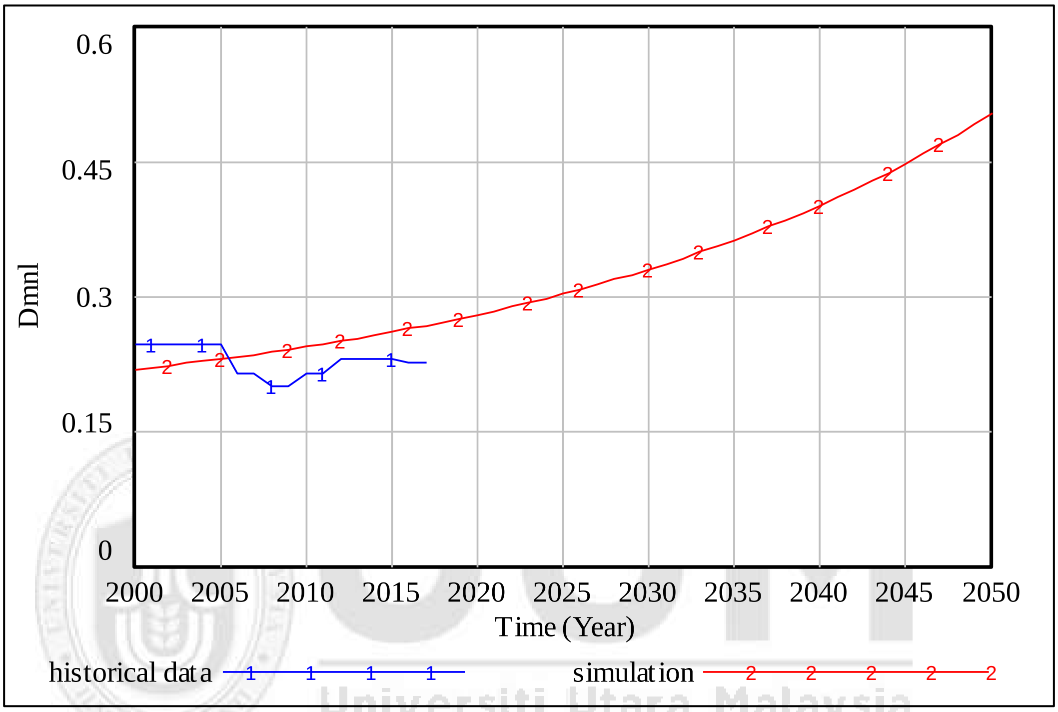


Figure 4.2 The comparison trends of simulation and historical data for smoking prevalence

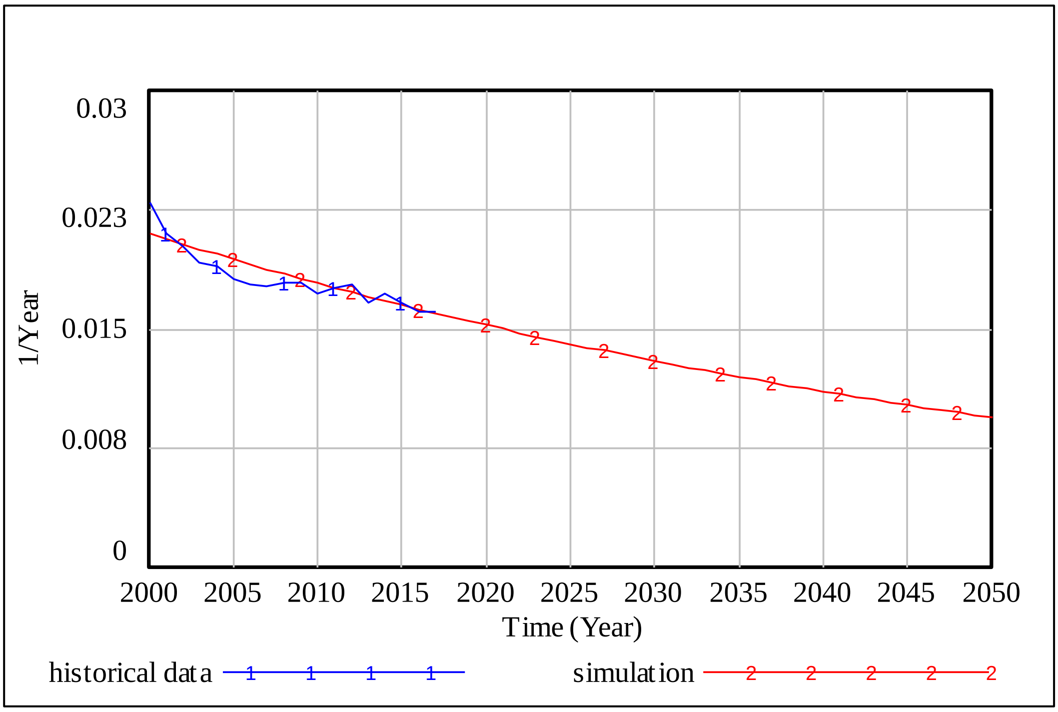


Figure 4.3 The comparison trends of simulation and historical data birth rate

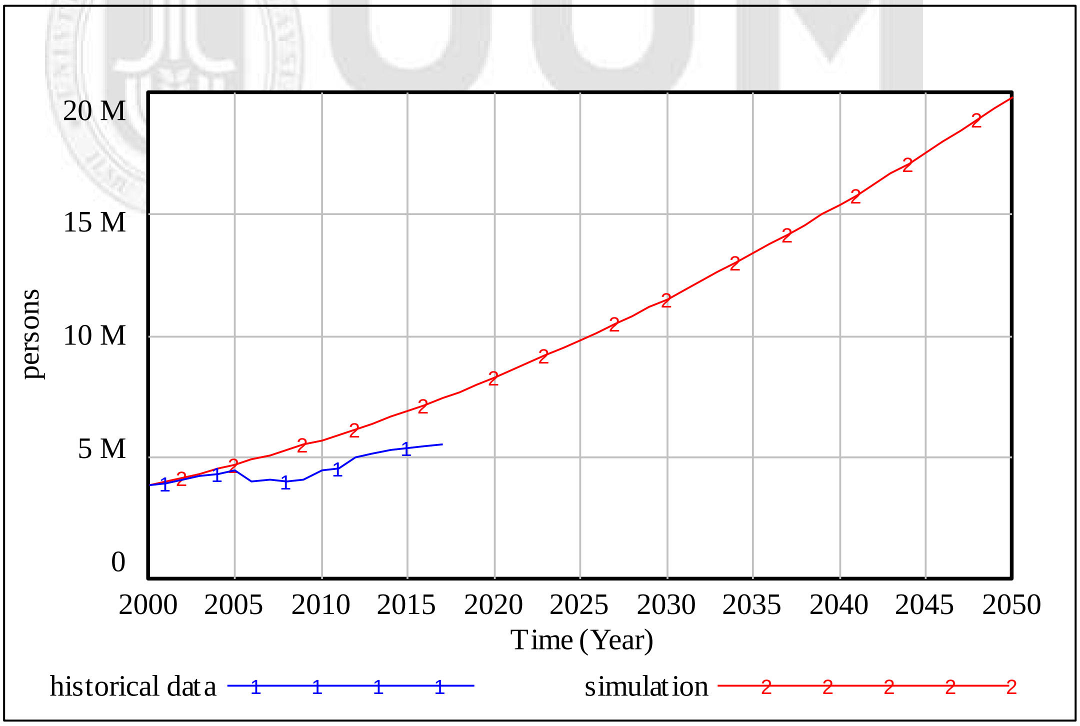


Figure 4.4 The comparison trends of simulation and historical data for adult smokers

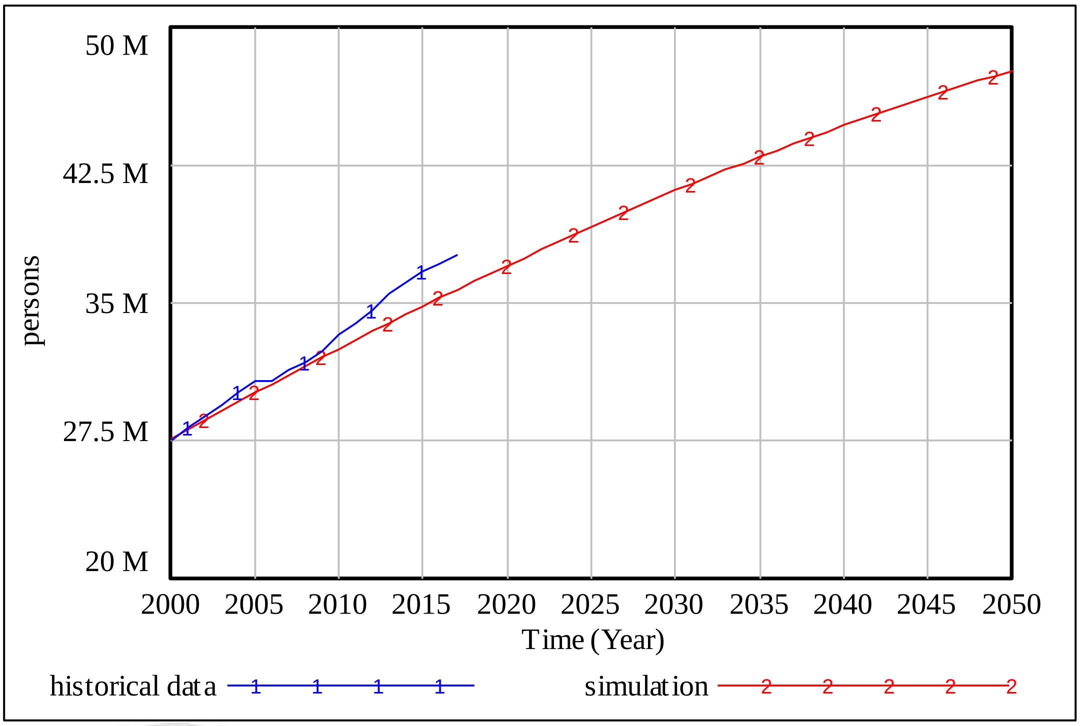


Figure 4.5 The comparison trends of simulation and historical data for the total population

Table 4.7

Result of mean square error test

Variables	**MSE**
Smoking prevalence	0.0802
Birth rate	0.0001
Adult smokers	1.2537
Total population	0.0110

The trends showing good resemblance between historical and simulated data is also supported by the MSE values presented in Table 4.7 which are all below 10%, which infers that it is acceptable, as recommended by Sterman (2000). Thus, the small deviation validated the model.

4.2.6 Validated Extreme Condition Values

The extreme condition test is a test to examine whether simulated models behave appropriately when extreme values are inserted into the models (Sterman, 2000). In extreme conditions, a model should be robust and behave realistically no matter how extreme the values inserted. Table 4.8 presented the extreme condition assessment setup, as well as the expected outcome. For this test, the value of the birth rate was assigned with an extreme value of 0. This simulates the condition where it is assumed that no births are occurring in the population. All the expected outcome is shown in Figure 4.6 to Figure 4.10.

Table 4.8

Compilation of results for selected variables with extreme condition test

Sub-model	Variable	Initial value	Extreme value	Expected outcome	Illustration
Population	birth rate	0.021	0	Number of adults never smokers fall	Refer to Figure 4.6
				Number of adult smokers fall	Refer to Figure 4.7
				Number of ex-smokers fall	Refer to Figure 4.8
				Smoking prevalence fall	Refer to Figure 4.9
				Number of total population fall	Refer to Figure 4.10

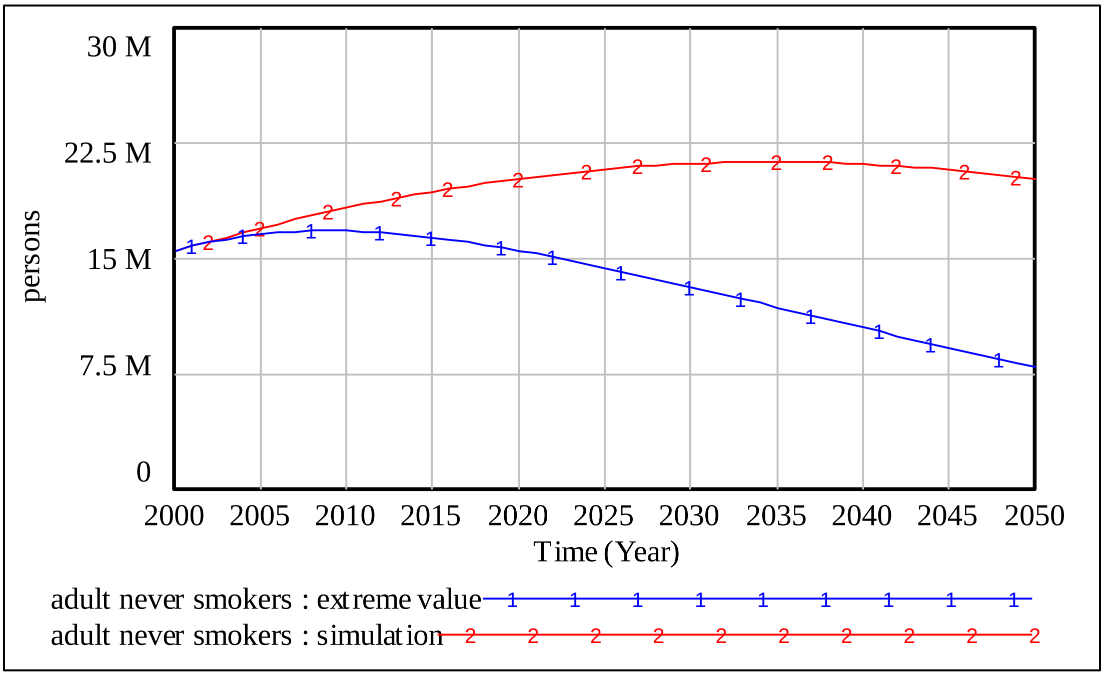


Figure 4.6 The result of extreme condition test for adult never smokers

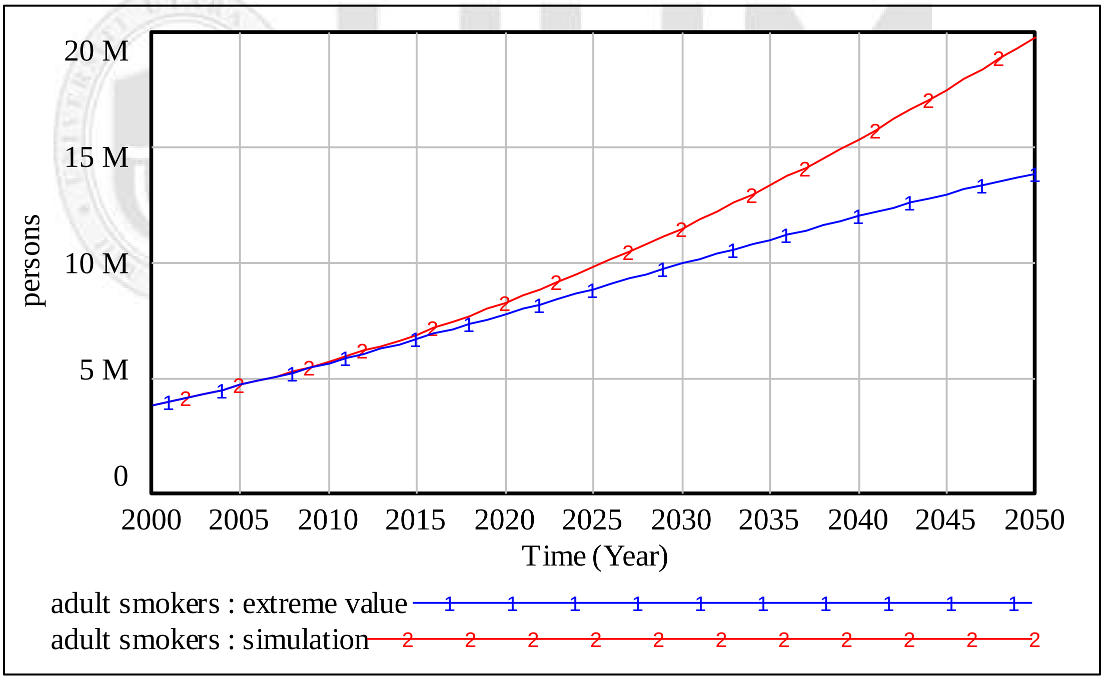


Figure 4.7 The result of extreme condition test for adult smokers

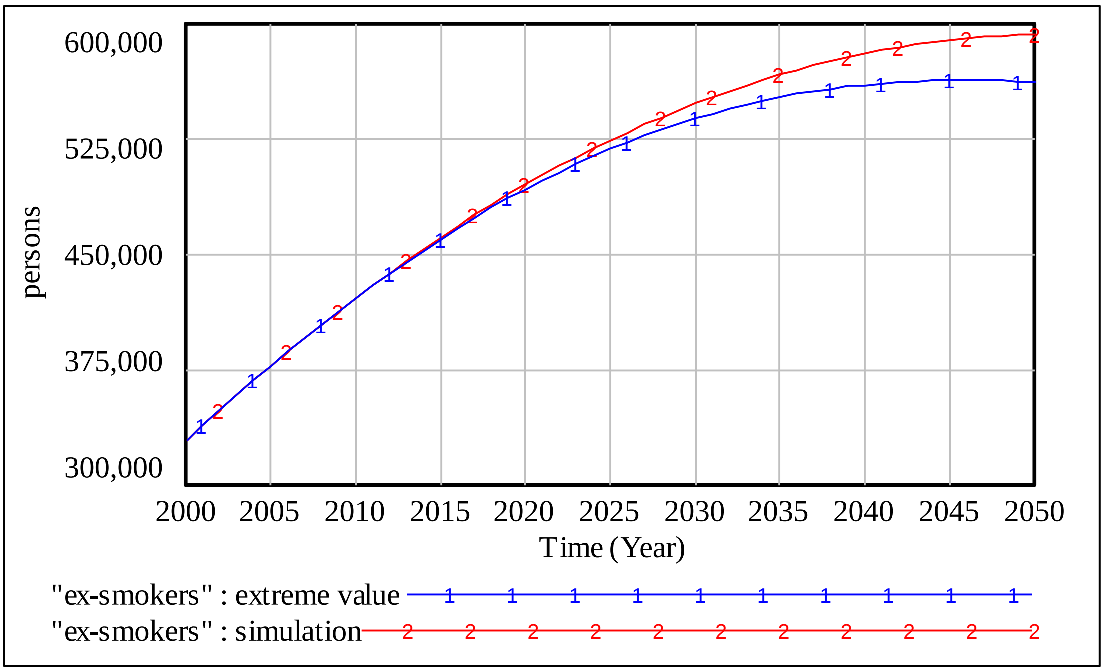


Figure 4.8 The result of extreme condition test for ex-smokers

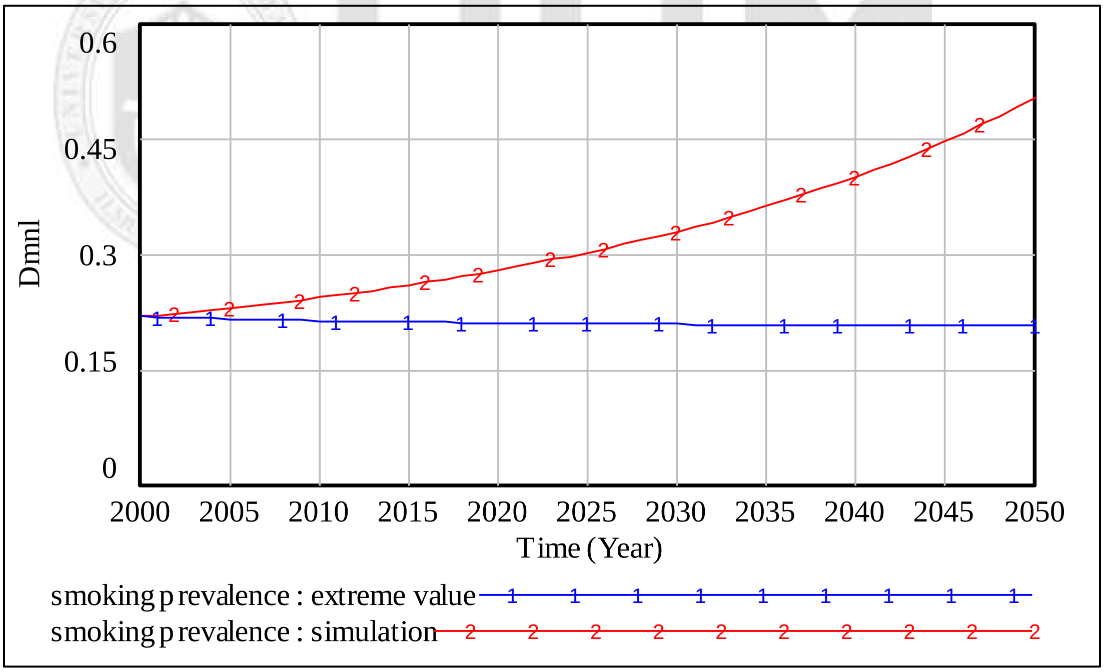


Figure 4.9 The result of extreme condition test for smoking prevalence

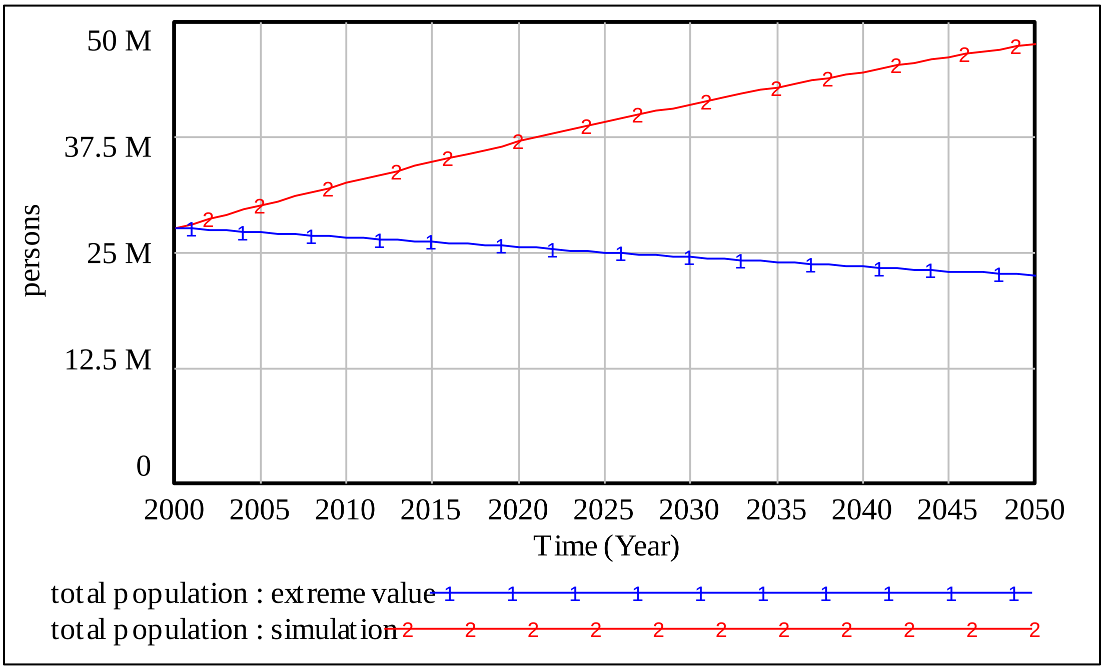


Figure 4.10 The result of extreme condition test for the total population

Based on the trends in Figure 4.6 to Figure 4.10, it is clearly seen from the population density which consists of adult never smokers, adult smokers, ex-smokers, and the total population as well as the smoking prevalence had declined compared to base run values. The result is expected because the birth rate is one of the correspondent parameters in smoking population dynamics. Therefore, while changing the parameter value of birth rate from 0.021 to 0, it will impact the population density and smoking prevalence. This test shows that the developed EAHPSD model logically produces consistent output when an extreme value is applied to the equations of the related model. The result had built confidence that the model is similar to the structure of the real system.

4.3 Simulation Analysis of the Integrated EAHPSD Model

Once the EAHPSD model is validated, a sufficient level of confidence has been inculcated in the model as the basis for further simulation analysis. In this section, simulation analysis is divided into three parts: EAHPSD base run, EAHPSD sensitivity analysis series, and EAHPSD optimisation. The output from the simulation runs are presented in Section 4.3.1 until Section 4.3.3. Then, it continues with the comparison of results from all the simulation runs in Section 4.3.4.

4.3.1 The Output from EAHPSD Base Run

The first simulation run is a base run representing the current scenario of the tobacco system in Malaysia. In other words, all anti-smoking strategies are still in place with the expectation of no future changes. The base run for smoking prevalence from the year 2000 until 2050 is presented in Figure 4.11.

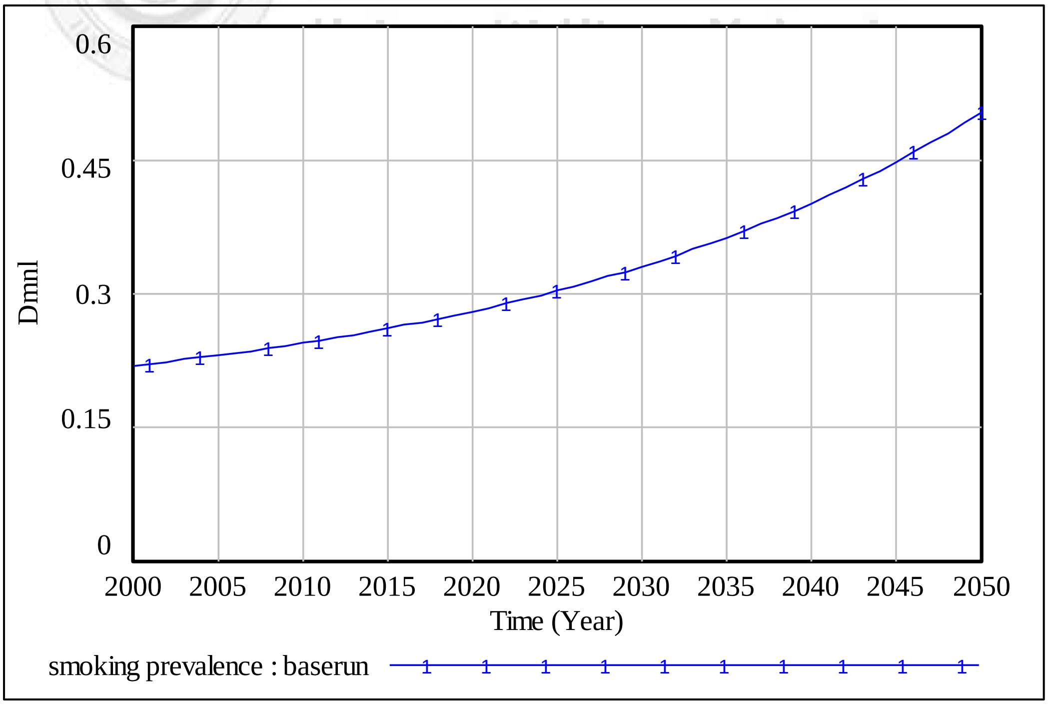


Figure 4.11 The behaviour trend of smoking prevalence for the base run

The trend in Figure 4.11 shows that there has been a gradual increase in the smoking prevalence from the year 2000 until 2050. From the simulated baseline, the smoking prevalence is 0.22 in 2000, increasing to 0.2764 in 2019 and is projected to be 0.5043 in 2050. To reverse the trends, the Malaysian government set a target to achieve tobacco endgame by 2045 with a smoking prevalence of less than 0.05. Next, Figure 4.12 illustrates smoking prevalence behaviour for the base run and the desired smoking prevalence generated from the simulated model. The blue coloured line represents the baseline behaviour for the smoking prevalence from the simulated model, while the red coloured line represents the desired smoking prevalence by the year 2050. Table 4.9 presents the values of smoking prevalence for the base run and the desired smoking prevalence between 2019 and 2050.

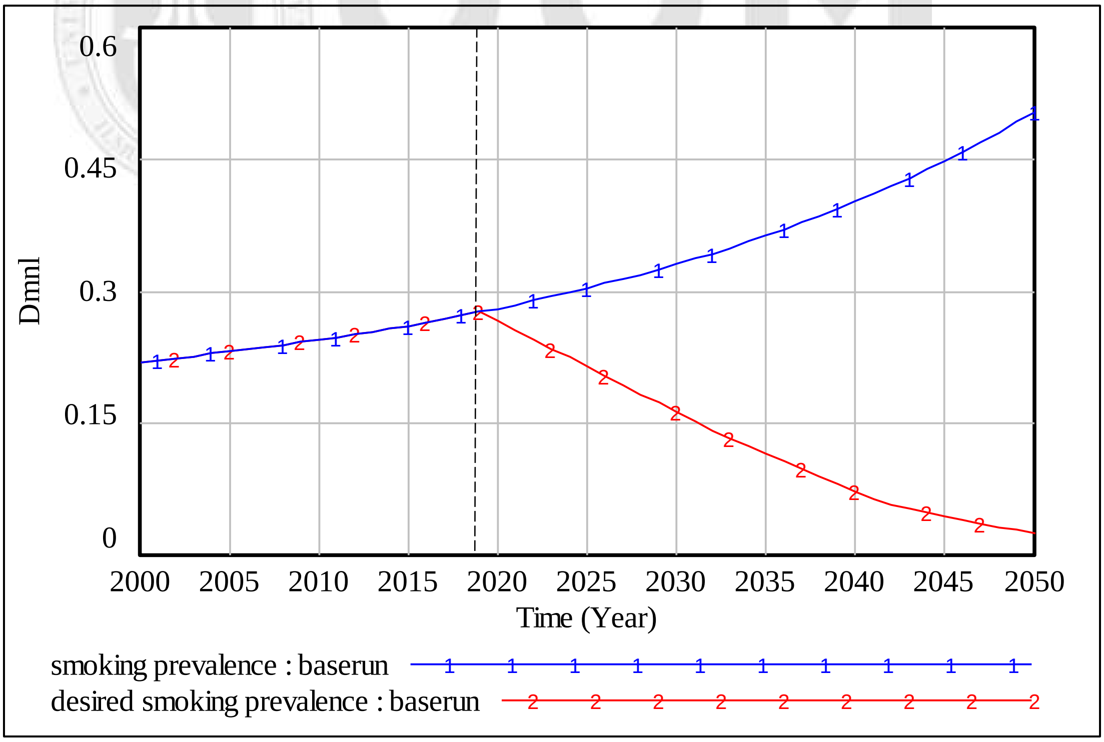


Figure 4.12 The behaviour trend of smoking prevalence for the base run and the desired smoking prevalence between 2019 and 2050

Table 4.9

Changes in smoking prevalence from the past (2000-2019) and into the future (2045)

Smoking prevalence trend	**2000**	**2019**	**2045**	**2050**
Baseline smoking prevalence	0.22	0.2764	0.4483	0.5043
Desired smoking prevalence			Less than 0.05	

Referring to Figure 4.12 and Table 4.9, the base run output shows that the smoking prevalence is projected to be 0.4483 in 2045. Therefore, it is clearly seen that, compared to the desired smoking prevalence set by the government, the simulated value of smoking prevalence in 2045 is far-fetched in achieving tobacco endgame. The reasons for such a high smoking prevalence can be traced from the smoking habit's driving forces, which are the factors influencing smoking as it is known that smoking initiation exerts a direct impact on smoking prevalence. There are six factors influencing smoking: personal beliefs and values, physiological influence, psychosocial influence, family influence, cultural influence, and legislative influence. Based on the behaviour trend of the factors in Figure 4.13, psychosocial influence is depicted as the dominant factor, while personal beliefs and values are the least dominant factors in influencing people to smoke. Next, Figure 4.13 shows the behaviour trend of all the factors influencing smoking.

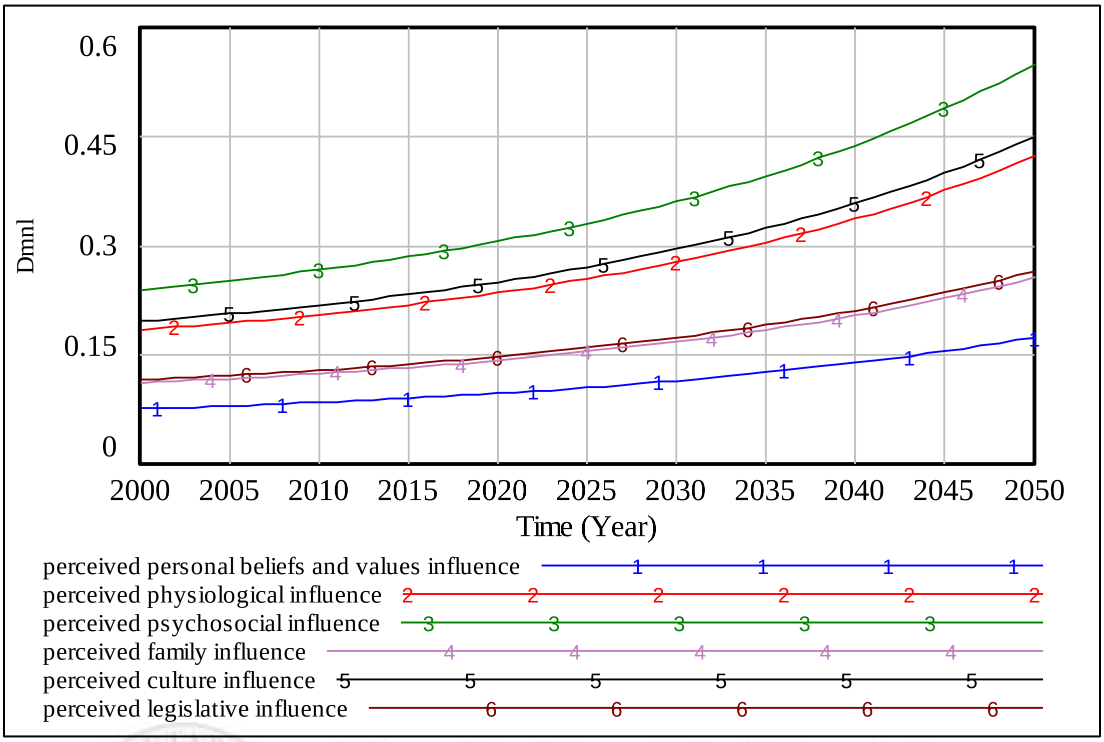


Figure 4.13 The behaviour trend of factors influencing smoking between 2000 and 2050

Further, the implication of such an increasing trend in smoking prevalence can be reflected in the number of current adult smokers and ex-smokers. The behaviour trend of the number of adult smokers and ex-smokers between 2000 until 2050 is presented in Figure 4.14 and Table 4.10.

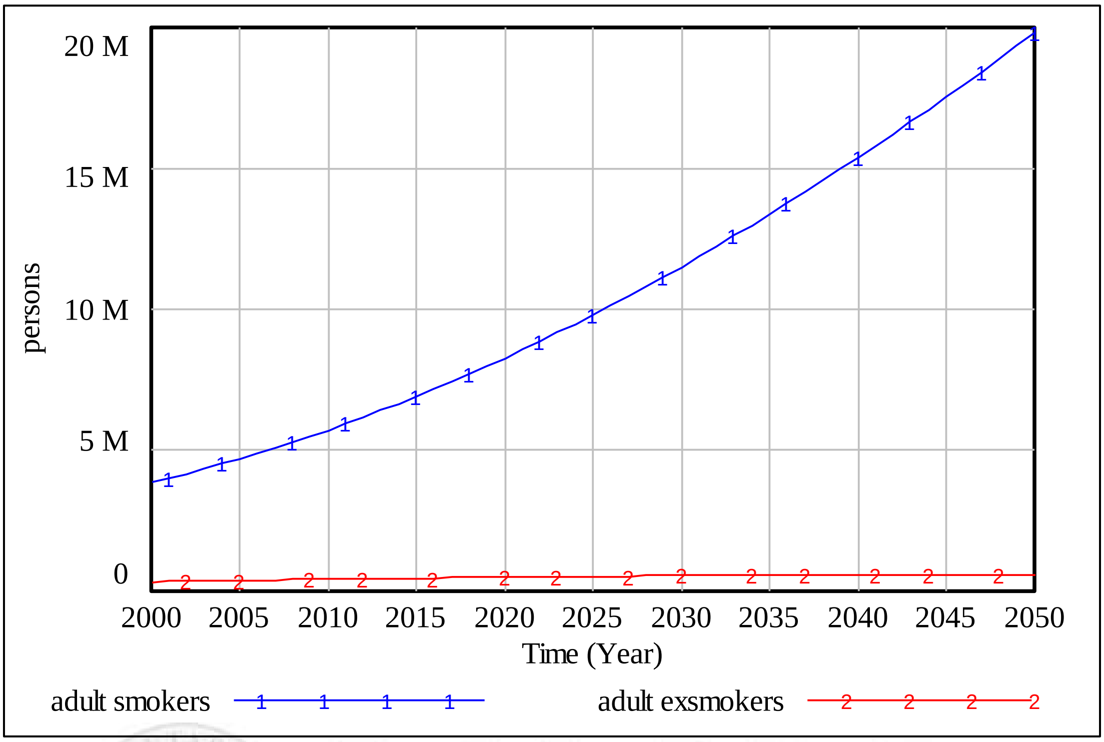


Figure 4.14 The behaviour trend of adult smokers and ex-smokers by smoking status for the base run

Table 4.10

Results of EAHPSD base run model

Variables	Time (t)			
	t = 2000	t = 2019	t = 2045	t = 2050
Smoking prevalence (per year)	0.22	0.2764	0.4483	0.5043
Adult smokers (persons)	3.84M	7.98M	17.53M	19.80M
Ex-smokers (persons)	328 929	488 901	589 457	593 673

The trend in Figure 4.14 shows that there has been a steep increase in the number of adult smokers from the year 2000 until 2050. From the baseline, the number of adult smokers is 3.84M in 2000, increasing sharply to 7.98M in 2019 and is projected to be

19.80M in 2050. However, the number of ex-smokers shows a prolonged increase from the year 2000 until 2050. From the baseline, the number of ex-smokers is 328 929 in 2000, increasing slowly to 488 901 in 2019 and is projected to be 593 673 in 2050. In addition, the number of adult smokers and ex-smokers are expected to be 17.53M and 589 457 by the year 2045. From the baseline trajectory, the trends reveal that if no action taken by the authorities to curb smoking habits, the population is moving towards a severe tobacco epidemic in the future.

4.3.2 The Output from EAHPSD Sensitivity Analysis Series

In this section, the EAHPSD model is assessed on the basis of three scenarios: (i) changes in *enforcement level imposed by the government* while maintaining the *promotion level by the tobacco industry* as its initial value set during the base run, (ii) changes in *promotion level by the tobacco industry* while maintaining the *enforcement level imposed by the government* as its initial value set during the base run and (iii) changes in both *enforcement level imposed by the government* and *promotion level by the tobacco industry* as shown in Table 4.11.

Table 4.11

Parameter values for the evaluation process

		Control variables	
		Enforcement level imposed by the government (initial value = 0)	**Promotion level by the tobacco industry (initial value = 1)**
Scenario 1: Changes in the enforcement level imposed by the government	Strategy 1	0.25	1.00
	Strategy 2	0.50	1.00
	Strategy 3	0.75	1.00
	Strategy 4	1.00	1.00
Scenario 2: Changes in the promotion level by the tobacco industry	Strategy 5	0	0.75
	Strategy 6	0	0.50
	Strategy 7	0	0.25
Scenario 3: Combination	Strategy 8	0.25	0.25
	Strategy 9	0.50	0.50
	Strategy 10	0.75	0.75

For scenario 1, the parameter *enforcement level imposed by the government* is increased in the interval from 0 to 0.25, 0.5, 0.75, and 1.0 to evaluate the impact of the sole increment of the parameter and to what degree the government required to take action. For scenario 2, the parameter *promotion level by the tobacco industry* is decreased in the interval from 1 to 0.75, 0.50, and 0.25 to evaluate the impact of the sole decrement of the parameter and to what degree the government required to diminish the influence by tobacco industry since reducing the parameter to 0 seem impossible. On the other hand, for scenario 3, both of the parameters, *enforcement level imposed by the government* and *promotion level by the tobacco industry* were tested simultaneously, whereby the parameter *enforcement level imposed by the government* is increased. In contrast, the parameter *promotion level by the tobacco industry* is decreased to evaluate the effect of changing both parameters and to what degree the government required to take action for both. All the output from the three scenarios is classified into three sub-sections according to their scenario tested. The explanation for each scenario is as follows:

i. **Scenario 1: Changes in enforcement level imposed by the government**

In scenario 1, the parameter value for the *enforcement level imposed by the government* was increased from 0 to 1, with 0.25 increments for each level. The output for strategy 1, strategy 2, strategy 3, and strategy 4 are presented in Figure 4.15. Note that from 2000 to 2018, the trend is similar to the base run as the changes only made in 2019.

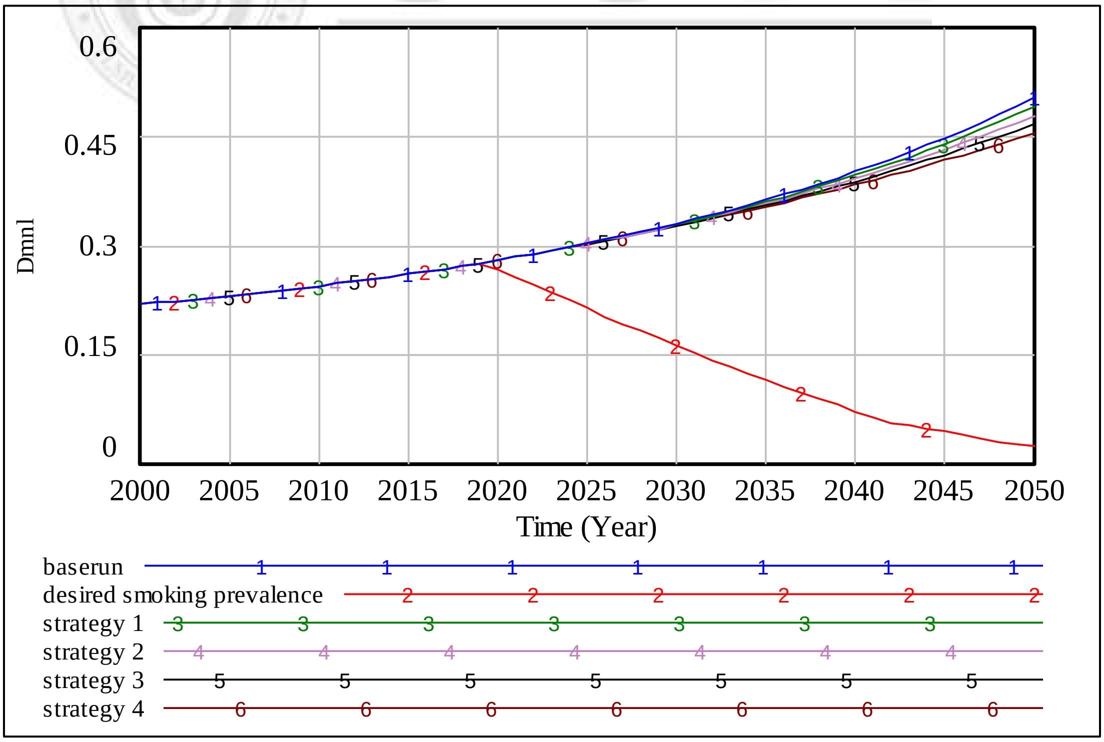


Figure 4.15 The behaviour trend of smoking prevalence for Scenario 1

Figure 4.15 shows that the trend lines are steadily increasing until it hits the year 2019, where smoking prevalence trend is gradually decreasing. The decrement occurs when the enforcement level increases from 0 to 0.25, as shown in line labeled strategy 1, from 0 to 0.50 shown in strategy 2, from 0 to 0.75 shown in strategy 3, and from 0 to 1.0 shown in strategy 4. The cause of this can be sourced from the hardly observable trends of the dominant factors of influencing smoking, which is the psychosocial influence, as shown in Figure 4.16.

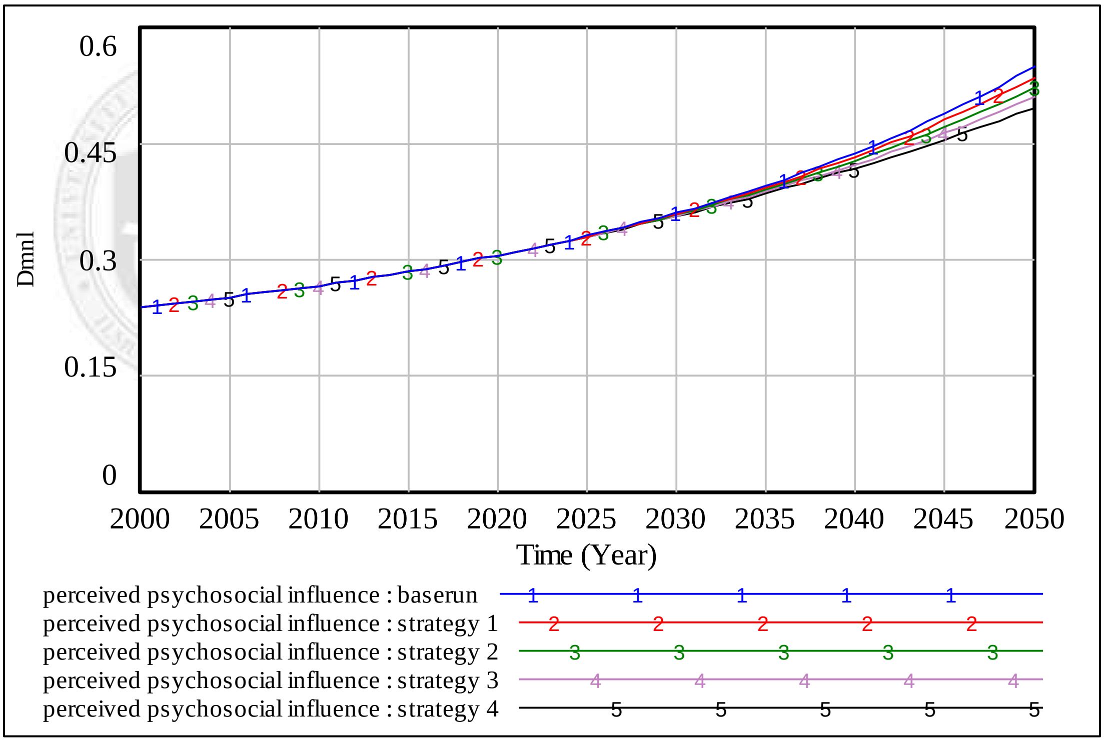


Figure 4.16 The behaviour trends of perceived psychosocial influence for scenario 1

Referring to the hardly noticeable trends in Figure 4.16, as the parameter value *enforcement level imposed by the government* is increasing, it shows a prolonged decrease in perceived psychosocial influence among Malaysians.

This is due to the insufficient level of enforcement imposed to overcome the smoking habit in reducing smoking prevalence. Further, similar trends can also be observed from the number of adult smokers and the number of ex-smokers. Based on the variation in the parameter value *enforcement level imposed by the government*, the behaviour trend in adult smokers did slightly decrease while ex-smokers did pose a slight increase, as shown in Figure 4.17 and Figure 4.18.

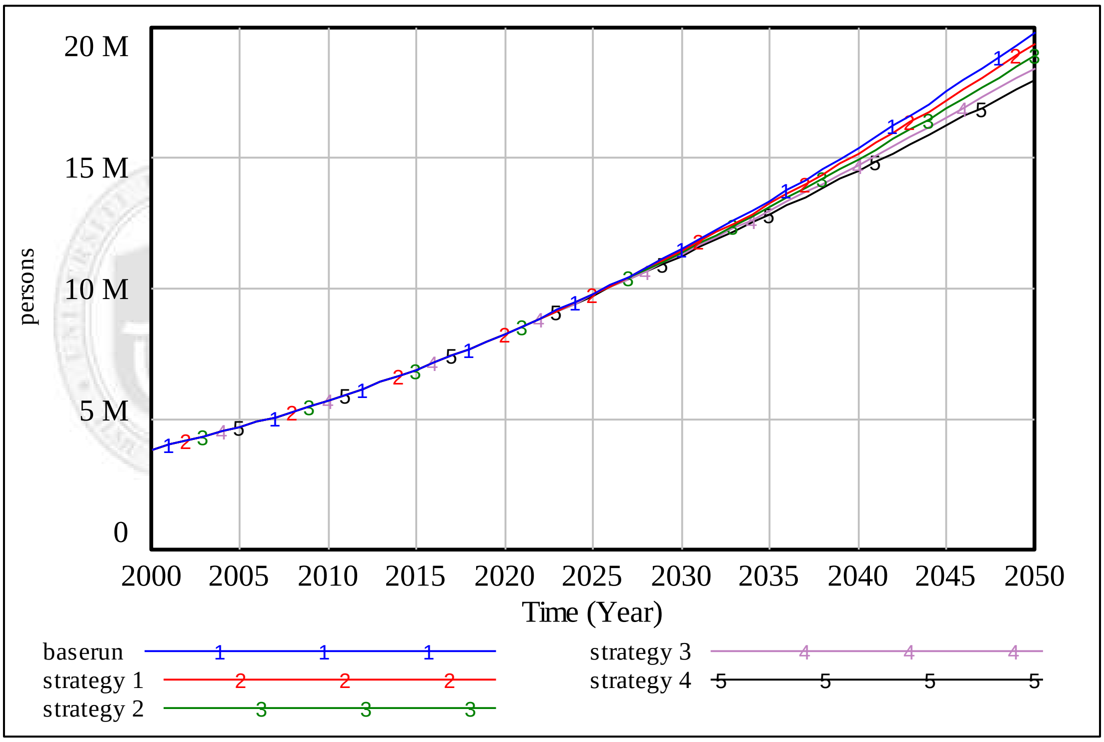


Figure 4.17 The behaviour trend of adult smokers for scenario 1.

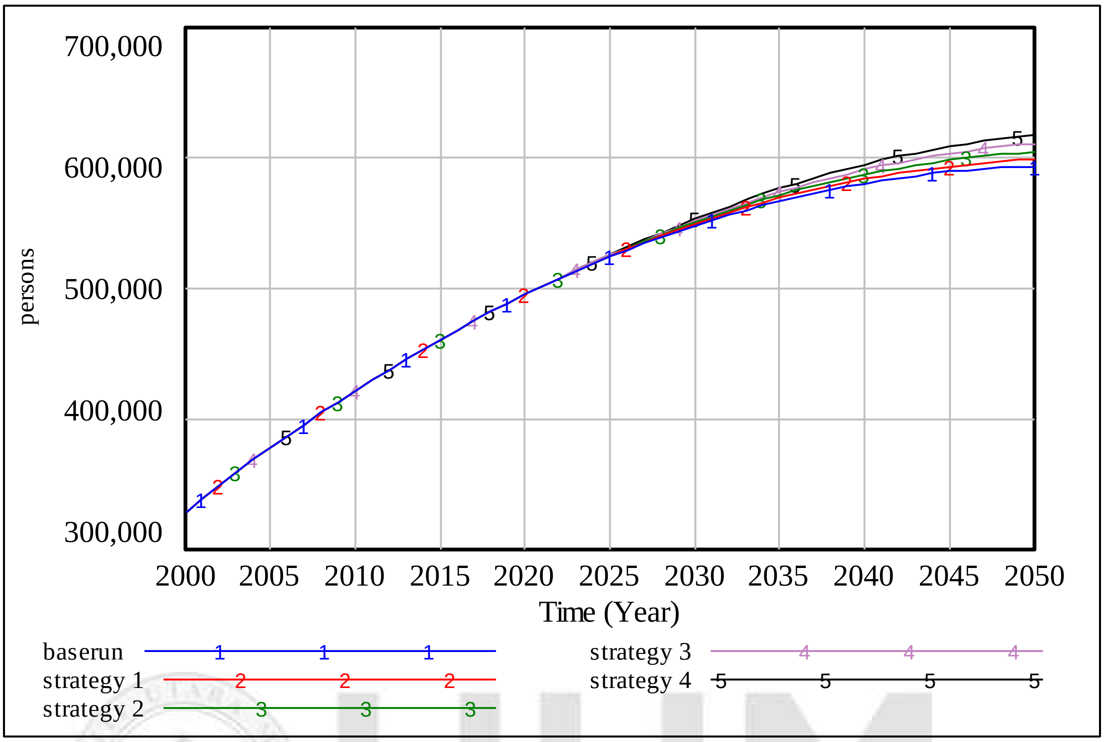


Figure 4.18 The behaviour trend of ex-smokers for scenario 1.

Subsequently, a description of the results of the EAHPSD model for scenario 1 based on a variation in the parameter values is summarised in Table 4.12. As shown in Table 4.12, the smoking prevalence is 0.22 in 2000, increasing slightly to 0.2764 in 2019 and is projected to be 0.4404 by the year 2045 if strategy 1 is implemented, 0.4327 if strategy 2 is implemented, 0.4251 if strategy 3 is implemented, and 0.4177 if full enforcement is implemented as in strategy 4. Among all the four strategies in scenario 1, strategy 4 generated the lowest smoking prevalence value, which is 0.4177. However, the lowest smoking prevalence value obtained in strategy 4 is still far-fetched from the targetted value since the smoking prevalence values difference between base run (0.4483) and strategy 4 (0.4177) is only 0.036 reduction.

Table 4.12

Results of EAHPSD model for Scenario 1

Variables	Simulation run	Time (t)			
		t = 2000	**t =2019**	**t = 2045**	**t=2050**
Smoking prevalence	Base run	0.22	0.2764	0.4483	0.5043
	Strategy 1			0.4404	0.4917
	Strategy 2			0.4327	0.4794
	Strategy 3			0.4251	0.4673
	Strategy 4			0.4177	0.4556
Adult smokers (persons)	Base run	3.84M	7.98M	17.53M	19.80M
	Strategy 1			17.21M	19.36M
	Strategy 2			16.89M	18.92M
	Strategy 3			16.56M	18.46M
	Strategy 4			16.23M	18M
Ex-smokers (persons)	Base run	328 929	488 901	589 457	593 673
	Strategy 1			593 747	598 948
	Strategy 2			598 392	604 732
	Strategy 3			603 445	611 103
	Strategy 4			608 968	618 164

Even though there is a hardly visible change to smoking prevalence trends and the value obtained is still implausible from 0.05 as targetted by the government, the output of smoking prevalence, adult smokers and ex-smokers do pose slight positive change indicating the correct solution direction to strengthen the laws of education, communication, and public awareness in Malaysia. By increasing the enforcement level, the smoking prevalence is reducing, but the outcome is still not favourable to achieve tobacco endgame.

The next scenario tested the circumstances where parameter values of *promotion level by the tobacco industry* are changing while sustaining the parameter values of *enforcement level imposed by the government.*

ii. Scenario 2: Changes in the promotion level by tobacco industry

In scenario 2, the parameter value for the *promotion level by the tobacco industry* was decreased, ranging from 1 to 0.25, with 0.25 decrements for each level. The output for strategy 5, strategy 6, and strategy 7 are presented in Figure 4.19. Note that from 2000 to 2018, the trend is similar to the base run as the changes were only made in 2019.

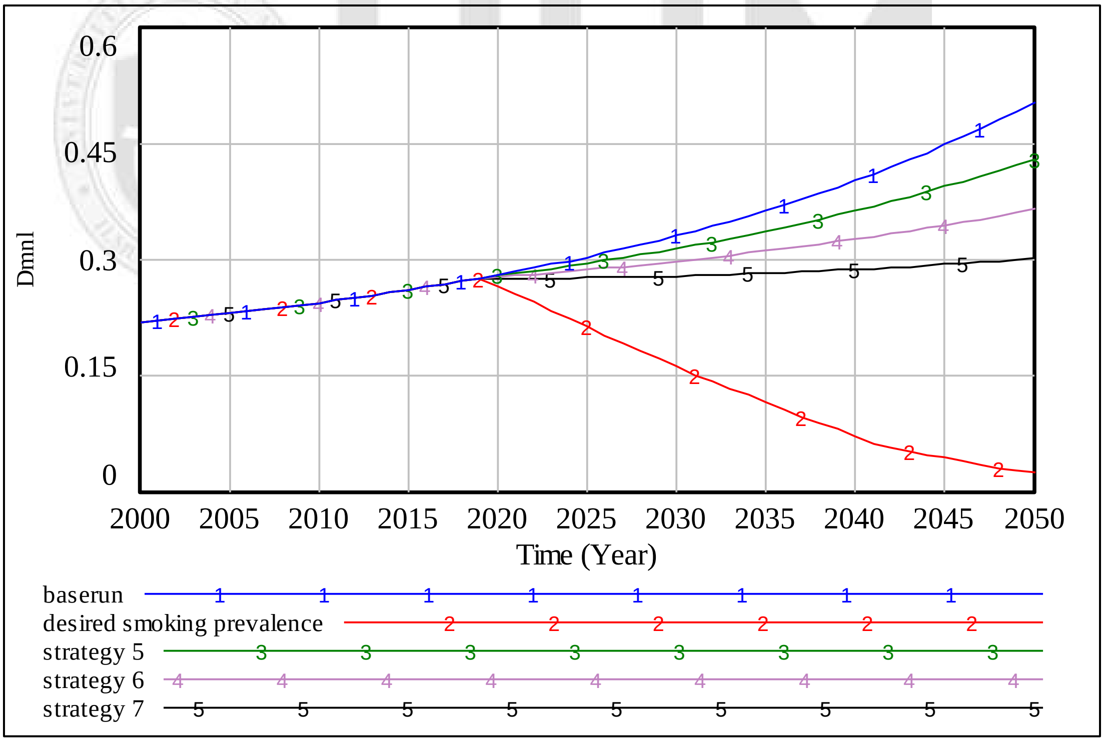


Figure 4.19 The behaviour trend of smoking prevalence for Scenario 2

Starting 2019, the results from scenario 2 simulation shows a moderate decline in the smoking prevalence behaviour trends due to the decrement of *promotion* *level by tobacco industry* from 1 to 0.75 as shown in strategy 5, from 1 to 0.50 shown in strategy 6, and from 1 to 0.25 shown in strategy 7. The cause of this can be sourced from the behaviour trends of the dominant factors of influencing smoking which is the psychosocial influence as shown in Figure 4.20.

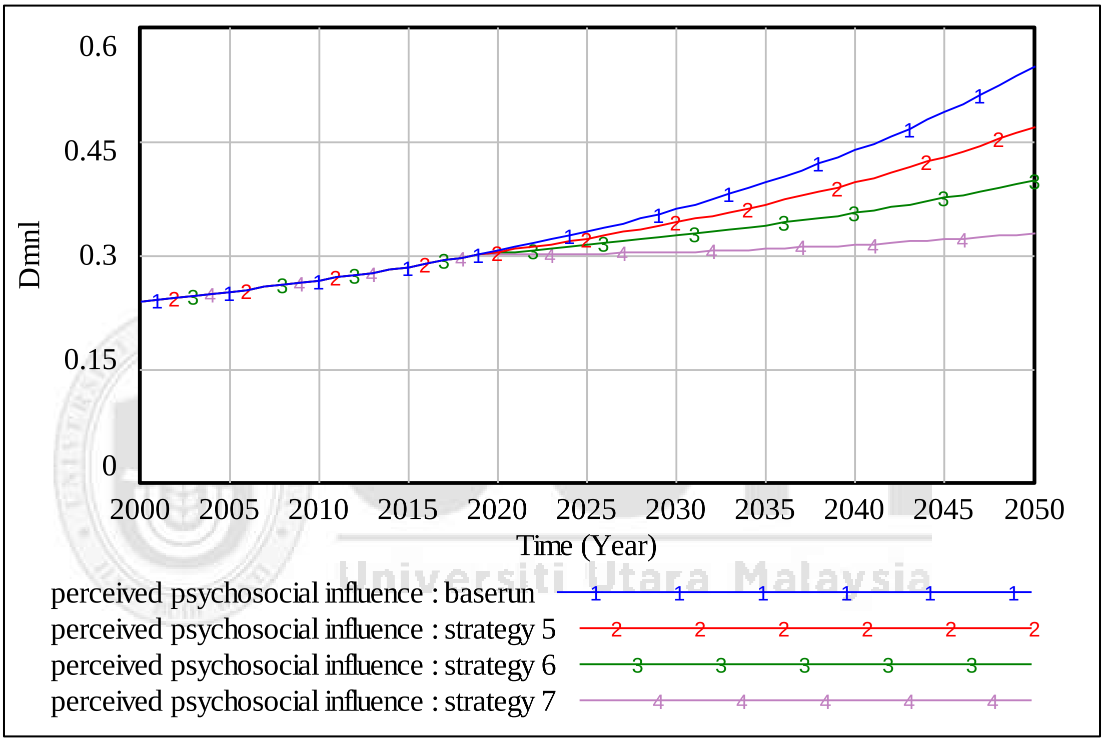


Figure 4.20 The behaviour trends of perceived psychosocial influence for scenario 2.

Referring to Figure 4.20, as the parameter value *promotion level by the tobacco industry* decreases, it shows a moderate decrease in perceived psychosocial influence among Malaysians. The trends indicate that smoking prevalence shows a better decrement in smoking prevalence if compared to scenario 1. Further, similar trends can also be observed from the number of adult smokers and the number of ex-smokers. Based on the variation in the parameter value *promotion level by the tobacco industry*, the behaviour trend in adult smokers is decreasing while ex-smokers is increasing, as shown in Figure 4.21 and Figure 4.22.

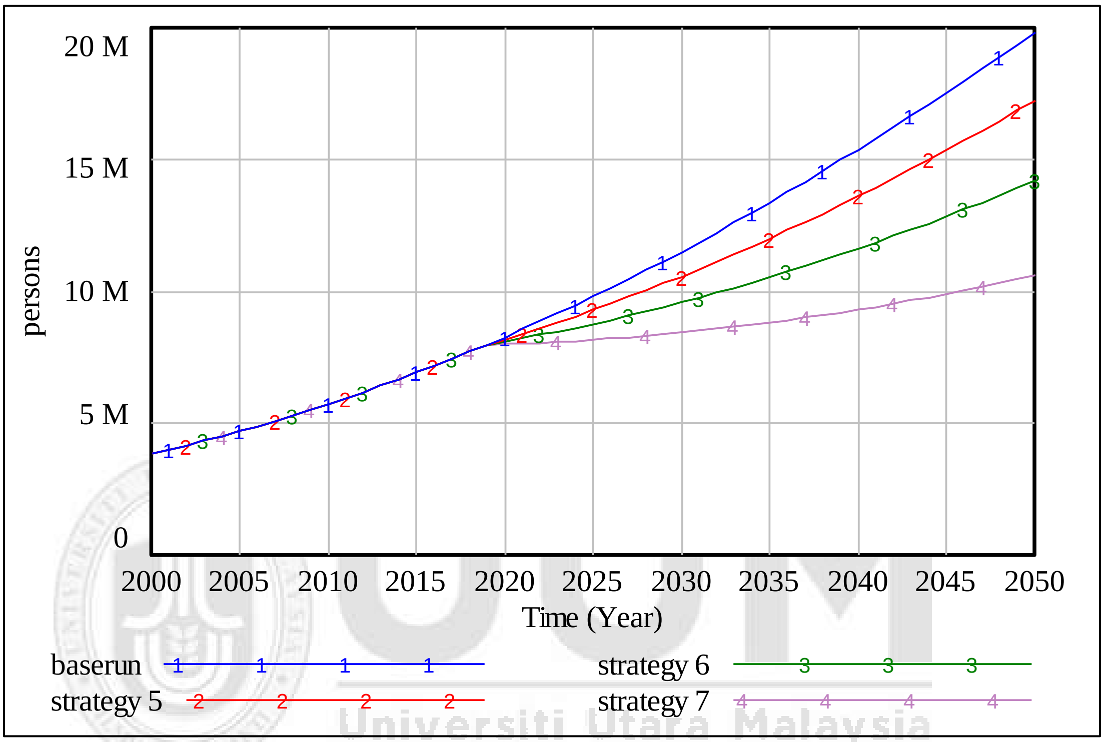


Figure 4.21 The behaviour trend of adult smokers for scenario 2.

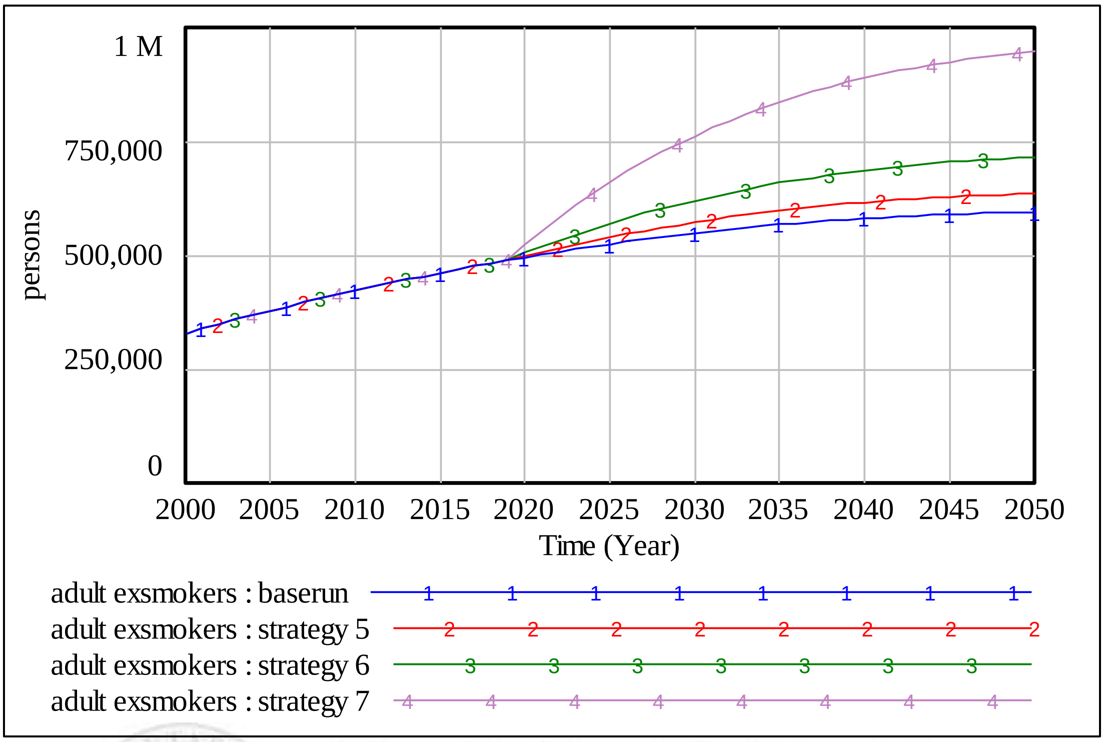


Figure 4.22 The behaviour trend of ex-smokers for scenario 2.

Also, by referring to the summary of all the output in scenario 2, as shown in Table 4.13, observation of the number of adult smokers and ex-smokers shows positive change, but the outcome is still implausible to achieve tobacco endgame. For instance, the smoking prevalence is 0.22 in 2000, increasing to 0.2764 in 2019 and is projected to be 0.3943 if strategy 5 is implemented, 0.3444 if strategy 6 is implemented, and 0.2939 in 2045 if strategy 7 is implemented. Among all the three strategies in scenario 2, strategy 7 generated the lowest values of smoking prevalence which is 0.2939. However, the lowest smoking prevalence obtained in strategy 5 is still far-fetched from the targetted value since the difference between base run (0.4483) and strategy 7 (0.2939) is only 0.1544 reduction in smoking prevalence. Theoretically, decreasing the tobacco industry’s promotion level can be accepted as one of the ways to reduce smoking prevalence. However, in reality, to enforce a sudden ban in promoting tobacco products is challenging.

Table 4.13

Results of EAHPSD model for Scenario 2

Variables	Simulation run	Time (t)			
		t = 2000	t = 2019	t = 2045	t = 2050
Smoking prevalence	Base run	0.22	0.2764	0.4483	0.5043
	Strategy 5			0.3943	0.4309
	Strategy 6			0.3444	0.3649
	Strategy 7			0.2939	0.3014
Adult smokers (persons)	Base run	3.84M	7.98M	17.53M	19.80M
	Strategy 5			15.34M	17.23M
	Strategy 6			12.84M	14.21M
	Strategy 7			9.91M	10.61M
Ex-smokers (persons)	Base run	328 929	488 901	589 457	593 673
	Strategy 5			628 329	634 869
	Strategy 6			704 349	715 152
	Strategy 7			924 599	946 065

Similar to scenario 1, although there is a moderate decreasing change to smoking prevalence trend and the value obtained is still implausible from the targetted value, the output of smoking prevalence, the number of adult smokers, and the number of ex-smokers shows a better result compared to scenario 1. Again, this indicates the correct solution direction to implement and strengthen the laws of education, communication, and public awareness in

Malaysia. The next scenario tested the circumstances where both parameter values are changed.

iii. Scenario 3: Combination

In scenario 3, both parameter values of *enforcement level imposed by the government* and *promotion level by the tobacco industry* were changed ranging from 0 to 1, with 0.25 increments in the *enforcement level imposed by the government* and from 1 to 0.25, with 0.25 decrements in the *promotion level by the tobacco industry*, respectively. The output for strategy 8, strategy 9, and strategy 10 are all presented in Figure 4.23. Note that from 2000 to 2018, the trend is similar to the base run as the changes were only made in 2019.

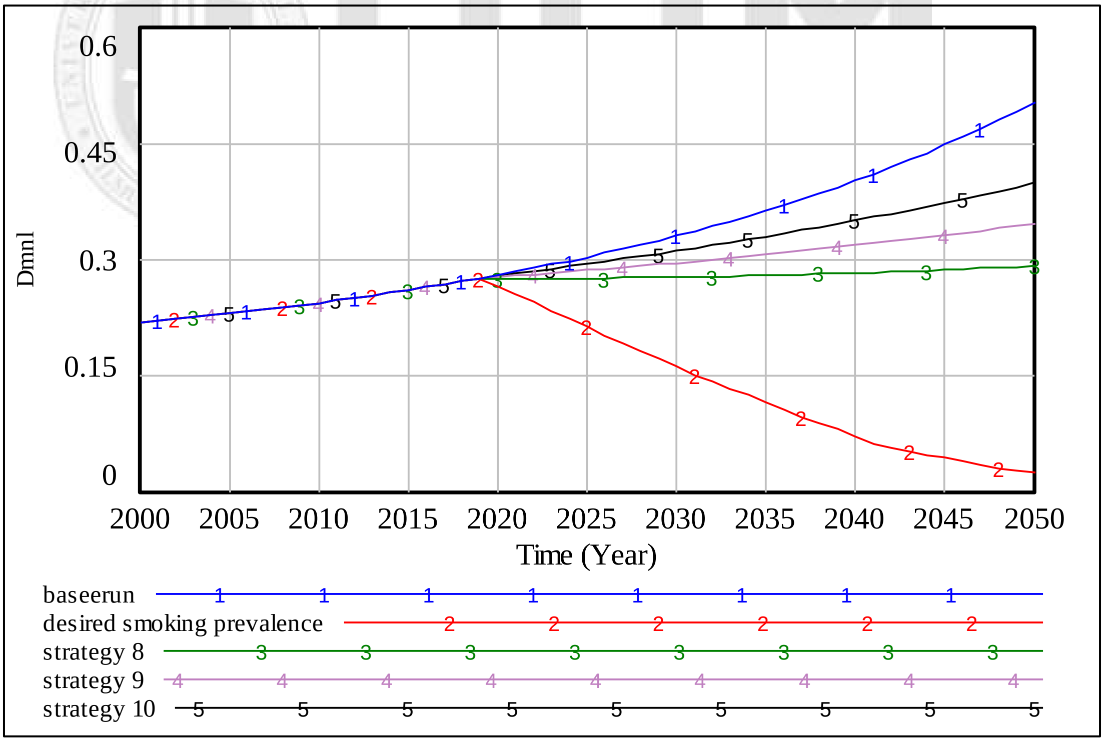


Figure 4.23 The behaviour trend of smoking prevalence for Scenario 3

Starting 2019, there is a clear decreasing trends of smoking prevalence if changes were made in both parameter values. Most notably, it can be illustrated in Figure 4.23 as both parameter values of *enforcement level imposed by the government* and *promotion level by the tobacco industry* were set at the value of 0.25, 0.50, and 0.75 in strategy 8, 9, and 10 respectively. Similarly, the cause of this can be sourced from the behaviour trends of the dominant factors of influencing smoking, which is the psychosocial influence, as shown in Figure 4.24.

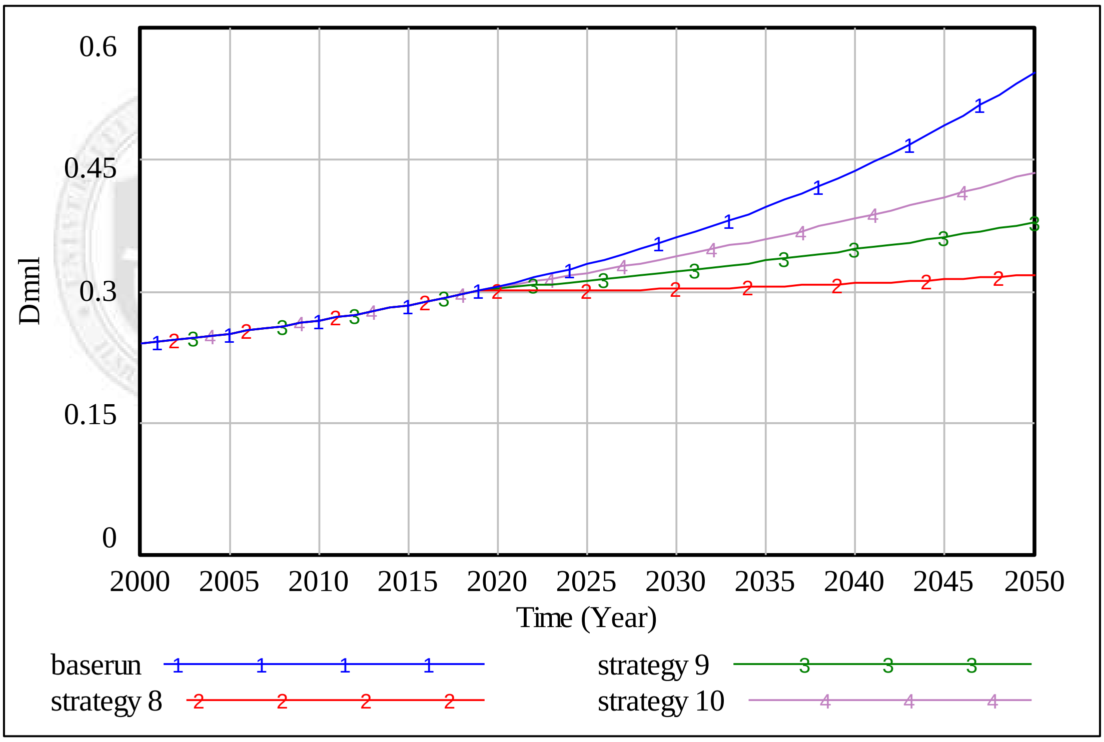


Figure 4.24 The behaviour trends of perceived psychosocial influence for scenario 3.

Referring to the observable trends in Figure 4.24, as both parameter values changed, it shows a considerable decrease in perceived psychosocial influence among Malaysians. Further, similar trends can also be observed from the number of adult smokers and the number of ex-smokers. Based on the variation in both parameter values, the behaviour trend in adult smokers decreases while the trend in ex-smokers increases, as shown in Figure 4.25 and Figure 4.26.

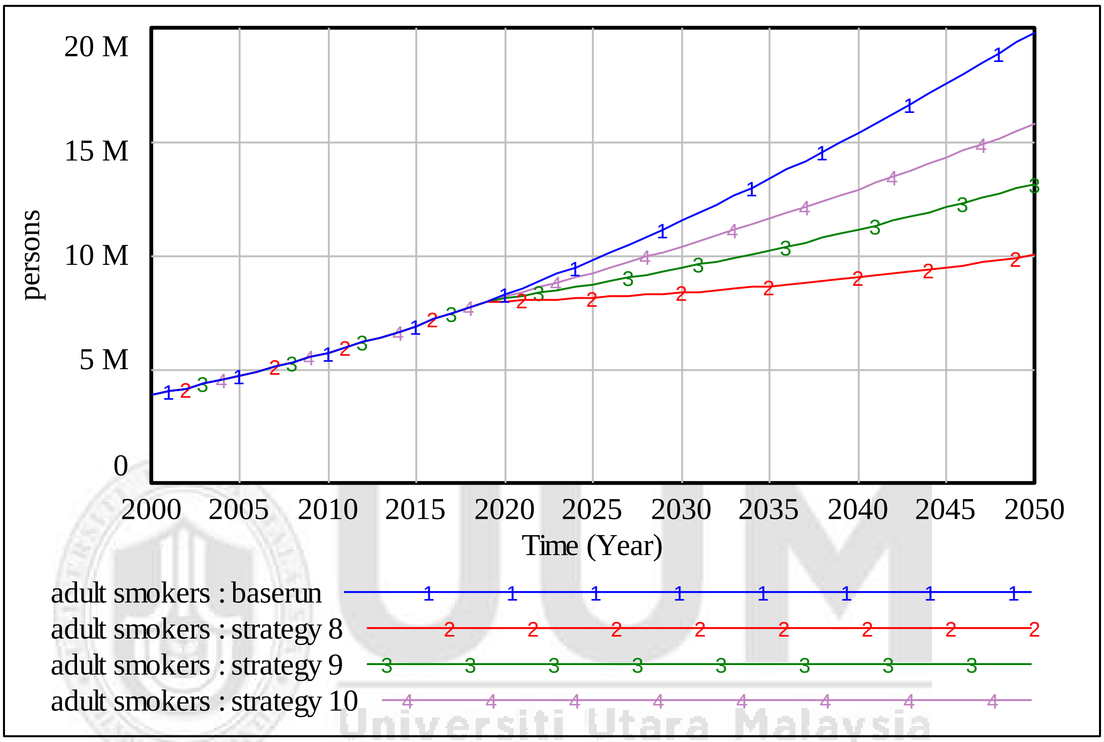


Figure 4.25 The behaviour trend of adult smokers for scenario 3.

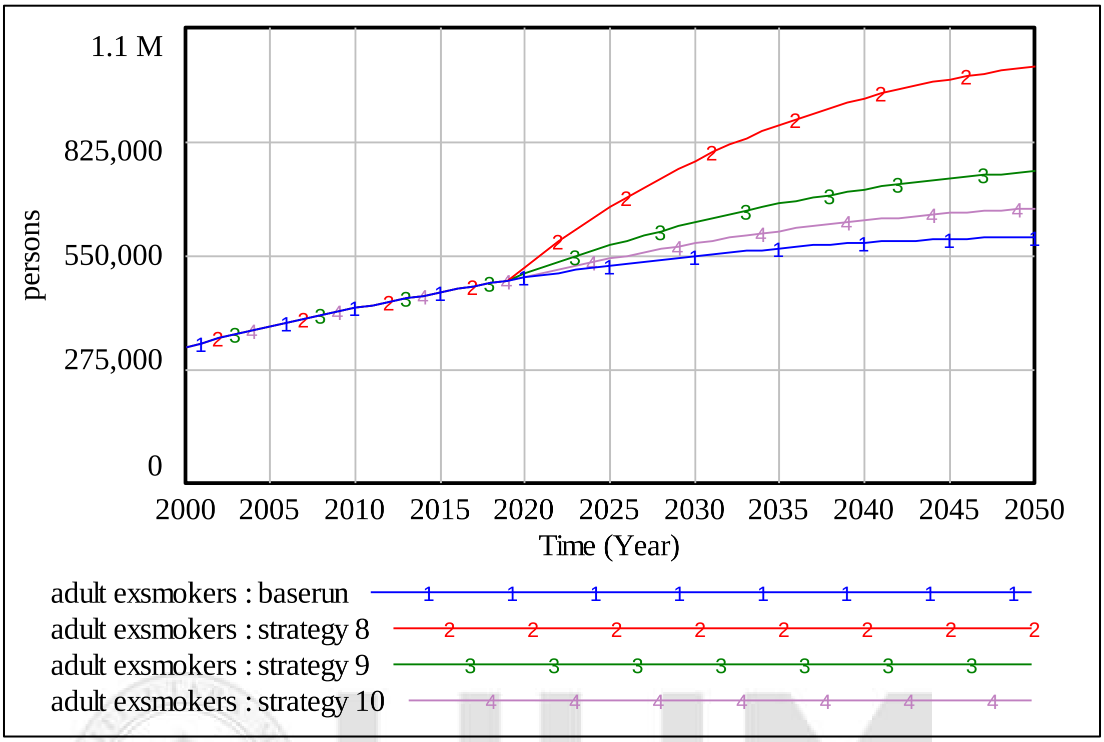


Figure *4.26* The behaviour trend of ex-smokers for scenario 3.

Subsequently, a description of the results of the EAHPSD model for scenario 3 based on a variation in the parameter values is summarised in Table 4.14. As shown in Table 4.14, the smoking prevalence is 0.22 in 2000, increasing slightly to 0.2764 in 2019 and is projected to be 0.2874 by the year 2045 if strategy 8 is implemented, 0.3321 if strategy 9 is implemented and 0.3740 if strategy 10 is implemented. Among all the three strategies in scenario 3, strategy 8 generated the lowest values of smoking prevalence, which is 0.2874. However, the lowest smoking prevalence value obtained in strategy 4 is still far-fetched from the targetted value since the smoking prevalence values difference between base run (0.4483) and strategy 8 (0.2874) is only 0.1609 reduction. Particularly, if compared to scenario 1 and scenario 2, scenario 3 reveals that by implementing both enforcements with the value of 0.25, a better result can be obtained in reducing smoking prevalence.

Table 4.14

Results of EAHPSD model for Scenario 3

Variables	Simulation run	Time (t)			
		t = 2000	**t = 2019**	**t = 2045**	**t = 2050**
Smoking prevalence	Base run	0.22	0.2764	0.4483	0.5043
	Strategy 8			0.2874	0.2924
	Strategy 9			0.3321	0.3468
	Strategy 10			0.3740	0.3995
Adult smokers (persons)	Base run	3.84M	7.98M	17.53M	19.80M
	Strategy 8			9.48M	10M
	Strategy 9			12.09M	13.15M
	Strategy 10			14.30M	15.76M
Ex-smokers (persons)	Base run	328 929	488 901	589 457	593 673
	Strategy 8			975 855	1.01M
	Strategy 9			734 728	751 816
	Strategy 10			651 467	663 449

Despite the visible positive change to smoking prevalence trends, adult smokers, and ex-smokers from scenario 3, the value obtained is still implausible from 0.05 as targetted by the government. On that account, the search for the right value of control variables can be done using EAHPSD optimisation in the following section.

4.3.3 The Output from EAHPSD Optimisation

In scenario 4, both the parameter *enforcement level imposed by the government* and *promotion level by the tobacco industry* were tested simultaneously by using optimisation to find the optimal values for both parameters to get the closest result to 0.05 as targetted by the government to achieve tobacco endgame. The results of the optimised values for the two chosen control variables, which are *enforcement level imposed by the government* and *promotion level by the tobacco industry*, are represented as strategy 11 in Figure 4.27. In this scenario, the ranges for each control variable were defined based on strategy 8 in scenario 3, which is 0 to 0.25.

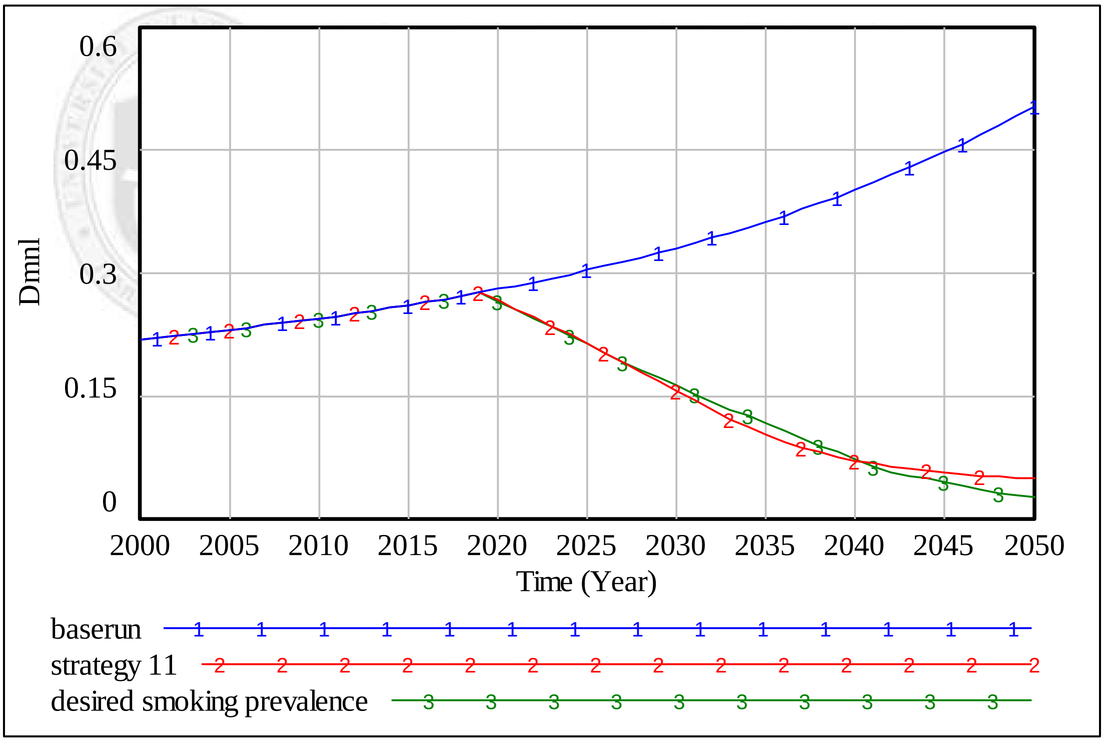


Figure 4.27 The behaviour trend of smoking prevalence for Scenario 4

In reference to Figure 4.27, it should be mentioned that, by using optimisation in strategy 11, the smoking prevalence trend shows a significant decrease from the base run towards the desired smoking prevalence value of achieving a smoking prevalence value less than 0.05. The cause of this can be traced to the rapid changes in the dominant factors of influencing smoking which is the psychosocial influence shown in Figure 4.28.

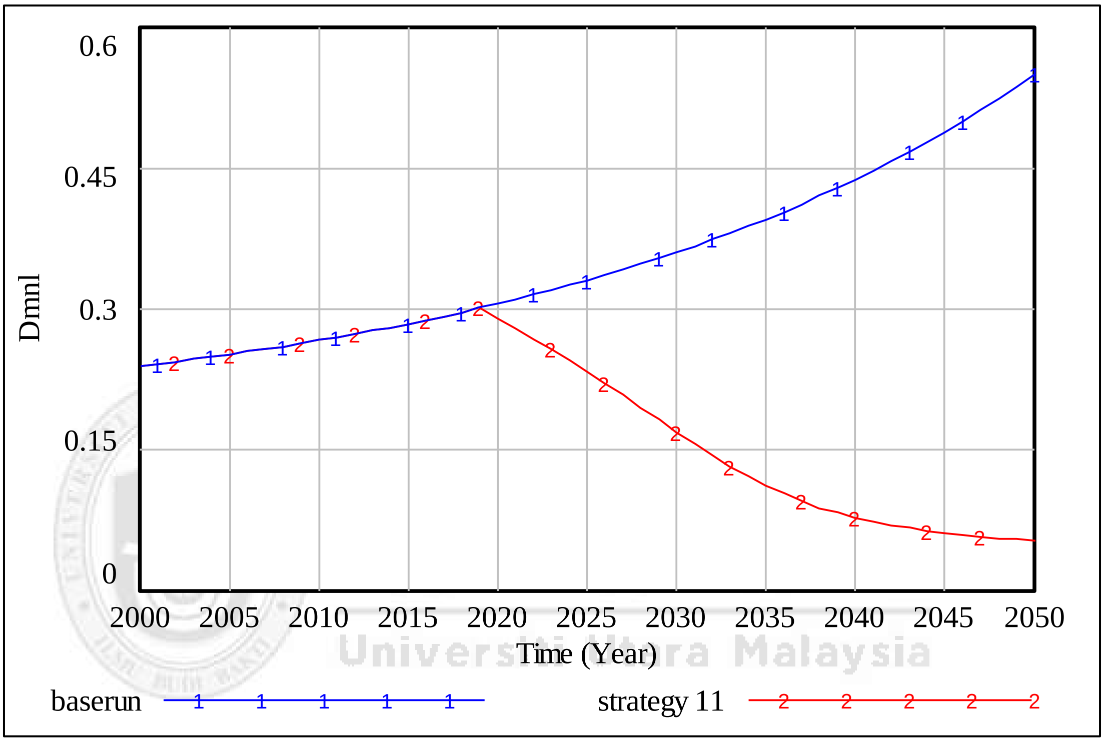


Figure 4.28 The behaviour trends of perceived psychosocial influence for scenario 4.

Referring to the significant observable trends in Figure 4.28, as both parameter values are optimised, it shows a very steady decrease in smoking prevalence trends as well as in perceived psychosocial influence among Malaysians. This is due to the sufficient level of enforcement imposed, and a realistic level of promotion by the tobacco industry permitted to overcome smoking habit in reducing smoking prevalence. Further, similar trends can also be observed from the number of adult smokers and the number of ex-smokers. Based on the variation in the parameter values, the behaviour trend in adult smokers shows positive results with decreasing behaviour trends while ex-smokers did pose a sharp increase, as shown in Figure 4.29 and Figure 4.30.

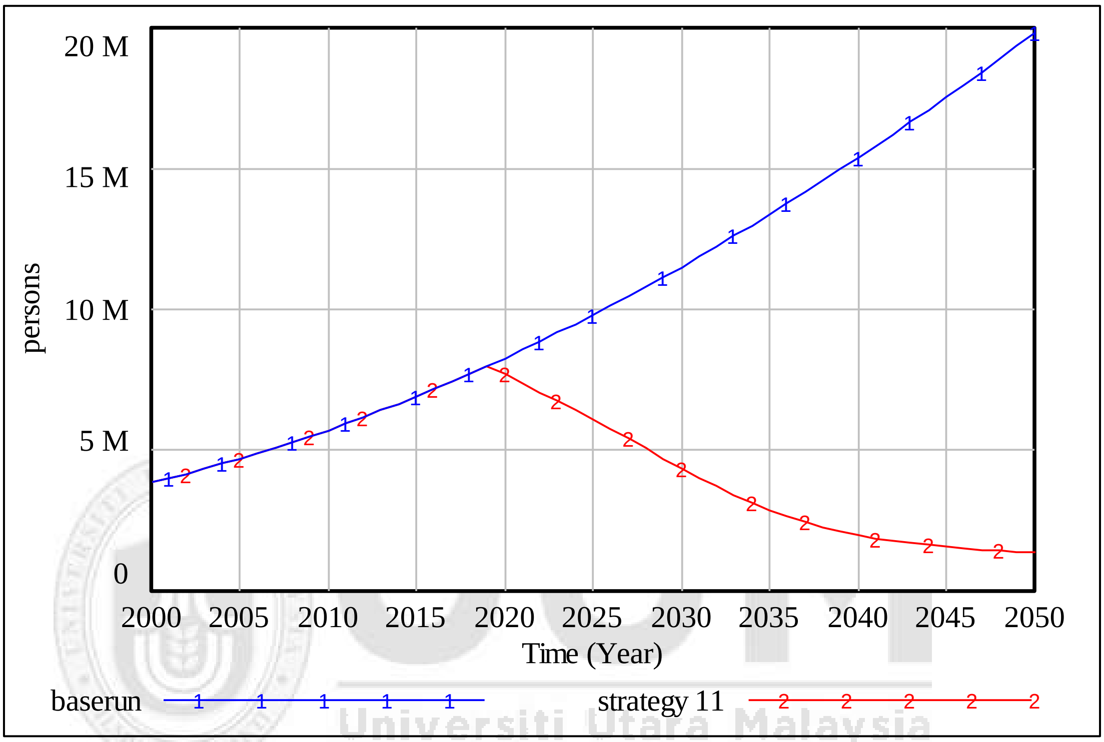


Figure 4.29 The behaviour trend of adult smokers for Scenario 4

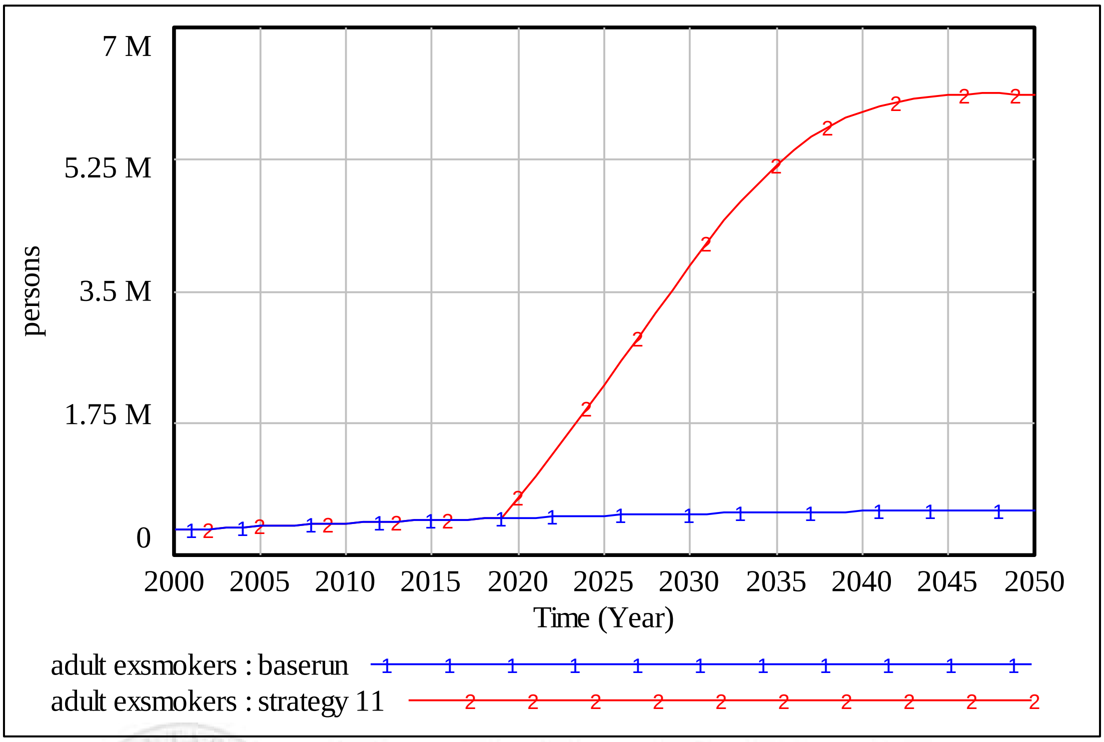


Figure 4.30 The behaviour trend of ex- smokers for Scenario 4

Subsequently, a description of the results of the EAHPSD model for scenario 4 using optimisation is summarised in Table 4.15. From the results, the smoking prevalence is 0.22 in 2000, increasing to 0.2764 in 2019 and is projected to be 0.0567 in 2045, if strategy 11 is implemented. This indicates that the smoking prevalence difference between base run (0.4483) and strategy 11 (0.0567) is 0.3916 reduction in smoking prevalence, and 0.0067 deviates from target tobacco endgame, which is 0.05. Further, the smoking prevalence value's implication can be reflected in the number of current smokers (1.57M) and ex-smokers (6.1M) by the year 2045. Additionally, the most interesting result to emerge from the simulation is that the endgame of tobacco can be achieved by the year 2050, with smoking prevalence 0.0492. The log file for the EAHPSD optimisation run is shown in Appendix F.

Table 4.15

Results of optimised values

Variables	**Initial value**	**Optimised value**	**Smoking prevalence**		**Adult smokers (persons)**		**Ex-smokers (persons)**	
			t = 2045	**t = 2050**	**t = 2045**	**t = 2050**	**t = 2045**	**t = 2050**
Enforcement level imposed by the government	0	0.2396	0.0567	0.0492	1.57M	1.38M	6.10M	6.11M
Promotion level by the tobacco industry	1	0.0312						

4.3.4 Comparison of Results

In this section, results from the analysis from the base run, EAHPSD sensitivity analysis series, and EAHPSD optimisation approaches were compared and presented in Table 4.16. Based on scenario 1, scenario 2, scenario 3, and scenario 4, it was found that the lowest smoking prevalence towards 2045 is generated by strategy 11 from scenario 4 with 87.352% deviation percentage (DP_{11}) by the year 2045. Referring to Table 4.16, if the government increases the enforcement level by 0.25 and decrease the promotion level by industry is monitored to be at 0.0317, smoking prevalence can be reduced to 0.0567 by the year 2045 and 0.049 by the year 2050. Even though the result deviates from the government's target, which is 0.05, the deviation is relatively small and the result shows positive changes towards achieving the endgame of tobacco compared from the base run which is 0.4483. Consequently, scenario 4 appears as the best-so-far scenario compared to other strategies. Thus, the fourth objective has been achieved. Subsequently, the best-so-far scenario for policy improvement is further discussed in the following section.

Table 4.16
Compilation of simulation results

Simulation run			**Smoking prevalence at t = 2045**	**Deviation percentage (DP) of smoking prevalence from base run at t = 2045**
EAHPSD base run model			0.4483	-
EAHPSD model - sensitivity analysis	Scenario 1	Strategy 1	0.4404	1.762%
		Strategy 2	0.4327	3.480%
		Strategy 3	0.4251	5.175%
		Strategy 4	0.4177	6.826%
		Strategy 5	0.3943	12.046%
	Scenario 2	Strategy 6	0.3444	23.176%
		Strategy 7	0.2939	34.441%
		Strategy 8	0.2874	35.891%
	Scenario 3	Strategy 9	0.3321	25.920%
		Strategy 10	0.3740	16.574%
EAHPSD model – optimisation	Scenario 4	Strategy 11	0.0567	87.352%

4.4 The Best-so-far Scenario Towards Achieving Tobacco Endgame

Based on the simulation analysis, the highest deviation percentage of smoking prevalence from each scenario is shown in Figure 4.31 and Table 4.17 below.

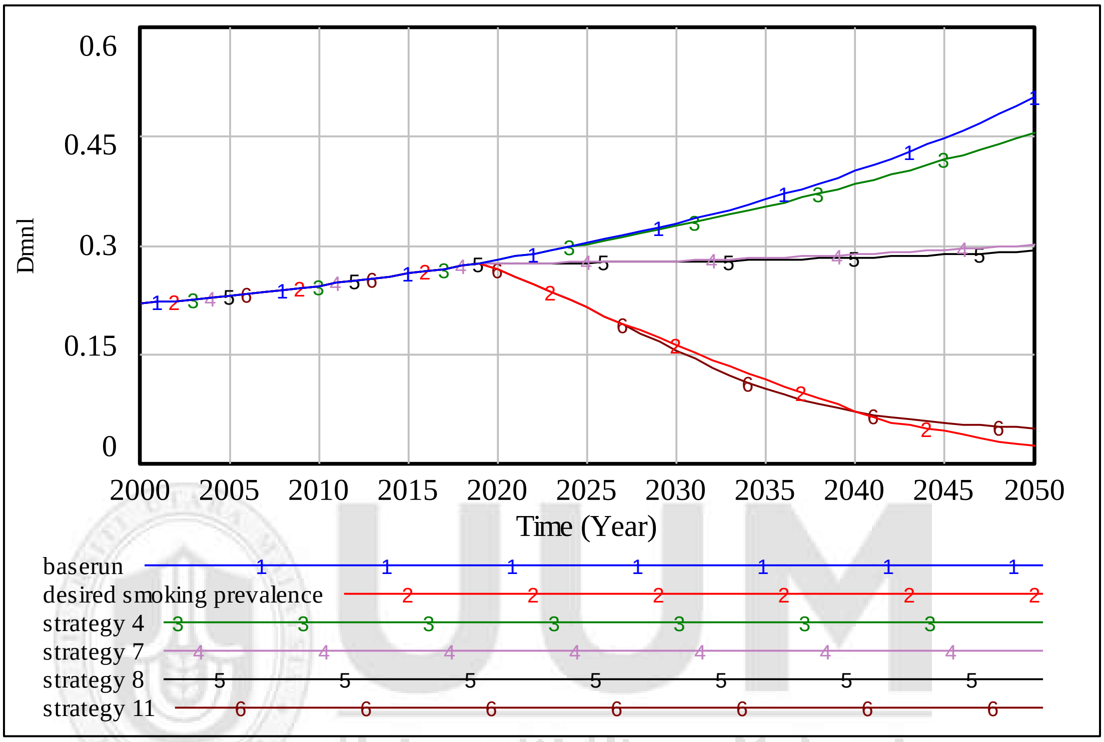


Figure 4.31 The highest deviation percentage of smoking prevalence from each scenario

Table 4.17

The best-so-far scenario from each scenario

Scenario	**Intervention strategy**	**Smoking prevalence at t=2045**	**The highest deviation percentage of smoking prevalence**	**Deviation from the desired smoking prevalence**
Scenario 1	Strategy 4	0.4177	6.826%	0.3677
Scenario 2	Strategy 7	0.2939	34.441%	0.2439
Scenario 3	Strategy 8	0.2874	35.891%	0.2374
Scenario 4	Strategy 11	0.0567	87.352%	0.0067

Referring to Table 4.17 as elaborated in Section 4.8, the deviation percentage is measured through Equation (3.61) as suggested in work by Ahmarofi (2019). As a result, the highest deviation percentage, DP_{11} was recorded through scenario 4 (in strategy 11) which was 87.352% since increasing enforcement level imposed by the government to 0.25 and decreasing promotion level by the tobacco industry to 0.0311 could contribute 1.57M persons of current adult smokers as compared to 17.53M persons from the base run. Surprisingly, the results show that full implementation of education, communication, and public awareness program and full promotion by the tobacco industry as simulated in scenario 1 through strategy 4 could contribute to 16.23M persons of current smokers and only 608 968 persons of ex-smokers as compared to the combination of both implementations, which could reduce only 6.826% deviation percentage from the base run.

Similarly, the highest deviation percentage recorded by strategy 7 is 34.441% by solely reducing the promotion level by the tobacco industry to 0.75 since 9.91M persons of current smokers, and 924 599 persons of ex-smokers were obtained as compared to the base run. Subsequently, the highest deviation percentage recorded by strategy 8 is 35.891% since increasing the enforcement level and reducing promotion level simultaneously to 0.25 could obtain 9.48M of current smokers, and 975 855 of ex-smokers as compared to the base run.

Based on the best-so-far scenario, changes in both the enforcement level imposed by the government and promotion level by the tobacco industry, as shown in strategy 11, could be suggested to the policymakers. From the four-scenario carried out in the model, the finding discovered that a combination of both changes (strategy 11) is a satisfactory way to reduce smoking prevalence, providing the closest solution to the desired smoking prevalence value less than 0.05 by 2045. In addition, by implementing strategy 11, tobacco endgame is expected to achieve by the year 2050 with smoking prevalence 0.0492, 1.38M and 6.11M persons of adult smokers and ex-smokers, respectively.

4.5 Discussions

As discussed in Chapter 2, the need for a dynamic model to simulate the impact of anti-smoking strategies to achieve tobacco endgame was highlighted. Particularly in tobacco epidemic, reviews of past studies mostly focus on the simulating the impact of anti-smoking strategies with less emphasizing in the root of the problem which is the initiation factors of smoking as in Ahmad (2005), Cavana and Tobias (2007), Levy et al. (2010), Richardson (2007), and Roberts et al. (1982). It is admitted that past studies had successfully modelled the tobacco epidemic and understand the feedback process as well as the underlying mechanism in the system. However, the analysis mostly did not include the driving forces of the problem to reduce smoking prevalence to achieve the endgame. Furthermore, to the best of our knowledge, it is found that there was no study explored the factors influencing smoking and anti-smoking strategies in a single study. This is believed due to the qualitative nature of factors influencing smoking. Thus, it is difficult to determine the parameter values. Hence, prioritisation is applied to determine the parameter values.

In this study, the integrated EAHPSD model was found to be capable of modelling the tobacco epidemic and including the initiation factors of smoking. The simulation was initially done to understand the impact of anti-smoking strategy with the inclusion of its driving forces of the problem. In the development of the EAHPSD model, the most influential factors of smoking and anti-smoking strategies are obtained through the Enhanced Analytic Hierarchy Process (EAHP) method, as presented in Section 4.1. The ranks and the weight values obtained help the researcher to determines the best anti-smoking strategy to be implemented and the level of importance for influential factors of smoking and anti-smoking strategy. In addition, the EAHP also helps the SD model by serving parameter values for smoking factors in order to capture qualitative variables.

From the simulation analysis, the output from the developed EAHPSD model highlighted that psychosocial influence emerged as the most influential factor in the smoking habit, while personal beliefs and values appear to be the least influential factors of smoking. These findings are aligned with the findings by Arnett (2007), Bauman and Ennett (1996), Khan et al. (2018), Kobus (2003), Lim et al. (2020), Poulin et al. (2011), Scalici and Schulz (2017), and the U.S. Department of Health and Human Services (2012). Due to its dominance effect, further action or strategies proposed by the government involving psychosocial aspects should be given more attention.

Next, turning to the anti-smoking strategies, it is found that education, communication, and public awareness are the most impactful anti-smoking strategies to be implemented in Malaysia. However, by considering the fact there has been a continuous struggle between those committed to tobacco market shrinkage and those committed to tobacco market expansion, the combination impact of education, communication, and public awareness in reducing smoking prevalence, and promotion level by tobacco industry is evaluated. From the model evaluation, the highest deviation percentage of smoking prevalence is recorded by the combination of changes in enforcement level by the government and promotion level by the tobacco industry in strategy 11. The finding is in line with Mendez's (2013) study, where public awareness program contributes the most robust anti-smoking strategy in reducing smoking prevalence. The findings of the public awareness program as the best-so-far scenario on reducing smoking prevalence are also supported by Levy (2014), which emphasised that creating public awareness through social media could effectively reduce smoking prevalence.

Thus far, the integrated EAHPSD model has proven its capability to integrate prioritisation and simulation in evaluating the impact of anti-smoking strategy for reducing smoking prevalence. The results also revealed that the combination of increased enforcement level and decreased promotion level by tobacco industry is the best way to reduce the smoking prevalence, providing the closest solution to the desired smoking prevalence target, which is 0.057 by the year 2045. Despite the desired target is unachievable by 2045, the results from the run of EAHPSD optimisation suggested that the government's target can be achieved in 2050, with smoking prevalence of 0.049. Importantly, the findings allow policymakers to target specific high-risk target groups that are focusing on limiting psychosocial exposure when designing smoking prevention programs.

4.6 Summary

In summary, the model has been structural and behavioural validated, as explained. With the model being validated, a sufficient level of confidence has been instilled in the model. Therefore, the base run and simulation analysis from various scenario setting have been conducted. The simulation analysis discovered that the EAHPSD model provides information on future planning towards tobacco endgame in Malaysia. The results show that the closest solution to the desired target smoking prevalence is by combining the implementation of increasing enforcement on tobacco control and reducing promotion level by the tobacco industry.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

This chapter presents the conclusion of the research. In Section 5.1, the summary of the research is presented. Next, the contributions of the research is presented in Section 5.2. It continues by presenting the limitations of the research in Section 5.3. Finally, the recommendations for future work concludes the chapter.

5.1 Summary of the Integrated EAHPSD Model

The tobacco epidemic had been a constant threat to public health worldwide, including Malaysia. The notable consequences of tobacco use are the increasing trend of smoking prevalence and tobacco-related morbidity and mortality. For these reasons, the World Health Organisation (WHO) through Framework Convention on Tobacco Control (FCTC) targets the smoking prevalence value to be less than 0.05 for Malaysia to achieve the tobacco endgame by 2045. Therefore, finding a suitable approach to control tobacco use is highly needed.

This research highlights the development of the integrated Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) model to evaluate the impact of anti-smoking strategies on reducing smoking prevalence in Malaysia. In controlling tobacco use, factors influencing smoking and anti-smoking strategies are the critical components as they act as the driving forces and the correctors of the problem. Therefore, it is essential to conduct a study to help policymakers gain insights and understand the impact of anti-smoking strategies on achieving tobacco endgame.

The research aims to evaluate the anti-smoking strategies towards achieving tobacco endgame in Malaysia. Furthermore, this research successfully achieved five specific objectives in order to fulfil the main objective. The first objective of this research is to identify the factors influencing smoking habit. The factors are personal beliefs and values, personal physiological, family influence, psychosocial influence, cultural influence, and legislative influence, adopted from the Theory of Triadic Influence (TTI) (Flay et al., 1995). This objective has been achieved through literature review and discussion with tobacco experts. The identification of factors also including published reports from the World Health Organisation (WHO) and the Ministry of Health (MOH) Malaysia.

The second objective is to determine the weights of the contributing factors while the third objective is to prioritise the anti-smoking strategies. The EAHP technique was used to fulfill these objectives. In Malaysia, anti-smoking strategies that have been implemented are packaging and labelling tobacco products, pricing and taxation, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education, communication, and public awareness. In order to achieve these two objectives, the tobacco experts from WHO FCTC evaluate the importance of anti-smoking strategies of packaging and labelling tobacco products, pricing and taxation, tobacco advertising, promotion, and sponsorship, smoke-free legislation, and education, communication, and public awareness and weighting the factors influencing smoking of personal beliefs and values, personal physiological, family influence, psychosocial influence, cultural influence, and legislative influence. Based on the prioritisation output, the psychosocial influence was the most influencing smoking factor, while education, communication, and public awareness were the most suitable anti-smoking strategies for reducing smoking prevalence in Malaysia.

The fourth objective is to simulate the tobacco control system to examine the effects of education, communication, and public awareness in reducing smoking prevalence. In this instance, the dynamic complexity and feedback process involved in the tobacco control system is simulated to examine the effects of anti-smoking strategy over time. This objective was achieved through the development of the integration of Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) model. A conceptual model was produced using a causal loop diagram (CLD) that captures the main component of the tobacco control system, their interrelationships, and underlying feedback processes. Based on the CLD, the next stage is the development of stock and flow model was constructed to quantify these interrelationships in the form of stock and flow. The stock and flow model consist of three sectors: population, factors influencing smoking and education, communication, and public awareness. The final model has passed six validation tests, which include boundary adequacy, structure and parameter test, dimensional consistency test, behaviour reproduction test, and extreme condition test. Next, a base run and four simulation setting run had been conducted

The fifth objective is to evaluate the integrated EAHPSD model in order to achieve the minimum value of smoking prevalence by the year 2045. The evaluation is done by comparing the output of the simulation runs. It is highlighted that scenario 4 was proven to give the minimum value of smoking prevalence of 0.095 compared to the other simulation runs. The result shows that the implementation of education, communication, and public awareness strategy by increasing 0.2017% from the current implementation and reducing promotion level by the tobacco industry by 0.0317% from the current implementation demonstrates the most significant reduction in smoking prevalence which is 0.095 in 2045. This value is the closest to achieving the desired smoking prevalence target of 0.05 by the year 2045.

5.2 Contributions of the Research

This research's contributions can be classified into two main aspects: (i) contribution to the body of knowledge, and (ii) contribution to managerial. The explanation for each aspect is discussed in Section 5.2.1 and Section 5.2.2.

5.2.1 Contributions to the Body of Knowledge

One notable contribution of this research is to expand the decision science literature, particularly related to simulation techniques, with the notion of synergies among Enhanced Analytic Hierarchy Process (EAHP) and System Dynamics (SD) as an improved decision-making tool to model the tobacco epidemic. Specifically, the main contribution of this research is the development of an improved version of the tobacco-SD model as developed in the studies by Ahmad (2005), Cavana and Tobias (2007), Levy et al., (2010), Richardson (2007), Roberts et al., (1982) and Zagonel et al., (2011). Previously, the inclusion of influential factors is omitted and not discussed in detail. This study can be considered a continuation of previous studies with the addition of a multi-criteria decision-making technique to prioritise the causes and correctors of the problem using the integrated EAHPSD model. The integration of EAHP and SD in this study offers a prioritisation capability where the targetted approach in prioritising anti-smoking strategies and factors influencing smoking can be implemented to evaluate the impact of anti-smoking strategies on reducing smoking prevalence. The targetted approach is in line with the fact that the factors influencing smoking and anti-smoking strategies are natural partners where factors influencing smoking are the causes of the problem, and anti-smoking strategies are the correctors of the problem. Hence, this study can add to a gradually growing trend of simulation studies on the tobacco epidemic, particularly in Malaysia.

Next, the output obtained from the prioritisation is presented in the form of ranks and weight values. The ranks and weight values are obtained from the analysis of EAHP, which is the transparent prioritisation formulation that offers consistency guaranteed. The output from the prioritisation is translated as an input in the development of stock and flow. Subsequently, the highest rank for anti-smoking strategies is selected as the policy to be tested during the model intervention. On the other hand, the highest rank for factors influencing smoking habit is selected as the element that should be emphasised in implementing anti-smoking strategy, compared to other influencing factors. These processes contribute more objective and strategic planning in decision making.

In addition, through the usage of the integrated EAHPSD model, this study has proposed the utilisation of weight values obtained in the prioritisation as the parameter values to be used in the development of the stock and flow model. The usage of weight values permeates the use of qualitative variables in the development of the SD model. In this study, the weight values for factors influencing smoking are translated as parameter values in the development of stock and flow since the nature of the factors under study are qualitative. The use of qualitative variables helps the modeller give precise judgement for evaluating the impact of anti-smoking strategies since both the quantitative and qualitative aspects have been captured in this study. To the best of researcher's knowledge, no studies have yet employed EAHP to provide parameter values for qualitative variables in tobacco-SD studies.

Another contribution is the various combination of parameters tested in policy evaluation to assess the best combination that gives the minimum value of smoking prevalence. Through this process, the modellers can foresee the future scenario of the tobacco system while implementing the education, communication, and public awareness that focuses on psychosocial influence in the community.

5.2.2 Contributions to the Managerial Aspect

The Enhanced Analytic Hierarchy Process and System Dynamics (EAHPSD) integrated model could be potentially utilised by policymakers and practitioners in the Ministry of Health (MOH) and World Health Organisation (WHO) to serve as planning tools, designed to foresee the future scenario for reducing smoking prevalence. The developed model acts as a decision support system, allowing authorities to make an informed decision by providing insights and visualisation on the interrelationships and feedback process in controlling tobacco use. Importantly, the developed model is useful input to the policy-making process. This research will improve policymakers' and practitioners' understanding of the causes that are influencing people to smoke. Therefore, these research findings will highlight to the policymakers and practitioners that results obtained from this research can be used effectively to help in designing more effective intervention strategies.

In addition, this research introduces a structured policy design framework applicable to the tobacco control context. This framework offers a platform to evaluate, experiment, and design a new policy with zero-risk where the actual system is not interrupted, and cost-consequences can be avoided. Furthermore, with appropriate modification this research design can be generalised for assessing the intervention strategy in other substance use problems, such as e-cigarettes, drugs, and alcohol.

5.3 Research Limitations

Although the research has achieved all five objectives, some unavoidable limitations will be discussed as follows:

i) This research only focuses on cigarette smoking. However, other types of tobacco, such as e-cigarettes, chewing tobacco, cigars, and smokeless tobacco, should be included to understand their role in reducing overall tobacco use.

ii) In conducting this research, data sources are one of the limitations have been experienced. The access to related information is limited due to lack of historical national data, especially on tobacco. Therefore, the development of EAHPSD model is derived from the best information available from the Ministry of Health (MOH), the World Health Organisation's published reports, literature and tobacco experts.

5.4 Recommendations for Future Work

There are several opportunities to expand in this research, as follows:

i) To develop a holistic tobacco control system that includes e-cigarettes, cigars, and smokeless tobacco. Other tobacco products should be regulated in such a way as to reduce smoking tobacco products to the greatest extent possible.

ii) The present research could be extended to include other sub-factors of influencing smoking habits in the model to expand the understanding of the dynamic of the Theory of Triadic Influence.

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Journal (Peer-reviewed)

1) Halim, T. F. A., Sapiri, H., & Abidin, N. Z. (2017). Development of dynamic hypothesis framework of tobacco control model for first hand smokers. *Advanced Science Letters*, *23*(6), 5430–5433.
2) Halim, T. F. A., Sapiri, H., & Abidin, N. Z. (2018). A framework for prioritizing the effectiveness of anti-smoking strategies using enhanced analytic hierarchy process. *ESTEEM Academic Journal*, 14, 53–60.

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Appendix A

Letter of Authorisation from the NMRR

JAWATANKUASA ETIKA & PENYELIDIKAN PERUBATAN
(Medical Research & Ethics Committee)
KEMENTERIAN KESIHATAN MALAYSIA
d/a Institut Pengurusan Kesihatan
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Ruj. Kami : (5)KKM/NIHSEC/P16-564
Tarikh : 15hb April 2016

DR HASIMAH BINTI SAPIRI
UNIVERSITI UTARA MALAYSIA (UUM)

TUAN/PUAN,

NMRR- 14-1916-22969 (IIR)
A Novel Integrated System Dynamics Tobacco Control Model for Preventing Smoking Prevalence and Smoking-attributable Mortality

Lokasi Kajian:
DEPARTMENT OF STATISTICS MALAYSIA
INSTITUTE FOR MEDICAL RESEARCH (IMR)
INSTITUTE FOR PUBLIC HEALTH (IPH)
MINISTRY OF HEALTH

Dengan hormatnya perkara di atas adalah dirujuk.

2. Jawatankuasa Etika & Penyelidikan Perubatan (JEPP), Kementerian Kesihatan Malaysia (KKM) tiada halangan, dari segi etika, ke atas pelaksanaan kajian tersebut. JEPP mengambil maklum bahawa kajian tersebut hanya melibatkan pengumpulan data melalui **borang kaji selidik dan temuramah** sahaja.

3. Segala rekod dan data subjek adalah **SULIT** dan hanya digunakan untuk tujuan kajian ini dan semua isu serta prosedur mengenai *data confidentiality* mesti dipatuhi.

4. Kebenaran daripada Pegawai Kesihatan Daerah/Pengarah Hospital dan Ketua-Ketua Jabatan atau pegawai yang bertanggungjawab disetiap lokasi kajian di mana kajian akan dijalankan mesti diperolehi sebelum kajian dijalankan. Dato'/Dr/ Tuan/ Puan perlu akur dan mematuhi keputusan tersebut. Sila rujuk kepada garis panduan Institut Kesihatan Negara mengenai penyelidikan di Institusi dan fasiliti Kementerian Kesihatan Malaysia (Pindaan 01/2015) serta lampiran *Appendix 5* untuk templet surat memohon kebenaran tersebut.

5. Adalah dimaklumkan bahawa kelulusan ini adalah sah sehingga **14hb April 2017**.Dato'/Dr./ Tuan/ Puan perlu menghantar perkara-perkara berikut kepada JEPP selepas mengikut kesesuaian. Borang-borang berkaitan boleh dimuat turun daripada laman web MREC (http://www.nih.gov.my/mrec).

I. Borang ***Continuing Review Form*** perlu dihantar ke JEPP selewat-lewatnya 2 bulan sebelum tamat tempoh kelulusan ini bagi memperbaharui kelulusan etika.

II. ***Study Final Report*** perlu dihantar ke JEPP pada penghujung kajian.
III. Mendapat kelulusan etika sekiranya terdapat pindaan ke atas sebarang dokumen kajian/ lokasi kajian/ penyelidik.

6. Sila ambil maklum bahawa sebarang urusan surat-menyurat berkaitan dengan penyelidikan ini haruslah dinyatakan nombor rujukan surat ini untuk melicinkan urusan yang berkaitan.

Sekian terima kasih.

BERKHIDMAT UNTUK NEGARA

Saya yang menurut perintah,

....

(DATO' DR. CHANG KIAN MENG)
Pengerusi
Jawatankuasa Etika & Penyelidikan Perubatan
Kementerian Kesihatan Malaysia

Appendix B

Questionnaire for Enhanced Analytic Hierarchy Process

QUESTIONNAIRE SURVEY:

MULTI-CRITERIA ANALYSIS FOR EVALUATING THE IMPACT OF ANTI-SMOKING STRATEGIES

School of Quantitative Sciences

Dear Participant,

We are currently undertaking a research project into evaluating the impact of anti-smoking strategies towards reducing smoking prevalence in Malaysia.

As part of this research, we are conducting a multi-criteria analysis using Enhanced Analytic Hierarchy Process (EAHP) in order to prioritize the anti-smoking strategies as well as the factors influencing smoking habit in Malaysia.

Smoking is a complex problem. The complexity is due to its dynamic nature involving multi-disciplinary interrelated components. The driving forces of the smoking problem is the factors influencing smoking habit such as personal, social and environmental factors. Therefore, making decisions on the most impactful anti-smoking strategies is deemed important towards an endgame of tobacco by the year 2045 as outlined by the government.

Mindful of this, the purpose of this study is to identify the most influential factors of smoking and the most impactful anti-smoking strategies which could reduce the prevalence of smoking towards 2045.

In the following pages we would like to obtain your opinion as an expert through a survey questionnaire, in which you are requested to prioritize the six influential factors of smoking and five anti-smoking strategies with respect to the overall goal.

The information you provide will be of great value for this research, and accordingly, your participation is anticipated and very much appreciated.

We sincerely hope you can assist.

Tisya Farida Abdul Halim

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QUESTIONNAIRE SURVEY:

MULTI-CRITERIA ANALYSIS FOR EVALUATING THE IMPACT OF ANTI-SMOKING STRATEGIES

School of Quantitative Sciences

Introduction

Through a survey questionnaire, we intend to evaluate six influential factors of smoking and five anti-smoking strategies by obtaining the opinions of experts. For a multi-criteria analysis, Enhanced Analytic Hierarchy Process (EAHP) is employed. The EAHP is a method designed to help in prioritizing complex decision alternatives involving multiple criteria.

By using the questionnaire, the participants identify the level of impact with respect to criteria and goal as presented below in Figure 1.

The first level of hierarchy is the ultimate goal; the second level represents the influential factors of smoking to be evaluated. Finally, the third level presents the anti-smoking strategies.

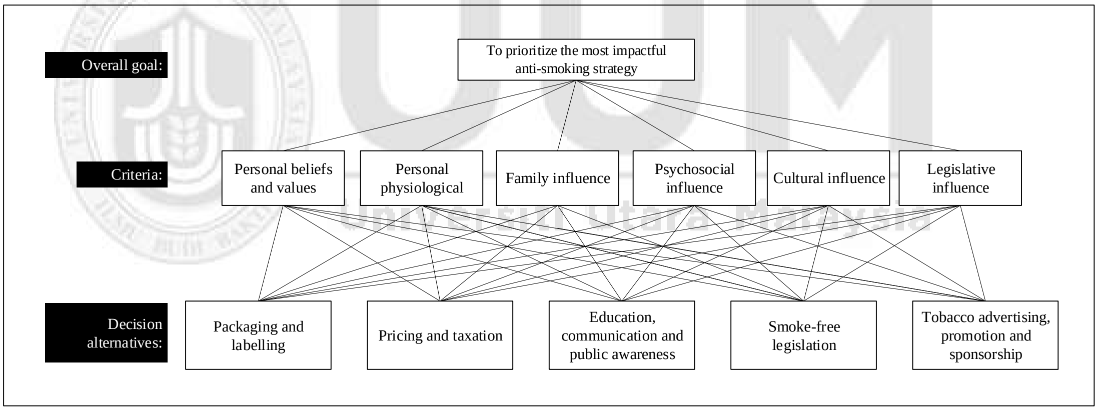

Figure 1 Hierarchical representation of tobacco epidemic

Goal: To select the most impactful anti-smoking strategy

Criteria: Six criteria were chosen in the EAHP evaluation. There are:

1. **Personal beliefs and values**
2. **Personal physiological**
3. **Family influence**
4. **Psychosocial influence**
5. **Cultural influence**
6. **Legislative influence**

Alternatives: Five anti-smoking strategies were identified. There are:

1. **Packaging and labelling**
2. **Pricing and taxation**
3. **Education, communication, and public awareness**
4. **Smoke-free legislation**
5. **Tobacco advertising, promotion, and sponsorship**

The respondent is requested to kindly give rating from 1-9 based on the importance of the criteria being considered. The judgements for the rating are as given below:

***Preference Level**	**Numeric Value**
Equally preferred	1
Equally to moderately preferred	2
Moderately preferred	3
Moderately to strongly preferred	4
Strongly preferred	5
Strongly to very strongly preferred	6
Very strongly preferred	7
Very strongly to extremely preferred	8
Extremely preferred	9

*Preference level can also be replaced by importance level, significance level, or any other appropriate levels.

QUESTIONNAIRE SURVEY:

MULTI-CRITERIA ANALYSIS FOR EVALUATING THE IMPACT OF ANTI-SMOKING STRATEGIES

School of Quantitative Sciences

In the following sheets, we would like to elicit your opinion in order to select amongst the alternatives with respect to several criteria. The pairwise comparison scale is used to express the importance of one element over another.

Level 1: Influential factors of smoking (criteria)

For each criterion below, please rate the level of its influence that contributes to smoking habits among adults (above 15 years old) in Malaysia, by **circling or ticking** the appropriate number.
(Hint: 1= No influence at all, 9 = extremely influence)

Criteria	Level of influence								
1. Personal beliefs and values	1	2	3	4	5	6	7	8	9
2. Personal physiological	1	2	3	4	5	6	7	8	9
3. Family influence	1	2	3	4	5	6	7	8	9
4. Psychosocial influence	1	2	3	4	5	6	7	8	9
5. Cultural influence	1	2	3	4	5	6	7	8	9
6. Legislative influence	1	2	3	4	5	6	7	8	9

Level 2: Anti-smoking strategies (alternatives)

In order to cope with the "*personal beliefs and values*", which anti-smoking strategy is considered important to reduce smoking prevalence among adults (above 15 years old) in Malaysia? Please rate by **circling or ticking** the appropriate number.
(Hint: 1= Not important at all, 9 = extremely important)

Criteria	Level of importance								
1. Packaging and labelling	1	2	3	4	5	6	7	8	9
2. Pricing and taxation	1	2	3	4	5	6	7	8	9
3. Education, communication, and public awareness	1	2	3	4	5	6	7	8	9
4. Smoke-free legislation	1	2	3	4	5	6	7	8	9
5. Tobacco advertising, promotion, and sponsorship	1	2	3	4	5	6	7	8	9

In order to cope with the "*personal physiological*", which anti-smoking strategy is considered important to reduce smoking prevalence among adults (above 15 years old) in Malaysia? Please rate by **circling or ticking** the appropriate number.
(Hint: 1= Not important at all, 9 = extremely important)

Criteria	Level of importance								
1. Packaging and labelling	1	2	3	4	5	6	7	8	9
2. Pricing and taxation	1	2	3	4	5	6	7	8	9
3. Education, communication, and public awareness	1	2	3	4	5	6	7	8	9
4. Smoke-free legislation	1	2	3	4	5	6	7	8	9
5. Tobacco advertising, promotion, and sponsorship	1	2	3	4	5	6	7	8	9

In order to cope with the "*family influence*", which anti-smoking strategy is considered important to reduce smoking prevalence among adults (above 15 years old) in Malaysia? Please rate by **circling or ticking** the appropriate number.
(Hint: 1= Not important at all, 9 = extremely important)

Criteria		Level of importance								
1.	Packaging and labelling	1	2	3	4	5	6	7	8	9
2.	Pricing and taxation	1	2	3	4	5	6	7	8	9
3.	Education, communication, and public awareness	1	2	3	4	5	6	7	8	9
4.	Smoke-free legislation	1	2	3	4	5	6	7	8	9
5.	Tobacco advertising, promotion, and sponsorship	1	2	3	4	5	6	7	8	9

In order to cope with the "*psychosocial influence*", which anti-smoking strategy is considered important to reduce smoking prevalence among adults (above 15 years old) in Malaysia? Please rate by **circling or ticking** the appropriate number.
(Hint: 1= Not important at all, 9 = extremely important)

Criteria		Level of importance								
1.	Packaging and labelling	1	2	3	4	5	6	7	8	9
2.	Pricing and taxation	1	2	3	4	5	6	7	8	9
3.	Education, communication, and public awareness	1	2	3	4	5	6	7	8	9
4.	Smoke-free legislation	1	2	3	4	5	6	7	8	9
5.	Tobacco advertising, promotion, and sponsorship	1	2	3	4	5	6	7	8	9

In order to cope with the "*cultural influence*", which anti-smoking strategy is considered important to reduce smoking prevalence among adults (above 15 years old) in Malaysia? Please rate by **circling or ticking** the appropriate number.
(Hint: 1= Not important at all, 9 = extremely important)

Criteria		Level of importance								
1.	Packaging and labelling	1	2	3	4	5	6	7	8	9
2.	Pricing and taxation	1	2	3	4	5	6	7	8	9
3.	Education, communication, and public awareness	1	2	3	4	5	6	7	8	9
4.	Smoke-free legislation	1	2	3	4	5	6	7	8	9
5.	Tobacco advertising, promotion, and sponsorship	1	2	3	4	5	6	7	8	9

In order to cope with the "*legislative influence*", which anti-smoking strategy is considered important to reduce smoking prevalence among adults (above 15 years old) in Malaysia? Please rate by circling **or ticking** the appropriate number.
(Hint: 1= Not important at all, 9 = extremely important)

Criteria		Level of importance								
1.	Packaging and labelling	1	2	3	4	5	6	7	8	9
2.	Pricing and taxation	1	2	3	4	5	6	7	8	9
3.	Education, communication, and public awareness	1	2	3	4	5	6	7	8	9
4.	Smoke-free legislation	1	2	3	4	5	6	7	8	9
5.	Tobacco advertising, promotion, and sponsorship	1	2	3	4	5	6	7	8	9

Thank you for your cooperation.

Appendix C

Respondents Pre-evaluations by Using Enhanced Analytic Hierarchy Process

Respondent 1

Rating table for factors influencing smoking.

Criteria	1	2	3	4	5	6	7	8	9
Personal beliefs and values					x				
Personal physiological						x			
Family influence								x	
Psychosocial influence								x	
Cultural influence									x
Legislative influence	x								

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values					
		5	**6**	**8**	**8**	**9**	**1**
Rating values	**5**	$5-5=0$ $(=0)$	$5-6=-1$ (<0)	$5-8=-3$ (<0)	$5-8=-3$ (<0)	$5-9=-4$ (<0)	$5-1=4$ (>0)
	6	$6-5=1$ (>0)	$6-6=0$ $(=0)$	$6-8=-2$ (<0)	$6-8=-2$ (<0)	$6-9=-3$ (<0)	$6-1=5$ (>0)
	8	$8-5=3$ (>0)	$8-6=2$ (>0)	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-1=7$ (>0)
	8	$8-5=3$ (>0)	$8-6=2$ (>0)	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-1=7$ (>0)
	9	$9-5=4$ (>0)	$9-6=3$ (>0)	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-1=8$ (>0)
	1	$1-5=-4$ (<0)	$1-6=-5$ (<0)	$1-8=-7$ (<0)	$1-8=-7$ (<0)	$1-9=-8$ (<0)	$1-1=0$ $(=0)$

The converted pairwise comparison table matrix for factors influencing smoking from Respondent 1.

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1	1/2	1/4	1/4	1/5	5
C_2	2	1	1/3	1/3	1/4	6
C_3	4	3	1	1	1/2	8
C_4	4	3	1	1	1/2	8
C_5	5	4	2	2	1	9
C_6	1/5	1/6	1/8	1/8	1/9	1

C_1=Personal beliefs and values, C_2=Personal physiological, C_3=Family influence, C_4=Psychosocial influence, C_5=Cultural influence, C_6=Legislative influence

Rating table for anti-smoking strategies.

i) Personal beliefs and values

Factors	1	2	3	4	5	6	7	8	9
Packaging and labelling									x
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)
	9	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)
	9	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)
	9	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)
	9	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)	9 − 9 = 0 (= 0)

The converted pairwise comparison table matrix for personal beliefs and values from Respondent 1.

	DA_1	DA_2	DA_3	DA_4	DA_5
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

ii) Personal physiological

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling									x
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)
	9	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)
	9	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)
	9	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)
	9	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)	$9-9=0$ (= 0)

The converted pairwise comparison table matrix for personal physiological from Respondent 1.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

iii) Family influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling									x
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)

The converted pairwise comparison table matrix for family influence from Respondent 1.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

iv) Psychosocial influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling									x
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)

The converted pairwise comparison table matrix for psychosocial influence from Respondent 1.

	$\mathbf{DA_1}$	$\mathbf{DA_2}$	$\mathbf{DA_3}$	$\mathbf{DA_4}$	$\mathbf{DA_5}$
$\mathbf{DA_1}$	1	1	1	1	1
$\mathbf{DA_2}$	1	1	1	1	1
$\mathbf{DA_3}$	1	1	1	1	1
$\mathbf{DA_4}$	1	1	1	1	1
$\mathbf{DA_5}$	1	1	1	1	1

$\mathbf{DA_1}$=Packaging and labelling $\mathbf{DA_2}$=Pricing and taxation, $\mathbf{DA_3}$=Education, communication, and public awareness, $\mathbf{DA_4}$=Smoke-free legislation, $\mathbf{DA_5}$=Tobacco advertising, promotion, and sponsorship

v) Cultural influence

Factors	1	2	3	4	5	6	7	8	9
Packaging and labelling									x
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)

The converted pairwise comparison table matrix for cultural influence from Respondent 1.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

vi) Legislative influence

Factors	1	2	3	4	5	6	7	8	9
Packaging and labelling									x
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)

The converted pairwise comparison table matrix for legislative influence from Respondent 1.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Respondent 2

Rating table for factors influencing smoking

Factors	1	2	3	4	5	6	7	8	9
Personal beliefs and values							x		
Personal physiological								x	
Family influence								x	
Psychosocial influence							x		
Cultural influence								x	
Legislative influence							x		

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values					
		7	**8**	**8**	**7**	**8**	**7**
Rating values	**7**	$7-7=0$ $(=0)$	$7-8=-1$ (<0)	$7-8=-1$ (<0)	$7-7=0$ $(=0)$	$7-8=-1$ (<0)	$7-7=0$ $(=0)$
	8	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-7=1$ (>0)
	8	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-7=1$ (>0)
	7	$7-7=0$ $(=0)$	$7-8=-1$ (<0)	$7-8=-1$ (<0)	$7-7=0$ $(=0)$	$7-8=-1$ (<0)	$7-7=0$ $(=0)$
	8	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-7=1$ (>0)
	7	$7-7=0$ $(=0)$	$7-8=-1$ (<0)	$7-8=-1$ (<0)	$7-7=0$ $(=0)$	$7-8=-1$ (<0)	$7-7=0$ $(=0)$

The converted pairwise comparison table matrix for factors influencing smoking from Respondent 2.

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1	1/2	1/2	1	1/2	1
C_2	2	1	1	2	1	2
C_3	2	1	1	2	1	2
C_4	1	1/2	1/2	1	1/2	1
C_5	2	1	1	2	1	2
C_6	1	1/2	1/2	1	1/2	1

C_1=Personal beliefs and values, **C_2**=Personal physiological, **C_3**=Family influence, **C_4**=Psychosocial influence, **C_5**=Cultural influence, **C_6**=Legislative influence

Rating table for anti-smoking strategies

i) Personal beliefs and values

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling								x	
Pricing and taxation								x	
Mass-media campaign								x	
Smoke-free legislation								x	
Education and support								x	

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)

The converted pairwise comparison table matrix for personal beliefs and values from Respondent 2.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

ii) Personal physiological

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling							x		
Pricing and taxation								x	
Mass-media campaign								x	
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		7	**8**	**8**	**9**	**9**
Rating values	**7**	$7-7=0$ $(=0)$	$7-8=-1$ (<0)	$7-8=-1$ (<0)	$7-9=-2$ (<0)	$7-9=-2$ (<0)
	8	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)
	8	$8-7=1$ (>0)	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)
	9	$9-7=2$ (>0)	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$
	9	$9-7=2$ (>0)	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$

The converted pairwise comparison table matrix for personal physiological from Respondent 2.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1/2	1/2	1/3	1/3
DA_2	2	1	1	1/2	1/2
DA_3	2	1	1	1/2	1/2
DA_4	3	2	2	1	1
DA_5	3	2	2	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

iii) Family influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling								x	
Pricing and taxation								x	
Mass-media campaign									x
Smoke-free legislation									x
Education and support								x	

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**8**	**9**	**9**	**8**
Rating values	**8**	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-8=0$ $(=0)$
	8	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-8=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)
	9	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)
	8	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-8=0$ $(=0)$

The converted pairwise comparison table matrix for family influence from Respondent 2.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1/2	1/2	1
DA_2	1	1	1/2	1/2	1
DA_3	2	2	1	1	2
DA_4	2	2	1	1	2
DA_5	1	1	1/2	1/2	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

iv) Psychosocial influence

Factors	1	2	3	4	5	6	7	8	9
Packaging and labelling								x	
Pricing and taxation								x	
Mass-media campaign								x	
Smoke-free legislation								x	
Education and support								x	

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**8**	**8**	**8**	**8**
Rating values	**8**	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$
	8	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$
	8	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$
	8	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$
	8	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$

The converted pairwise comparison table matrix for psychosocial influence from Respondent 2.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

v) Cultural influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling								x	
Pricing and taxation								x	
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**8**	**9**	**9**	**9**
Rating values	**8**	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-9=-1$ (<0)
	8	$8-8=0$ $(=0)$	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-9=-1$ (<0)
	9	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$

The converted pairwise comparison table matrix for cultural influence from Respondent 2.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1/2	1/2	1/2
DA_2	1	1	1/2	1/2	1/2
DA_3	2	2	1	1	1
DA_4	2	2	1	1	1
DA_5	2	2	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

vi) Legislative influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling									x
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		9	**9**	**9**	**9**	**9**
Rating values	**9**	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)
	9	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)	9 – 9 = 0 (= 0)

The converted pairwise comparison table matrix for legislative influence from Respondent 2.

	DA$_1$	**DA$_2$**	**DA$_3$**	**DA$_4$**	**DA$_5$**
DA$_1$	1	1	1	1	1
DA$_2$	1	1	1	1	1
DA$_3$	1	1	1	1	1
DA$_4$	1	1	1	1	1
DA$_5$	1	1	1	1	1

DA$_1$=Packaging and labelling **DA$_2$**=Pricing and taxation, **DA$_3$**=Education, communication, and public awareness, **DA$_4$**=Smoke-free legislation, **DA$_5$**=Tobacco advertising, promotion, and sponsorship

Respondent 3

Rating table for factors influencing smoking

Factors	1	2	3	4	5	6	7	8	9
Personal beliefs and values					x				
Personal physiological									x
Family influence					x				
Psychosocial influence									x
Cultural influence					x				
Legislative influence									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values					
		5	**9**	**5**	**9**	**5**	**9**
Rating values	**5**	$5-5=0$ $(=0)$	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-9=-4$ (<0)
	9	$9-5=4$ (>0)	$9-9=0$ $(=0)$	$9-5=4$ (>0)	$9-9=0$ $(=0)$	$9-5=4$ (>0)	$9-9=0$ $(=0)$
	5	$5-5=0$ $(=0)$	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-9=-4$ (<0)
	9	$9-5=4$ (>0)	$9-9=0$ $(=0)$	$9-5=4$ (>0)	$9-9=0$ $(=0)$	$9-5=4$ (>0)	$9-9=0$ $(=0)$
	5	$5-5=0$ $(=0)$	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-9=-4$ (<0)
	9	$9-5=4$ (>0)	$9-9=0$ $(=0)$	$9-5=4$ (>0)	$9-9=0$ $(=0)$	$9-5=4$ (>0)	$9-9=0$ $(=0)$

The converted pairwise comparison table matrix for factors influencing smoking from Respondent 3.

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
C_1	1	1/5	1	1/5	1	1/5
C_2	5	1	5	1	5	1
C_3	1	1/5	1	1/5	1	1/5
C_4	5	1	5	1	5	1
C_5	1	1/5	1	1/5	1	1/5
C_6	5	1	5	1	5	1

C_1=Personal beliefs and values, **C_2**=Personal physiological, **C_3**=Family influence, **C_4**=Psychosocial influence, **C_5**=Cultural influence, **C_6**=Legislative influence

Rating table for anti-smoking strategies

i) Personal beliefs and values

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling								x	
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support								x	

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**9**	**9**	**9**	**8**
Rating values	**8**	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-8=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)
	8	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-8=0$ $(=0)$

The converted pairwise comparison table matrix for personal beliefs and values from Respondent 3.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1/2	1/2	1/2	1
DA_2	2	1	1	1	2
DA_3	2	1	1	1	2
DA_4	2	1	1	1	2
DA_5	1	1/2	1/2	1/2	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

ii) Personal physiological

Factors	1	2	3	4	5	6	7	8	9
Packaging and labelling								x	
Pricing and taxation					x				
Mass-media campaign									x
Smoke-free legislation						x			
Education and support								x	

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**5**	**9**	**6**	**8**
Rating values	**8**	$8-8=0$ $(=0)$	$8-5=3$ (>0)	$8-9=-1$ (<0)	$8-6=2$ (>0)	$8-8=0$ $(=0)$
	5	$5-8=-3$ (<0)	$5-5=0$ $(=0)$	$5-9=-4$ (<0)	$5-6=-1$ (<0)	$5-8=-3$ (<0)
	9	$9-8=1$ (>0)	$9-5=4$ (>0)	$9-9=0$ $(=0)$	$9-6=3$ (>0)	$9-8=1$ (>0)
	6	$6-8=-2$ (<0)	$6-5=1$ (>0)	$6-9=-3$ (<0)	$6-6=0$ $(=0)$	$6-8=-2$ (<0)
	8	$8-8=0$ $(=0)$	$8-5=3$ (>0)	$8-9=-1$ (<0)	$8-6=2$ (>0)	$8-8=0$ $(=0)$

The converted pairwise comparison table matrix for personal physiological from Respondent 3.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	4	1/2	3	1
DA_2	1/4	1	1/5	1/2	1/4
DA_3	2	5	1	4	2
DA_4	1/3	2	1/4	1	1/3
DA_5	1	4	1/2	3	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

iii) Family influence

Factors	1	2	3	4	5	6	7	8	9
Packaging and labelling								x	
Pricing and taxation									x
Mass-media campaign					x				
Smoke-free legislation					x				
Education and support								x	

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**9**	**5**	**5**	**8**
Rating values	**8**	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-5=3$ (>0)	$8-5=3$ (>0)	$8-8=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-5=4$ (>0)	$9-5=4$ (>0)	$9-8=1$ (>0)
	5	$5-8=-3$ (<0)	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-5=0$ $(=0)$	$5-8=-3$ (<0)
	5	$5-8=-3$ (<0)	$5-9=-4$ (<0)	$5-5=0$ $(=0)$	$5-5=0$ $(=0)$	$5-8=-3$ (<0)
	8	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-5=3$ (>0)	$8-5=3$ (>0)	$8-8=0$ $(=0)$

The converted pairwise comparison table matrix for family influence from Respondent 3.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1/2	4	4	1
DA_2	2	1	5	5	2
DA_3	1//4	1/5	1	1	1/4
DA_4	1/4	1/5	1	1	1/4
DA_5	1	1/2	4	4	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

iv) Psychosocial influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling								x	
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation								x	
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**9**	**9**	**8**	**9**
Rating values	**8**	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-8=0$ $(=0)$	$8-9=-1$ (<0)
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)	$9-9=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)	$9-9=0$ $(=0)$
	8	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-8=0$ $(=0)$	$8-9=-1$ (<0)
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-8=1$ (>0)	$9-9=0$ $(=0)$

The converted pairwise comparison table matrix for psychosocial influence from Respondent 3.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1/2	1/2	1	1/2
DA_2	2	1	1	2	1
DA_3	2	1	1	2	1
DA_4	1	1/2	1/2	1	1/2
DA_5	2	1	1	2	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

v) Cultural influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling								x	
Pricing and taxation						x			
Mass-media campaign						x			
Smoke-free legislation						x			
Education and support						x			

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**6**	**6**	**6**	**6**
Rating values	**8**	$8-8=0$ $(=0)$	$8-6=2$ (>0)	$8-6=2$ (>0)	$8-6=2$ (>0)	$8-6=2$ (>0)
	6	$6-8=-2$ (<0)	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$
	6	$6-8=-2$ (<0)	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$
	6	$6-8=-2$ (<0)	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$
	6	$6-8=-2$ (<0)	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$	$6-6=0$ $(=0)$

The converted pairwise comparison table matrix for cultural influence from Respondent 3.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	3	3	3	3
DA_2	1/3	1	1	1	1
DA_3	1/3	1	1	1	1
DA_4	1/3	1	1	1	1
DA_5	1/3	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

vi) Legislative influence

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Packaging and labelling								x	
Pricing and taxation									x
Mass-media campaign									x
Smoke-free legislation									x
Education and support									x

Arrange the rating values into table matrix and perform pre-evaluations.

		Rating values				
		8	**9**	**9**	**9**	**9**
Rating values	**8**	$8-8=0$ $(=0)$	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-9=-1$ (<0)	$8-9=-1$ (<0)
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$
	9	$9-8=1$ (>0)	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$	$9-9=0$ $(=0)$

The converted pairwise comparison table matrix for legislative influence from Respondent 3.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1/2	1/2	1/2	1/2
DA_2	2	1	1	1	1
DA_3	2	1	1	1	1
DA_4	2	1	1	1	1
DA_5	2	1	1	1	1

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Appendix D

First Respondent Weight Evaluation by Using Enhanced Analytic Hierarchy Process

The pairwise comparison matrix and the summed of each column for factors influencing smoking.

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
C_1	1	1/2	1/4	1/4	1/5	5
C_2	2	1	1/3	1/3	1/4	6
C_3	4	3	1	1	1/2	8
C_4	4	3	1	1	1/2	8
C_5	5	4	2	2	1	9
C_6	1/5	1/6	1/8	1/8	1/9	1
$\sum$	**16.20**	**11.67**	**4.71**	**4.71**	**2.56**	**37**

C_1=Personal beliefs and values, **C_2**=Personal physiological, **C_3**=Family influence, **C_4**=Psychosocial influence, **C_5**=Cultural influence, **C_6**=Legislative influence

Divide each element in the pairwise comparison matrix by column total.

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**
C_1	0.0617	0.0429	0.0531	0.0531	0.0781	0.1351
C_2	0.1235	0.0857	0.0708	0.0708	0.0976	0.1622
C_3	0.2469	0.2571	0.2124	0.2124	0.1952	0.2162
C_4	0.2469	0.2571	0.2124	0.2124	0.1952	0.2162
C_5	0.3086	0.3429	0.4248	0.4248	0.3905	0.2432
C_6	0.0123	0.0143	0.0265	0.0265	0.0434	0.0270

Calculate the average of the element in each row to determine the priority for each criterion.

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**Total**	**Weights**
C_1	0.0617	0.0429	0.0531	0.0531	0.0781	0.1351	0.4240	0.0707
C_2	0.1235	0.0857	0.0708	0.0708	0.0976	0.1622	0.6105	0.1018
C_3	0.2469	0.2571	0.2124	0.2124	0.1952	0.2162	1.3403	0.2234
C_4	0.2469	0.2571	0.2124	0.2124	0.1952	0.2162	1.3403	0.2234
C_5	0.3086	0.3429	0.4248	0.4248	0.3905	0.2432	2.1348	0.3558
C_6	0.0123	0.0143	0.0265	0.0265	0.0434	0.0270	0.1501	0.0250

$$(0.0707)\begin{bmatrix}1\\2\\4\\4\\5\\1/5\end{bmatrix} + (0.1018)\begin{bmatrix}1/2\\1\\3\\3\\4\\1/6\end{bmatrix} + (0.2234)\begin{bmatrix}1/4\\1/3\\1\\1\\2\\1/8\end{bmatrix} + (0.2234)\begin{bmatrix}1/4\\1/3\\1\\1\\2\\1/8\end{bmatrix}$$

$$+ (0.3558)\begin{bmatrix}1/5\\1/4\\1/2\\1/2\\1\\1/9\end{bmatrix} + (0.0250)\begin{bmatrix}5\\6\\8\\8\\9\\1\end{bmatrix} = \begin{bmatrix}1.1448\\1.1872\\1.0517\\1.0517\\0.9112\\0.9259\end{bmatrix}$$

$$\lambda_{max} = 1.1448 + 1.1872 + 1.0517 + 1.0517 + 0.9112 + 0.9259 = 6.2725$$

$$CI = \frac{6.2725 - 6}{6 - 1} = 0.0545$$

The value of RI

M	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

Sources: Saaty (1980)

$$CR = \frac{0.0545}{1.252} = 0.0435$$

The pairwise comparison table matrix table and the summed of each column for personal beliefs and values.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1
$\sum$	5	5	5	5	5

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Divide each element in the pairwise comparison table matrix by column total.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	0.2	0.2	0.2	0.2	0.2
DA_2	0.2	0.2	0.2	0.2	0.2
DA_3	0.2	0.2	0.2	0.2	0.2
DA_4	0.2	0.2	0.2	0.2	0.2
DA_5	0.2	0.2	0.2	0.2	0.2

Calculate the average of the element in each row to determine the weights for each criterion.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**	**Total**	**Weights**
DA_1	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_2	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_3	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_4	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_5	0.2	0.2	0.2	0.2	0.2	1.0	0.2

$$(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}=\begin{bmatrix}1.0\\1.0\\1.0\\1.0\\1.0\\1.0\end{bmatrix}$$

$$\lambda_{max} = 1.0 + 1.0 + 1.0 + 1.0 + 1.0 = 5.0$$

$$CI = \frac{5-5}{5-1} = 0$$

The value of RI

M	3	4	5	6	7	8	9	10	11	12	13
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

Sources: Saaty (1980)

$$CR = \frac{0.0545}{1.115} = 0$$

The pairwise comparison table matrix table and the summed of each column for personal physiological.

	DA_1	DA_2	DA_3	DA_4	DA_5
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1
$\sum$	5	5	5	5	5

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Divide each element in the pairwise comparison table matrix by column total.

	DA_1	DA_2	DA_3	DA_4	DA_5
DA_1	0.2	0.2	0.2	0.2	0.2
DA_2	0.2	0.2	0.2	0.2	0.2
DA_3	0.2	0.2	0.2	0.2	0.2
DA_4	0.2	0.2	0.2	0.2	0.2
DA_5	0.2	0.2	0.2	0.2	0.2

Calculate the average of the element in each row to determine the weights for each criterion.

	DA_1	DA_2	DA_3	DA_4	DA_5	Total	Weights
DA_1	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_2	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_3	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_4	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_5	0.2	0.2	0.2	0.2	0.2	1.0	0.2

$$(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}=\begin{bmatrix}1.0\\1.0\\1.0\\1.0\\1.0\\1.0\end{bmatrix}$$

$$\lambda_{max} = 1.0 + 1.0 + 1.0 + 1.0 + 1.0 = 5.0$$

$$CI = \frac{5-5}{5-1} = 0$$

The value of RI

M	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

Sources: Saaty (1980)

$$CR = \frac{0.0545}{1.115} = 0$$

The pairwise comparison table matrix table and the summed of each column for family influence

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1
∑	5	5	5	5	5

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Divide each element in the pairwise comparison table matrix by column total.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	0.2	0.2	0.2	0.2	0.2
DA_2	0.2	0.2	0.2	0.2	0.2
DA_3	0.2	0.2	0.2	0.2	0.2
DA_4	0.2	0.2	0.2	0.2	0.2
DA_5	0.2	0.2	0.2	0.2	0.2

Calculate the average of the element in each row to determine the weights for each criterion.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**	**Total**	**Weights**
DA_1	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_2	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_3	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_4	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_5	0.2	0.2	0.2	0.2	0.2	1.0	0.2

$$(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}=\begin{bmatrix}1.0\\1.0\\1.0\\1.0\\1.0\\1.0\end{bmatrix}$$

$$\lambda_{max} = 1.0 + 1.0 + 1.0 + 1.0 + 1.0 = 5.0$$

$$CI = \frac{5-5}{5-1} = 0$$

The value of RI

M	3	4	5	6	7	8	9	10	11	12	13
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

Sources: Saaty (1980)

$$CR = \frac{0.0545}{1.115} = 0$$

The pairwise comparison table matrix table and the summed of each column for psychosocial influence.

	DA_1	DA_2	DA_3	DA_4	DA_5
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1
$\sum$	5	5	5	5	5

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Divide each element in the pairwise comparison table matrix by column total.

	DA_1	DA_2	DA_3	DA_4	DA_5
DA_1	0.2	0.2	0.2	0.2	0.2
DA_2	0.2	0.2	0.2	0.2	0.2
DA_3	0.2	0.2	0.2	0.2	0.2
DA_4	0.2	0.2	0.2	0.2	0.2
DA_5	0.2	0.2	0.2	0.2	0.2

Calculate the average of the element in each row to determine the weights for each criterion.

	DA_1	DA_2	DA_3	DA_4	DA_5	Total	Weights
DA_1	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_2	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_3	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_4	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_5	0.2	0.2	0.2	0.2	0.2	1.0	0.2

$$(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix} + (0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix} + (0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix} + (0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix} + (0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix} + (0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix} = \begin{bmatrix}1.0\\1.0\\1.0\\1.0\\1.0\\1.0\end{bmatrix}$$

$$\lambda_{max} = 1.0 + 1.0 + 1.0 + 1.0 + 1.0 = 5.0$$

$$CI = \frac{5-5}{5-1} = 0$$

The value of RI

M	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

Sources: Saaty (1980)

$$CR = \frac{0.0545}{1.115} = 0$$

The pairwise comparison table matrix table and the summed of each column for cultural influence

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1
$\sum$	5	5	5	5	5

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Divide each element in the pairwise comparison table matrix by column total.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**
DA_1	0.2	0.2	0.2	0.2	0.2
DA_2	0.2	0.2	0.2	0.2	0.2
DA_3	0.2	0.2	0.2	0.2	0.2
DA_4	0.2	0.2	0.2	0.2	0.2
DA_5	0.2	0.2	0.2	0.2	0.2

Calculate the average of the element in each row to determine the weights for each criterion.

	DA_1	**DA_2**	**DA_3**	**DA_4**	**DA_5**	**Total**	**Weights**
DA_1	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_2	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_3	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_4	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_5	0.2	0.2	0.2	0.2	0.2	1.0	0.2

$$(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}=\begin{bmatrix}1.0\\1.0\\1.0\\1.0\\1.0\\1.0\end{bmatrix}$$

$$\lambda_{max} = 1.0 + 1.0 + 1.0 + 1.0 + 1.0 = 5.0$$

$$CI = \frac{5-5}{5-1} = 0$$

The value of RI

M	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

Sources: Saaty (1980)

$$CR = \frac{0.0545}{1.115} = 0$$

The pairwise comparison table matrix table and the summed of each column for legislative influence.

	DA_1	DA_2	DA_3	DA_4	DA_5
DA_1	1	1	1	1	1
DA_2	1	1	1	1	1
DA_3	1	1	1	1	1
DA_4	1	1	1	1	1
DA_5	1	1	1	1	1
$\sum$	5	5	5	5	5

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Divide each element in the pairwise comparison table matrix by column total.

	DA_1	DA_2	DA_3	DA_4	DA_5
DA_1	0.2	0.2	0.2	0.2	0.2
DA_2	0.2	0.2	0.2	0.2	0.2
DA_3	0.2	0.2	0.2	0.2	0.2
DA_4	0.2	0.2	0.2	0.2	0.2
DA_5	0.2	0.2	0.2	0.2	0.2

Calculate the average of the element in each row to determine the weights for each criterion.

	DA_1	DA_2	DA_3	DA_4	DA_5	Total	Weights
DA_1	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_2	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_3	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_4	0.2	0.2	0.2	0.2	0.2	1.0	0.2
DA_5	0.2	0.2	0.2	0.2	0.2	1.0	0.2

$$(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}+(0.2)\begin{bmatrix}1\\1\\1\\1\\1\end{bmatrix}=\begin{bmatrix}1.0\\1.0\\1.0\\1.0\\1.0\\1.0\end{bmatrix}$$

$$\lambda_{max} = 1.0 + 1.0 + 1.0 + 1.0 + 1.0 = 5.0$$

$$CI = \frac{5-5}{5-1} = 0$$

The value of RI

M	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
RI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

Sources: Saaty (1980)

$$CR = \frac{0.0545}{1.115} = 0$$

	C_1	C_2	C_3	C_4	C_5	C_6			
DA_1	0.2	0.2	0.2	0.2	0.2	0.2		**C_1**	0.0707
DA_2	0.2	0.2	0.2	0.2	0.2	0.2		**C_2**	0.1018
DA_3	0.2	0.2	0.2	0.2	0.2	0.2	×	**C_3**	0.2234
DA_4	0.2	0.2	0.2	0.2	0.2	0.2		**C_4**	0.2234
DA_5	0.2	0.2	0.2	0.2	0.2	0.2		**C_5**	0.3558
								C_6	0.0250

Therefore, the weights for factors influencing smoking and anti-smoking strategies for Respondent 1 are:

Influencing factors	**Weights**
Personal beliefs and values	0.0707
Personal physiological	0.1018
Family influence	0.2234
Psychosocial influence	0.2234
Cultural influence	0.3558
Legislative influence	0.0250

Anti-smoking strategies	**Weights**
Packaging and labelling	0.2
Pricing and taxation	0.2
Mass-media campaign	0.2
Smoke-free legislation	0.2
Education and support	0.2

Appendix E

Final Weights and Ranks of All the Respondents for the Criteria and the Consistency Using Enhanced Analytic Hierarchy Process

Final weights and ranks for factors influencing smoking.

	Respondent 1	Respondent 2	Respondent 3	Weights	Ranks
C_1	0.0707	0.1111	0.0556	0.0759	6
C_2	0.1018	0.2222	0.2778	0.1845	2
C_3	0.2234	0.2222	0.0556	0.1403	4
C_4	0.2234	0.1111	0.2778	0.1903	1
C_5	0.3558	0.2222	0.0556	0.1638	3
C_6	0.0250	0.1111	0.2778	0.0917	5

C_1=Personal beliefs and values, **C_2**=Personal physiological, **C_3**=Family influence, **C_4**=Psychosocial influence, **C_5**=Cultural influence, **C_6**=Legislative influence

Final weights and ranks for anti-smoking strategies.

	Respondent 1	Respondent 2	Respondent 3	Weights	Ranks
DA_1	0.2000	0.1460	0.1735	0.1717	5
DA_2	0.2000	0.1613	0.1914	0.1835	4
DA_3	0.2000	0.2208	0.2645	0.2269	1
DA_4	0.2000	0.2518	0.1475	0.1951	3
DA_5	0.2000	0.2201	0.2232	0.2142	2

DA_1=Packaging and labelling **DA_2**=Pricing and taxation, **DA_3**=Education, communication, and public awareness, **DA_4**=Smoke-free legislation, **DA_5**=Tobacco advertising, promotion, and sponsorship

Appendix F

Optimisation Log File

```
sim  strategy12 -l -o EAHPSD  optimization.voc -p EAHPSD  optimization.vpd -d desired
Initial point of search
  enforcement level imposed by government = 0
  promotion level by tobacco industry = 0.25
Simulations = 1
Pass = 0
Payoff = -0.614323
---------------------------------
Maximum payoff found at:
  enforcement level imposed by government = 0.239625
 *promotion level by tobacco industry = 0.0312307
Simulations = 103
Pass = 3
Payoff = -0.000483249
---------------------------------
The final payoff is -4.832491e-004
```

Appendix G
Sub-Model Equations

Population Sector

total population=youth never smokers+adult never smokers+adult smokers+adult exsmokers
Unit: persons

youth never smokers= INTEG (birth-transition, 8.0031e+006)
Unit: persons

adult never smokers= INTEG (transition-never smokers mortality-smoking initiation, 1.54918e+007)
Unit: persons

adult smokers= INTEG (smoking initiation-smokers mortality-smoking cessation, 3.84197e+006)
Unit: persons

adult exsmokers= INTEG (smoking cessation-exsmokers mortality, 328929)
Unit: persons

birth=total population*birth rate
Unit: person/Year

birth fraction=-0.016
Unit: 1/Year

birth rate=0.021*EXP(birth fraction*(Time-INITIAL TIME))
Unit: 1/Year

transition=never smokers/first 14 years
Unit: person/Year

first 14 years=14
Unit: Year

never smokers mortality=adult never smokers*never smokers mortality rate
Unit: person/Year

never smokers mortality rate=0.0042*EXP(never smokers mortality fraction*(Time-INITIAL TIME))
Unit: 1/Year

never smokers mortality fraction=0.0099
Unit: 1/Year

smokers mortality=adult smokers*smokers mortality rate
Unit: person/Year

smokers mortality rate=0.0054*EXP(smokers mortality fraction*(Time-INITIAL TIME))
Unit: 1/Year

smokers mortality fraction=-0.021
Unit: 1/Year

exsmokers mortality=adult exsmokers*never smokers mortality rate
Unit: person/Year

smoking initiation=adult never smokers*initiation rate*effect of net awareness on initiation
Unit: person/Year

initiation rate=0.0123*EXP(initiation fraction*(Time-INITIAL TIME))
Unit: 1/Year

initiation fraction=0.0143
Unit: 1/Year

smoking cessation=adult smokers*cessation rate*effect of net awareness on cessation
Unit: person/Year

cessation rate=0.003*EXP(cessation fraction*(Time-INITIAL TIME))
Unit: 1/Year

cessation fraction=-0.052
Unit: 1/Year

Factor Influencing Smoking Sector

perceived psychosocial influence= INTEG (increase psychosocial influence-decrease psychosocial influence, psychosocial influence weight)
Unit: Dmnl

increase psychosocial influence=fraction willing to smoke*perceived psychosocial influence
Unit: Dmnl/Year

decrease psychosocial influence=fraction unwilling to smoke*perceived psychosocial influence
Unit: Dmnl/Year

psychosocial influence weight=0.1903
Unit: Dmnl

perceived personal beliefs and values influence= INTEG (increase personal beliefs and values decrease personal beliefs and values,perceived personal beliefs and values influence weight)
Unit: Dmnl

increase personal beliefs and values=fraction willing to smoke*perceived personal beliefs and values influence
Unit Dmnl/Year

decrease personal beliefs and values=fraction unwilling to smoke*perceived personal beliefs and values influence
Unit Dmnl/Year

perceived personal beliefs and values influence weight=0.0759
Unit: Dmnl

perceived physiological influence= INTEG (increase change physiological-decrease change physiological,physiological influence weight)
Unit: Dmnl

increase change physiological=fraction willing to smoke*perceived physiological influence
Unit: Dmnl/Year

decrease change physiological=fraction unwilling to smoke*perceived physiological influence
Unit: Dmnl/Year

physiological influence weight=0.1845
Unit: Dmnl

perceived family influence= INTEG (increase family influence-decrease family influence, family influence weight)
Unit: Dmnl

increase family influence=fraction willing to smoke*perceived family influence
Unit: Dmnl/Year

decrease family influence=fraction unwilling to smoke*perceived family influence
Unit: Dmnl/Year

family influence weight=0.1403
Unit: Dmnl

perceived cultural influence= INTEG (increase cultural influence-decrease cultural influence,
culture influence weight)
Unit: Dmnl

increase cultural influence=fraction willing to smoke*perceived cultural influence
Unit: Dmnl/Year

decrease cultural influence=fraction unwilling to smoke*perceived cultural influence
Unit: Dmnl/Year

culture influence weight=0.1638
Unit: Dmnl

perceived legislative influence= INTEG (increase legislative influence-decrease legislative influence,
legislative influence weight)
Unit: Dmnl

increase legislative influence=fraction willing to smoke*perceived legislative influence
Unit: Dmnl/Year

decrease legislative influence=fraction unwilling to smoke*perceived legislative influence
Unit: Dmnl/Year

legislative influence weight=0.0917
Unit: Dmnl

fraction willing to smoke=initiation rate*effect of net awareness on initiation
Unit: Dmnl/Year

fraction unwilling to smoke=cessation rate*effect of net awareness on cessation
Unit: Dmnl/Year

fraction perceived initiating to smoke=
(perceived cultural influence*perceived family influence*perceived legislative influence\
*perceived personal beliefs and values influence*perceived physiological influence*\
perceived psychosocial influence)
Unit: Dmnl

Education, Communication, and Public Awareness Sector

smoking prevalence= INTEG (changes in initiation-changes in cessation,
initial smoking prevalence)
Unit: Dmnl

initial smoking prevalence=0.22
Unit: Dmnl

changes in initiation=initiation rate*effect of net awareness on initiation*smoking prevalence
Unit: 1/Year

changes in cessation=cessation rate*effect of net awareness on cessation*smoking prevalence
Unit: 1/Year

awareness of smoking morbidity= INTEG (gaining awareness-forgetting awareness, 0)
Unit: Dmnl

gaining awareness =perceived smoking morbidity*impact of public awareness programs
Unit: 1/Year

forgetting awareness =awareness of smoking morbidity/time to forget smoking risks
Unit: 1/Year

time to forget smoking risks=21
Unit: Year

net awareness=perceived enjoyment from smoking-awareness of smoking morbidity
Unit: Dmnl

effect of net awareness on initiation=net awareness^(1-(fraction to smoke))
Unit: Dmnl

effect of net awareness on cessation=net awareness^(-fraction to quit)
Unit: Dmnl

fraction to smoke=fraction perceived initiating to smoke
Unit: Dmnl

fraction to quit=1-fraction perceived initiating to smoke
Unit: Dmnl

perceived smoking morbidity=smoking prevalence/time to develop smoking morbidity
Unit: 1/Year

time to develop smoking morbidity=21
Unit: Year

enforcement level imposed by the government=0
Unit: Dmnl

impact of public awareness programs=IF THEN ELSE(Time<=2018,0,enforcement level imposed by the government)
Unit: Dmnl

promotion level by the tobacco industry=1
Unit: Dmnl

perceived enjoyment from smoking=IF THEN ELSE(Time<=2018,1,promotion level by the tobacco industry)
Unit: Dmnl