POTENTIAL IMPACT OF TOBACCO HARM REDUCTION ON LIFE YEARS LOST IN NEPAL

Prakriti Pragya Foundation

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Use of AI / Generative AI

All research content, analysis, and conclusions are the original work of the authors. ChatGPT was used for proofreading and language refinement in some sections. The authors take full responsibility for the content of this book.

Executive Summary

Tobacco smoking is one of the principal global public health challenges, as it is the leading cause of preventable death and disease globally. The cessation of smoking or the switch to potentially less harmful products is of broad interest. Many studies show that e-cigarette or vaping can help in lowering the initiation or accelerating the cessation. Though the health risk of e-cigarettes or vaping can't be neglected, its role as a substitute may be instrumental in the cessation of smoking.

This study assesses the impact of vaping on smoking behavior by deploying a dynamic population simulation model in the Nepalese context. It uses 210 different simulation scenarios spanning 80 years, with scenarios varying by initiation rate, cessation rate, and e-cigarette health risk. The baseline year considered in this model is 2019, and the data sourced from the UN Population Division, the Nepal STEPS survey 2019, and the Global Burden of Disease – 2019. The initiation rate in the baseline year for Nepal, estimated using STEPS-2019, is 29.41% for males and 1.38% for females. Similarly, cessation rate is estimated for three age groups: 19-34 (1.62% for males and 4.55% for females), 35-50 (5% for males and 4.41% for females), and 50+ (1.72% for males and 3.47% for females). The smoking prevalence for males in the baseline year is 32.83% and 11.42% for females. The simulation scenario is created based on different combinations of hypothetical impact of vaping on initiation rates (-20%, -15%, -10%, 0, 10%, 15%, 20%), cessation rates (5%, 10%, 25%, 50%, 100%, 200%), and health risk of vaping (0%, 2.5%, 5%, 10%, 20%).

The result shows, for males, a maximum of 57.62% of life years can be saved compared to life years lost due to smoking, and a minimum of -10.04%. In the context of females, the maximum and minimum value of life years saved as the share of life years lost due to smoking is 21.52% and 0.07%, respectively. Among the various scenarios, we consider four as plausible, based on previous evidence and discussions. These are the scenarios in which we assume vaping increases cessation by 25% and 50%, decreases initiation by 10%, and maintains a health risk of 5% and 10%.

For males, if there is an increase in cessation by 25% and a decrease in initiation by 10%, then the life year saved as a share of life years lost due to smoking after 50 years from baseline is 13.79%, with 5% health risk of vaping. And considering the health risk of vaping at 10%, 13.28% life years can be saved. In this same scenario, the share of e-quitters among all quitters after 50 years is 34.34% (with a vaping risk of 5%) and 33.76% (with a vaping risk of 10%). Smoking prevalence after 50 years would fall to 17.35% (with vaping risk of 5%) and 17.36 (with vaping risk of 10%).

For females, our model shows that if there is an increase in cessation by 25% and a decrease in initiation by 10%, then the life year saved as a share of life years lost due to smoking after 50 years from baseline is 2.27%, with 5% health risk of vaping. And considering the health risk of vaping at 10%, 2.24% life years can be saved. In this same scenario, the share of e-quitters among all quitters after 50 years is 56.78% (with a vaping risk of 5%) and 56.69% (with a vaping risk of 10%). Smoking prevalence after 50 years, with vaping risk of 5% and 10%, would fall to 0.44%.

For males, if there is an increase in cessation by 50% and a decrease in initiation by 10% then the life year saved as a share of life years lost due to smoking after 50 years from baseline is 22.19% (with vaping risk of 5%) and 21.3% (with 10% vaping risk). The share of e-quitters among all quitters is 48.31% (with a vaping risk of 5%) and 47.68% (with a vaping risk of 10%). Smoking prevalence falls to 16.07% (with vaping risk of 5%) and 16.08% (with vaping risk of 10%).

In the case of females, if there is an increase in cessation by 50% and a decrease in initiation by 10%, then the life year saved as a share of life years lost due to smoking after 50 years from baseline is 4.50% (with vaping risk of 5%) and 4.45% (with 10% vaping risk). The share of e-quitters among all quitters is 70.87% (with a vaping risk of 5%) and 70.79% (with a vaping risk of 10%). Smoking prevalence after 50 years, with vaping risk of 5% and 10%, would fall to 0.37%.

In conclusion, based on the Nepalese context, under the plausible scenario, the impact of vaping on increasing life years saved and decreasing the smoking prevalence is evident. The result also shows that the use of e-cigarettes is more effective for quitting among females than males. Vaping could be attributed to lowering the smoking prevalence. However, this study is based on hypothetical scenarios, and hence, real-world outcomes may vary. Instead of interpreting exact values, the study's overall trend may appear reliable.

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1. Introduction

1.1 Background

Tobacco use remains one of the most significant public health challenges globally and a leading cause of preventable death and disease. According to the World Health Organization (WHO) Tobacco Factsheet[1], tobacco kills more than 8 million people each year, with over 7 million of those deaths resulting from direct tobacco use and around 1.2 million from non-smokers exposed to second-hand smoke. The WHO global report on trends in prevalence of tobacco use shows the decline in tobacco use from 1.38 billion in 2000 to 1.2 billion in 2024, but still one in five adults is a tobacco user. Prevalence of tobacco use among women declined from 11% in 2010 to 6.6% in 2024. In contrast, the prevalence among men dropped from 41.4% in 2010 to 32.5% in 2024 (WHO, 2025).

Tobacco use prevalence has continued to decline over time across all countries, regardless of World Bank income group. In 2000, lower-middle-income countries had the highest average prevalence for both sexes combined (45.3%), but by 2024 their rate had fallen to about 20%, essentially matching levels seen in high-income and upper-middle-income countries. Low-income countries show a drop from 21.9% in 2000 to 12.1% in 2024 and are projected to decline further to 11.8% in 2025. Among men, upper-middle and lower-middle income countries show the highest average prevalence in 2024 at 39% and 33%, respectively, which is above the figures for high-income countries (25%) and low-income countries (21%). Among women, high-income countries have the highest prevalence, decreasing from 24.0% in 2000 to 14.6% in 2024. Women in lower-middle-income countries have the second-highest prevalence at 7.5%, roughly half the level observed in high-income countries (WHO, 2025).

In Nepal, the situation is particularly concerning. According to the 2019 STEPS survey (Nepal), 28.9% of adults aged 15-69 years currently use either smoked or smokeless tobacco products. Among smoked tobacco products, cigarettes were the most dominant, used by 86.7% of adults who

[1] For further see: https://www.who.int/news-room/fact-sheets/detail/tobacco

are current smokers. These statistics illustrate the popularity of cigarette smoking among the adult population in Nepal.

The global commitment to tackling tobacco use is addressed in the Sustainable Development Goals (SDGs), specifically SDG 3: Good Health and Well-Being. Target 3.a of this goal explicitly calls to "strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control (WHO FCTC) in all countries, as appropriate".

The new initiative of the WHO to estimate e-cigarette use shows that more than 100 million people worldwide are vaping. Most of the countries acknowledge that expanding access to non-cigarette products like electronic cigarettes (e-cigarettes) may serve as a useful harm-reduction policy tool (Kennedy et al., 2017; Shah et al., 2022)and (2.

Recent evidence indicates that vaping carries far fewer health risks than smoking (Sobczak et al., 2020), particularly by lessening the broader and oral-health harms linked to tobacco use (Liu et al., 2025; Polosa et al., 2025). Supporting this, an Italian clinical trial found that vaping can help smokers cut down on tobacco use and improve lung-related health outcomes (Lucchiari, 2019).

Whereas critics argue that the dangers of vaping could be greater, since the long-term health consequences are still not well established (National Academies of Sciences, 2018)little is known about their health effects, and perceptions of potential risks and benefits of e-cigarette use vary widely among the public, users of e-cigarettes, health care providers, and the public health community. For example, whether e-cigarette use confers lower risk of addiction compared with combustible tobacco cigarettes is one point of controversy. Likewise, there are uncertainties about the harm of e-cigarettes themselves, because of the exposure to potentially toxic substances contained in e-cigarette emissions, especially in individuals, such as youth and young adults, who have never used tobacco products. Furthermore, concerns have been raised that e-cigarettes will induce youth to begin using combustible tobacco cigarettes. Given their relatively recent introduction, there has been little time for a scientific body of evidence to develop on the health effects of e-cigarettes. The purpose of this report is to (1. As a result, research literature continues to reflect uncertainty about the exact magnitude of risk reduction provided by vaping.

1.2 Smoking in Nepal

A detailed examination of smoking prevalence in Nepal, primarily drawn from the comprehensive 2019 STEPS survey, reveals critical and deeply entrenched patterns across different demographics. Knowledge about these patterns is essential for understanding the country's tobacco epidemic. The overarching statistic that 28.9% of the adult population (aged 15-69) are current users of either smoked or smokeless tobacco products masks profound disparities. The most striking of these is the dramatic gender divide. The prevalence of any tobacco use is over four times higher among men (48.3%) than among women (10.5%), a pattern that is even more pronounced for smoked tobacco specifically. When isolating smoking, the data shows that 18.5% of all adults are current smokers, which breaks down to 35.3% of men compared to only 2.7% of women. This stark disparity is not merely a statistical observation but is rooted in a complex interplay of socio-cultural norms, where tobacco use among men is often more socially tolerated or even encouraged, while for women, it is frequently stigmatized.

Beyond gender, prevalence also follows distinct socio-economic and geographical gradients. Tobacco use is consistently higher among populations with lower levels of education and those in the poorer wealth quintiles, illustrating the cyclical relationship between poverty, lack of health awareness, and tobacco dependence. This intricate tapestry of demographics is not just descriptive; it is a crucial factor that must be fundamentally incorporated into any dynamic population model. The drivers of smoking initiation, the barriers to cessation, and the potential for switching to alternative products like e-cigarettes are likely to be vastly different for men and women, for the urban and rural populace, and across educational and economic strata in the Nepalese context. A model that fails to account for these subgroups risks producing misleading projections and ineffective policy recommendations.

Nepal has demonstrated a proactive stance in establishing a robust legal framework for tobacco control, a commitment solidified by its ratification of the World Health Organization Framework Convention on Tobacco Control (WHO FCTC) in 2006. This international commitment was translated into national law through the Tobacco Product (Control and Regulatory) Act, 2011, which serves as the cornerstone of the country's anti-tobacco efforts. This legislation is notably comprehensive in its demand-reduction measures. Key provisions include a strict ban on smoking in all public places, such as government offices, healthcare and educational institutions, and public transport, to protect citizens from harmful secondhand smoke. The Act institutes complete prohibition on all forms of tobacco advertising, promotion, and sponsorship, aiming to dismantle the industry's influence on potential new users. In a particularly impactful move, the law mandates that pictorial health warnings cover 90% of the principal display areas on both sides of all tobacco product packages, a requirement that ranks among the largest and most prominent in the world and serves as a powerful tool for public education.

Additional safeguards include a ban on the sale of tobacco to minors under 18 and a prohibition on selling single sticks or loose cigarettes, a measure designed to reduce affordability and accessibility, particularly for youth and low-income populations. Despite this strong foundation focused squarely on conventional tobacco products, the government's regulatory framework faces challenges. The existing legislation was drafted before the global emergence of Electronic Nicotine Delivery Systems (ENDS), such as e-cigarettes and vapes. These newer products operate in a significant regulatory gap, falling outside the explicit definitions and controls of the 2011 Act. This regulatory gap has coincided with the emergence of an informal market for vaping products, raising questions about how such products should be addressed within existing tobacco control frameworks.

1.3 Vaping in Nepal

Vaping in Nepal is best described as existing in a legal and regulatory gray area. While not explicitly legalized or approved for sale, vaping products are increasingly available, particularly in urban centers like Kathmandu and Pokhara, and are marketed through informal channels and social media.

The existing Tobacco Control Act of 2011 defines "tobacco products" in a way that may not comprehensively cover non-combustible, nicotine-containing liquids used in vaping devices. This legislative gap has allowed the market for these products to grow without oversight.

1.4 Policy and Regulation on Smoking and Vaping

At the international level, regulation of vaping products is strongly influenced by the WHO and the broader principles of the Framework Convention on Tobacco Control (FCTC). WHO treats electronic cigarettes as part of the electronic nicotine delivery systems (ENDS) market and adopts a distinctly precautionary stance. It recognizes that e-cigarettes expose users to nicotine and other toxicants, that they are not harmless, and that population-level impacts remain uncertain because long-term evidence is still developing. On this basis, WHO recommends that countries regulate vaping in ways that prevent new nicotine initiation among youth while not closing off potential harm-reduction benefits for adult smokers who might otherwise continue using cigarettes.

WHO guidance also outlines the specific policy tools that most governments have adopted. These include bans on sales to minors, strict controls on marketing and flavor availability that are likely to appeal to adolescents, mandatory disclosure of ingredients and emissions, product safety and quality standards, and extension of smoke-free policies to cover vaping in public spaces. WHO further recommends applying taxation proportional to health risk so that e-cigarettes do not become cheaper, more accessible substitutes for nicotine initiation among young people. The organization allows flexibility in classification, advising countries to regulate ENDS as tobacco products, consumer products with strict controls, or medicines, depending on national priorities and the health system context.

Within this global framework, three broad regulatory approaches dominate. The United Kingdom and many European settings most clearly represent a regulated harm-reduction model. In these contexts, vaping remains legal and is framed in policy as a cessation support or lower-risk substitute for smoking, but with tight restrictions on product design and promotion. The UK Tobacco and Related Products Regulations (TRPR 2016), which implement the EU Tobacco Products Directive, limit nicotine concentration to 20 mg/mL, require child-resistant packaging and prominent health warnings, mandate advance notification of ingredients to regulators, restrict advertising, and enforce minimum-age purchasing laws. Public health agencies in the UK reinforce these rules with messaging that vaping is substantially less harmful than smoking and can aid quitting for adult users, thereby strengthening the substitution and cessation pathway while attempting to reduce youth gateway risk through marketing and access controls.

A second model can be described as precautionary regulation driven by youth-epidemic concerns, most visible in the United States and Canada. In the U.S., e-cigarettes are legally treated as tobacco products under FDA authority and must pass premarket tobacco product application (PMTA) review demonstrating net public-health benefit. Regulatory enforcement has aggressively focused on youth-appealing products, particularly those with sweet or fruit flavors, because they are linked to rapid adolescent uptake. A major recent reinforcement of this approach came in April 2025, when the U.S. Supreme Court unanimously upheld FDA denials of flavored e-liquid applications, confirming the agency's right to block products judged likely to attract youth or undermine public health. At the same time, the FDA has continued to allow a narrow set of tobacco- or menthol-flavored devices when evidence suggests they may help adult smokers switch. Behaviorally, this approach aims to suppress the gateway pathway by shrinking youth-friendly markets, while keeping a limited harm-reduction channel open. However, the literature also warns that stringent flavor bans can foster informal markets, which may sustain youth access and complicate cessation messaging when product safety and legitimacy become uncertain.

A third model is outright prohibition, adopted in several countries, including India, Thailand, and some Middle Eastern states, and historically echoed in Nepal. Under this model, governments ban import, sale, or advertising of vaping products, typically arguing that precaution is justified by uncertain long-term harm and the priority of youth protection. Although prohibition intends to prevent both gateway initiation and the renormalization of smoking-like behaviors, international evidence suggests that bans often shift access to illegal or informal supply chains. Such markets reduce oversight and may increase exposure to unsafe counterfeit liquids, while also enabling hidden dual use rather than eliminating nicotine uptake. In behavioral terms, prohibition may therefore reduce visible normalization but not necessarily reduce real consumption among motivated youth or dependent smokers.

Nepal's approach to vaping has been shaped by its broader tobacco control framework rather than by a vaping-specific law. The Tobacco Products Control and Regulation Directive 2015 (2071 B.S.) has been interpreted by the Ministry of Health to cover electronic cigarettes under tobacco product controls, particularly under Sub-rule 3 of Rule 28. This rule has been repeatedly cited to justify prohibiting the production, import, sale, distribution, advertising, and public-place use of e-cigarettes. In formal terms, therefore, Nepal aligned with the prohibition model, similar to other South Asian countries that have attempted to suppress vaping on a preventive basis.

Despite this legal framing, Nepal's policy trajectory demonstrates a significant gap between regulation and enforcement. In 2024, the National Health Education, Information and Communication Center (NHEICC) issued renewed circulars directing customs and commerce authorities to actively stop the import and sale of vapes, emphasizing rising youth use and uncertain health harms as core rationales. Media reports at that time indicated substantial vape imports and a growing market despite the ban, signaling that vaping had already become embedded through informal availability. Behaviorally, this mismatch suggests that prohibition did not eliminate access; instead, it likely encouraged unregulated supply routes, the same condition that international literature links to sustained experimentation and dual use.

In mid-2025, Nepal's prohibition stance shifted sharply after judicial intervention. The Patan High Court ruled that the government could not impose a blanket restriction on the import and sale of vapes solely through ministerial circulars and ordered the earlier ban attempt lifted.[2] This decision moved Nepal from de facto prohibition to conditional legality, at least in practice, and reopened the policy question of how vaping should be regulated moving forward. From a smoking-behavior perspective, the ruling matters because it potentially re-enables vaping as a cessation substitute for adult smokers, while simultaneously risking wider youth access if retail enforcement remains weak.

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[2] For detail news see: https://myrepublica.nagariknetwork.com/news/patan-high-court-snuffs-out-govts-e-cigarette-ban-attempt-46-43.html

Tobacco control in Nepal operates with limited monitoring and inconsistent penalties. The implication for vaping is that any move toward regulated legality without strong enforcement of age-of-sale rules, marketing restrictions, and product standards could increase youth experimentation and create persistent dual-use norms in which vaping is used in some spaces while cigarettes continue in others. In that sense, Nepal's policy impact will be determined less by legal text and more by the strength of implementation systems.

Taken together, Nepal stands at a policy crossroads after the 2025 court ruling. It may attempt to restore prohibition through stronger legislative grounding, or it may transition toward a regulated harm-reduction model resembling the UK, where adult switching is supported, but youth appeal is tightly controlled. Understanding the public health impact of vaping would depend on improved monitoring of vaping prevalence, dual use, and cessation outcomes.

1.5 Objective of the study

The general objective of this study is to evaluate the impacts of e-cigarette use through its effects on health risk, smoking cessation, and initiation, using a dynamic population modeling approach.

The specific objectives of this study are to:

1. Assess the impact of e-cigarette use on smoking cessation and smoking initiation under a range of plausible behavioral and health-risk assumptions.
2. Analyze the distribution of health outcomes across different e-cigarette scenarios, identifying conditions under which vaping leads to net health gains or losses.
3. Examine gender-specific differences in smoking prevalence, cessation behavior, life years lost, and life years saved among males and females.

1.6 Rationale

Several countries have explored non-combustible nicotine products as part of broader harm-reduction strategies, although the public health impacts remain debated (Kennedy et al., 2017)and (2, while Nepal has not taken any clear action in this regard. The rationale for this study is threefold: to address critical gaps in public health policy, research methodology, and strategic planning in Nepal.

First, from a public health policy perspective, Nepal stands at a crossroads. The unchecked growth of the vaping market, coupled with a high baseline smoking prevalence, presents a complex challenge. Policymakers are faced with a dilemma: should vaping be banned to prevent a new nicotine epidemic, particularly among the youth, or could it be regulated as a less harmful alternative for entrenched adult smokers who are unable to quit? Currently, decisions are being made in an evidence vacuum. This study aims to fill this void by providing a quantitative, scenario-based analysis to inform evidence-based policymaking tailored to Nepal's unique socio-cultural and epidemiological landscape.

Second, from a methodological standpoint, static models are insufficient to capture the complex, feedback-rich dynamics of nicotine product use. A dynamic population simulation model, such as a system dynamics or agent-based model, is essential. This approach can account for transitions between different states of smoking and vaping, the influence of peer networks, the impact of marketing, and the effects of policy interventions over time. It allows testing "what-if" scenarios in a virtual environment, providing insights that are not possible through observational studies alone. This model will be the first of its kind developed specifically for the Nepalese context.

Third, from a strategic planning perspective, the findings of this study will be crucial for aligning Nepal's tobacco control efforts with SDG 3. The model allows exploration of how different behavioral assumptions may influence long-term tobacco-related health outcomes. It will provide a cost-effective tool for prioritizing limited public health resources. Should the government focus more on enforcing existing laws, launching campaigns against vaping, or developing a nuanced regulatory framework for nicotine products? This research provides scenario-based evidence that may inform future discussions on tobacco control strategies.

1.7 Organization of Study

This report is organized into five chapters. Chapter One introduces the study by outlining the background, public health relevance, and objectives related to tobacco harm reduction in Nepal. Chapter Two reviews the relevant literature, including theoretical perspectives, empirical evidence, and population-level modeling studies, with particular attention to identified research gaps. Chapter Three describes the research methodology, detailing the population simulation model, data sources, assumptions, and scenario design. Chapter Four presents the results of the baseline analysis, where initiation and cessation rates, and smoking status, are presented by wise status. Chapter Five presents the results of simulations across different scenarios and the results for the most plausible scenario. Chapter Six concludes the report by summarizing key findings, discussing policy implications, and identifying limitations and directions for future research. The references used in this report are listed in Chapter Seven.

2. Literature Review

The literature on tobacco control and emerging nicotine products reflects a transition from a singular focus on smoking cessation toward a broader evaluation of harm reduction strategies and their population-level implications. While traditional epidemiological evidence firmly established the health risks of combustible tobacco and informed global control measures, the introduction of alternative nicotine delivery systems, particularly e-cigarettes, has complicated the public health landscape. A few current research highlights a dynamic interplay between potential harm reduction benefits for existing smokers and risks related to youth initiation, dual use, and regulatory uncertainty. At the same time, variations in regulatory approaches and limitations in existing evaluation methods underscore the need for context-specific analysis. The following sections review key themes in this evolving field, including the conceptual basis of tobacco harm reduction, evidence on e-cigarettes, regulatory frameworks, the role of simulation models, the rationale for a Nepal-specific approach, and finally specifying research gaps.

2.1 Tobacco harm reduction as a public-health concept

Historical accounts situate tobacco's global spread within colonial trade and cultural appropriation, moving from Indigenous use in the Americas into European markets and then globally through imperial networks, becoming embedded in social norms (Musk & de Klerk, 2003). The transition from pipes and cigars to cigarettes, accelerated by mechanized production and wartime normalization, reframed tobacco as a scalable, everyday product with higher population exposure.

Epidemiological evidence established the causal relationship between smoking and disease through case–control studies (Doll & Hill, 1950; Wynder & Graham, 1950) and longitudinal cohort studies demonstrating dose–response relationships (Doll & Hill, 1954). Institutional syntheses expanded this evidence base to include cardiovascular and respiratory diseases (U.S. Department of Health, Education, and Welfare, 1964), while global estimates continue to highlight persistent disease burden despite declining prevalence in some regions (GBD, 2019). Evidence on secondhand smoke further broadened the public health focus, linking involuntary exposure to disease outcomes (Hirayama, 1981; NHMRC, 1997; WHO, 2025). This body of evidence not only established smoking as a leading preventable cause of disease but also shifted public health from individual-level risk recognition toward population-level intervention strategies, forming the empirical foundation for modern tobacco control policies and subsequent harm-reduction debates.

The concept of tobacco harm reduction (THR) emerged from attempts to reduce exposure to toxic constituents of tobacco products. Early strategies, such as low-tar cigarettes, were based on the assumption that reduced toxic exposure would lower disease risk (Hoffmann et al., 2001). However, these approaches failed due to compensatory smoking behavior and an incomplete understanding of nicotine addiction (Parascandola, 2005). Subsequent analyses emphasized that focusing solely on product design without accounting for user behavior limits real-world effectiveness (Hatsukami et al., 2002; Stratton et al., 2001). This experience highlighted that harm reduction strategies cannot be evaluated solely on product-level risk reduction, but must incorporate behavioral responses and patterns of use, which ultimately determine their real-world public health impact.

THR is now understood as a population-level risk management strategy shaped by interactions between product characteristics, user behavior, and regulatory context (Shiffman et al., 2002). Warner (2002) highlights the concept of a risk–use equilibrium, emphasizing that population-level outcomes depend not only on product toxicity but also on patterns of initiation, cessation, relapse, and dual use. While some evidence supports the potential of low-risk nicotine alternatives for highly dependent smokers, the literature consistently stresses that harm reduction must complement prevention and cessation efforts and be evaluated in terms of overall population impact (Warner, 2002; Shiffman et al., 2002; Phillips & Rodu, 2013). This framing underscores that the public health value of harm reduction is inherently conditional, requiring careful balancing of individual-level benefits against potential population-level risks arising from changes in behavior and product uptake.

2.2 Evidence on e-cigarettes

E-cigarettes were introduced in 2003 and promoted as safer alternatives to conventional cigarettes and as potential smoking cessation tools (West, 2017). Emerging evidence suggests that nicotine e-cigarettes may support smoking cessation in some adult smokers, though findings remain mixed and context-dependent (Hajek et al., 2019; Lindson et al., 2024). However, dual use, where individuals use both e-cigarettes and combustible cigarettes, is common and may reduce or negate potential harm-reduction benefits. This suggests that the effectiveness of e-cigarettes as a harm-reduction tool depends not only on their capacity to promote cessation but also on whether they lead to complete substitution rather than sustained concurrent use.

A significant concern is the rapid increase in youth uptake. E-cigarettes are widely marketed with appealing flavors, designs, and discreet usability, which has contributed to increased use among adolescents (Dinardo & Rome, 2019; Ford et al., 2016; University of Bath, 2021; Blaha, 2020b). Evidence suggests that early exposure to e-cigarettes may increase the likelihood of subsequent use of conventional cigarettes or other substances (Berry et al., 2019; Talih et al., 2018; Pesko et al., 2018). This pattern raises concerns that e-cigarettes may not only function as harm-reduction tools for existing smokers but also as potential pathways for nicotine initiation, thereby complicating their overall population-level impact.

E-cigarettes expose users to nicotine and various chemicals, including particulate matter and toxic substances, which have been associated with respiratory and cardiovascular effects, although long-term health impacts remain uncertain due to limited longitudinal evidence (Callahan-Lyon, 2014; National Academies of Sciences, Engineering, and Medicine, 2018; American Lung Association, 2024; Rowell et al., 2017; Marques et al., 2021; Ghosh et al., 2019). Taken together, this evidence indicates that while e-cigarettes are generally considered less harmful than combustible tobacco, they are not risk-free, and their long-term health effects remain uncertain. This uncertainty complicates their positioning within harm-reduction frameworks, as potential individual-level risk-reduction measures must be weighed against incomplete knowledge of cumulative exposure and population-level consequences. As a result, the public health evaluation of e-cigarettes remains contingent on both emerging scientific evidence and real-world use patterns.

2.3 Regulatory measures

Regulatory approaches to e-cigarettes vary across countries and are largely shaped by how products are classified—as tobacco products, medicinal products, or consumer goods (Kennedy et al., 2017). This classification determines the scope of regulatory instruments, including advertising restrictions, product standards, and market access.

Across jurisdictions, common regulatory measures include minimum age-of-sale laws, restrictions on indoor use, and controls on advertising and promotion (Kennedy et al., 2017). The European Union's Tobacco Products Directive (Directive 2014/40/EU) represents a key example of regional harmonization, including limits on nicotine concentration and product reporting requirements (Kennedy et al., 2017). However, regulatory implementation remains uneven, particularly in low- and middle-income countries, where enforcement capacity and market dynamics differ significantly.

Regulation is further complicated by a "regulate-while-learning" challenge, as policymakers must act despite incomplete evidence on long-term health effects and population-level impacts (Kennedy et al., 2017). Recent evidence suggests that regulatory frameworks should balance enabling access to smoking cessation for adults with strong protection against youth initiation and against misleading risk perceptions (Lindson et al., 2024; WHO, 2023; WHO, 2025). This highlights that e-cigarette regulation involves managing inherent policy trade-offs under uncertainty, where overly restrictive or permissive approaches may both produce unintended public health consequences.

2.4 Population simulation studies

Population simulation studies have become increasingly important in tobacco control because many of the most policy-relevant questions cannot be answered solely with short-term observational data. Smoking-related disease develops over decades, and the public-health effects of new nicotine products are mediated not only by toxicological risk but also by behavioral responses such as initiation, cessation, relapse, and dual use. For this reason, simulation modeling provides a way to translate existing epidemiological and behavioral evidence into long-term population projections. In the broader tobacco control literature, this methodological need is closely linked to the recognition that policy effects must be understood at the population level rather than only at the level of individual risk, an idea already emphasized in the harm-reduction literature by Warner (2002) and Shiffman et al. (2002), who argue that reduced-risk products can only be evaluated meaningfully through their net effects on cessation, initiation, and continued use rather than through product toxicology alone.

In this respect, simulation studies extend earlier public-health reasoning. Once epidemiological evidence had established the causal effects of smoking on mortality and morbidity, the next analytical challenge became estimating how changes in smoking behavior would affect future disease burdens. Dynamic population models address this by projecting populations over time while tracking transitions across smoking states such as never smoker, current smoker, and former smoker. Mendez and Warner (2021) employ such a model for the United States, following individuals by age, gender, and smoking status to estimate smoking-related life-years lost in a no-vaping scenario and then comparing these with alternative vaping scenarios. Likewise, Mzhavanadze and Yanin (2023) construct a tailored simulation model for the Russian Federation, using country-specific demographic and smoking data to estimate cumulative life-years lost from smoking and the extent to which vaping might alter this burden under different assumptions. These studies illustrate how simulation modelling can convert abstract harm-reduction debates into measurable public-health outcomes.

A major strength of population simulation studies is their ability to explicitly examine uncertainty. This is especially valuable in the e-cigarette field, where evidence remains contested regarding cessation efficacy, youth uptake, dual use, and long-term health risk. Rather than assuming a single, fixed pathway, models typically generate multiple scenarios by varying key parameters. Mendez and Warner (2021) examine 360 scenarios that differ according to the assumed effect of vaping on cessation, smoking initiation, vaping-related health risk, age-related cessation patterns, and which types of smokers benefit most from vaping. Their results show that

357 of 360 scenarios yield positive life-years saved, suggesting that vaping is highly likely to reduce smoking-related mortality under the assumptions tested, although the scale of benefit varies widely. Similarly, Mzhavanadze and Yanin (2023) simulate 210 scenarios for Russia and find positive life-years saved in 88.1% of them, with projected effects ranging from a loss of 3.3 million life-years to a gain of 38.5 million life-years over 80 years. This wide range is itself an important finding: it shows that projected population benefit is highly conditional, not automatic.

These studies also demonstrate what simulation models are particularly good at showing. First, they clarify the relative importance of different assumptions. In both the U.S. and Russian applications, the projected health impact of e-cigarettes is driven most strongly by their effect on smoking cessation rather than by moderate changes in assumed vaping risk. Mendez and Warner (2021) show that higher cessation effects consistently generate larger population benefits, and that outcomes are greatest when vaping helps smokers who would otherwise have the hardest time quitting. Mzhavanadze and Yanin (2023) reach a similar conclusion, noting that the life-saving potential of vaping is more sensitive to changes in cessation assumptions than to changes in initiation or relative harm assumptions within the ranges they test. In this sense, simulation studies help identify which empirical uncertainties matter most for policy.

Second, simulation studies are useful for illustrating trade-offs among competing public health concerns. This is highly relevant to e-cigarette policy, where a product may simultaneously support cessation for some adult smokers while increasing nicotine uptake among youth or sustaining dual use among others. The logic of balancing these competing pathways is consistent with earlier work on the population-level risk of harm-reduction strategies and with later regulatory scholarship emphasizing the need to weigh cessation benefits against youth protection and market expansion (Kennedy et al., 2017; Shah et al., 2022). Modeling does not eliminate these tensions, but it makes them analytically visible by testing how much benefit from increased cessation would be required to offset harm from increased initiation or residual product risk.

At the same time, literature is equally clear that simulation studies have important limits. The first and most fundamental limitation is that they are assumption dependent. Their outputs are conditional projections, not direct observations of future reality. If the assumptions about vaping's effect on cessation or initiation are wrong, the conclusions change accordingly. Mendez and Warner (2021) explicitly acknowledge that their model depends on the assumption that vaping increases cessation; if this assumption does not hold, the projected benefit disappears. Mzhavanadze and Yanin (2023) similarly show that negative population outcomes can emerge under combinations of low cessation benefit, increased initiation, and elevated vaping-related risk. Thus, simulation results should not be read as proof that e-cigarettes will necessarily improve public health, but rather as structured estimates of what may happen under specified conditions.

A second limitation is that simulation studies simplify behavior. Most models necessarily reduce complex real-world pathways into a manageable set of transition states and rates. For example, Mendez and Warner (2021) assume smoking initiation at age 18, fixed background initiation and cessation rates, and scenario-specific effects of vaping on these transitions. Mzhavanadze and Yanin (2023) also hold key parameters constant over time and acknowledge that their model does not fully capture relapses, all forms of dual use, or all possible changes in tobacco markets and policy environments. These simplifications are methodologically sound, but they mean models cannot fully capture the fluidity of real nicotine-use trajectories, especially when products evolve rapidly and regulation changes over time.

A third limitation concerns the measurement of policy and context. The earlier policy literature already suggests that simple presence-or-absence measures of regulation can miss important differences in enforcement, market structure, and compliance (Kennedy et al., 2017; Shah et al., 2022). This matters for simulation modeling because policy effects enter the model indirectly through assumed changes in cessation, initiation, or product uptake. If real-world enforcement is weak or markets are highly informal, the behavioral assumptions underlying the model may misstate likely outcomes. In this sense, simulation models are only as strong as the policy and behavioral evidence used to parameterize them.

A fourth limitation is external validity. Simulation results are highly context-sensitive and may not travel easily from one setting to another. This is one of the most important lessons from the Russian Federation study. Mzhavanadze and Yanin (2023) argue that estimates of vaping's population impact are scarce outside high-income countries such as the United States and the United Kingdom; therefore, they build a country-specific model using Russian demographic data, smoking prevalence, mortality profiles, and smoking transition estimates. Their work shows that baseline smoking prevalence, sex-specific smoking patterns, cessation rates, regulatory direction, and product accessibility all shape projected outcomes. This aligns closely with your earlier argument that policy evaluation must move beyond generic international models and instead attend to local behavioral and regulatory conditions.

For this reason, the value of simulation studies lies less in precise forecasting than in disciplined scenario analysis. They are especially useful for showing the range of plausible consequences under competing assumptions, identifying which parameters are most consequential, and clarifying where better evidence is most needed. Lee et al. (2020), as cited in the modeling literature, note that there are multiple approaches to estimating the population health impact of modified-risk products, each with different assumptions and implications, reinforcing that modeling results are inherently shaped by methodological design choices. This supports a cautious reading of simulation outputs: they are best understood as decision-support tools, not as definitive answers.

The simulation literature suggests that e-cigarettes may generate population health gains if they substantially increase cessation and do not produce large increases in initiation or prolonged dual use. However, the same literature also shows that these benefits are contingent, assumption-sensitive, and context-dependent. In that sense, population simulation studies can show the likely direction and possible magnitude of effects under specified conditions, but they cannot directly observe long-term outcomes, settle causal disputes in the empirical literature, or substitute for country-specific data. Their greatest contribution is therefore analytical rather than predictive: they help policymakers and researchers think more clearly about what must be true for harm reduction to produce a net public-health benefit (Mendez & Warner, 2021; Mzhavanadze & Yanin, 2023).

2.5 Research Gap

Simulation-based modeling has become an established and increasingly important approach for assessing the long-term population health impacts of tobacco control and harm-reduction strategies, particularly in contexts where experimental or longitudinal epidemiological evidence is not feasible. Dynamic population models allow researchers to translate changes in smoking behaviour, such as initiation, cessation, relapse, and product substitution, into measurable outcomes such as life-years lost (LYL) and life-years saved (LYS). Existing studies demonstrate that under a wide range of assumptions, e-cigarettes may contribute to reductions in smoking-related mortality, primarily through increased cessation, although outcomes remain highly sensitive to behavioural assumptions and product risk profiles (Mendez & Warner, 2021; Mzhavanadze & Yanin, 2023).

Despite these methodological advances, the current body of simulation-based evidence is both geographically and contextually limited. Most modeling studies have been conducted in high-income or selected upper-middle-income countries, such as the United States and the Russian Federation, where demographic structures, baseline smoking prevalence, healthcare access, and regulatory environments differ substantially from those in low and middle-income countries. These models are calibrated using country-specific data inputs, such as cessation rates, initiation patterns, and mortality risks, which are not directly transferable across contexts. As highlighted in broader tobacco control literature, the effectiveness of policies and the dynamics of tobacco use are strongly shaped by local factors, including enforcement capacity, informal markets, cultural norms, and public risk perception (Kennedy et al., 2017; Shah et al., 2022; WHO, 2023; WHO, 2025). Consequently, applying findings from existing models to different settings may lead to inaccurate or misleading policy conclusions.

The existing simulation studies often simplify behavioral pathways and may not fully capture context-specific patterns of tobacco and nicotine use. For example, assumptions regarding initiation age, dual use, cessation dynamics, and product transition pathways are typically standardized within models, yet these patterns can vary significantly across populations. In low- and middle-income settings, factors such as affordability, accessibility of cessation support, regulatory enforcement gaps, and the presence of informal or unregulated markets may alter how individuals interact with both conventional tobacco and emerging products such as e-cigarettes. These contextual differences introduce additional uncertainty that models developed in other settings do not adequately address.

In Nepal, this gap is particularly evident. Nepal faces a significant burden of tobacco-related morbidity and mortality, while simultaneously experiencing evolving patterns of nicotine product availability and use. However, there is a lack of simulation-based studies that systematically evaluate how different tobacco use trajectories may influence long-term population health outcomes in the Nepalese context.

Therefore, a critical research gap exists in the application of dynamic population simulation modeling to Nepal. Addressing this gap requires developing a context-specific model that incorporates Nepal's demographic structure, smoking prevalence, and behavioral patterns. Such a model would not only extend existing methodological frameworks to a previously under-researched setting but also provide locally relevant evidence to support more informed, evidence-based tobacco control and harm-reduction policy decisions.

3. Data And Methodology

3.1 Research Design

This study adopts a quantitative research design employing a dynamic population simulation model to estimate the long-term impact of vaping on smoking behavior in Nepal. This design builds a population-level smoking model and then introduces vaping through a large set of alternative behavioral assumptions. In the Nepalese context, the model will track cohorts from birth through older ages, stratified by sex and smoking status, and project population transitions across nicotine-use states under counterfactual vaping scenarios. The central logic is that vaping may alter smoking behavior through three pathways identified in the literature and operationalized in the base model: it may increase adult cessation (harm-reduction pathway), change youth initiation (gateway or replacement pathway), and introduce vaping-related residual health risk among those who quit smoking by switching to vaping.

The simulation begins from a Nepal-specific baseline year selected as the most recent pre-pandemic year with complete data on population structure, smoking prevalence, and mortality by age and sex (the base paper uses 2019 for the same reason). From that baseline, the model updates annually: a new birth cohort enters; individuals age forward; never-smokers may initiate smoking at the initiation age; current smokers may quit and enter the former-smoker category; and each group experiences mortality risks that differ by smoking status. The model is then run forward for a long horizon (80 years in the base paper), because the full health and behavioral effects of smoking and vaping are only visible in long-run cohort replacement.

3.2 Data and Sources

This study relies exclusively on secondary data sources to parameterize and calibrate the dynamic population simulation model for Nepal. Data inputs were selected to ensure consistency with internationally recognized demographic, epidemiological, and tobacco surveillance standards, as well as comparability with the base simulation study on which the methodology is adapted.

Population data were obtained from the United Nations Population Division Data Portal, which provides official demographic estimates and projections by age and sex. Age-specific population counts were extracted for Nepal for the year 2019, using the medium (median) variant, and stratified into age groups ranging from 0 years to 65 years and above. These data were used to initialize the simulation model's baseline population structure and to model cohort ageing over time.

Mortality data were also derived from the United Nations Population Division Data Portal. The total number of deaths by age and sex for Nepal in 2019 (medium variant) was extracted and subsequently converted into age- and sex-specific death rates. These mortality rates were applied in the model to estimate population exits and to calculate survival differences across smoking status categories, after adjustment using relative risk estimates.

Smoking prevalence data were obtained from the WHO STEP-wise Approach to Surveillance (STEPS) Survey 2019, which is the most recent nationally representative source of tobacco-use data for Nepal. Age- and sex-specific smoking prevalence estimates were used to classify the baseline population into never smokers, current smokers, and former smokers, and to estimate background smoking initiation and cessation patterns consistent with the approach used in the base paper.

Disease-specific mortality and burden estimates required for model validation and health impact assessment were sourced from the Global Burden of Disease (GBD) Collaborative Network. The GBD Study Results Tool was used to extract age- and sex-specific disease burden data, classified by ICD-10 codes. These data support the estimation of smoking-attributable mortality and facilitate consistency with global comparative risk assessment frameworks.

3.3 Analytical Framework

In this study, a dynamic population model with baseline year 2019 was employed to track individuals from the age of 0 to 65+, who are differentiated by gender and smoking status[1]. The preliminary requirement for constructing the model is to estimate the population by age, sex, and smoking status at

[3] Smoking status includes never smokers, current smokers, and former smokers.

the baseline year. Sex- and age-specific population data for the baseline year (2019) are extracted from the UN Population Division's Data Portal. Further, to estimate the sex and age-specific smoking prevalence in the baseline year, STEPS-2019[2] was used. STEPS is a representative dataset that collects socio-demographic and behavioral information (tobacco, alcohol, diet, and physical activity) in Nepal. Apart from the smoking prevalence, behavioral parameters such as smoking initiation rate and cessation rate are also estimated using the same microdata.

Based on STEPS-2019, all the adults who presently report smoking are attributed to the current smoker group, regardless of their smoking intensity. These are the individuals who respond positively to the question “T1: Do you currently smoke any tobacco products?” in the survey. Similarly, all the adults who used to smoke in the past but do not smoke at present are grouped as former smokers. These are the individuals who respond positively to the question “T8: In the past, did you ever smoke any tobacco products?” and respond negatively to the question “T1: Do you currently smoke any tobacco products?”. Those individuals who are not currently smoking and have not smoked in the past are grouped as never smokers. From this microdata, the proportion of the population by smoking prevalence is estimated, which is later interacted with the sex- and age-specific baseline-year population to obtain the baseline-year population by age, sex, and smoking status.

A constant new birth cohort is assumed each year, with the number of births remaining at the baseline year level. Furthermore, the smoking initiation is assumed to occur only at the age of 18 years, and those who start after this age are considered current smokers. A similar assumption can be found in the various studies, like Jin et al. (2015) and Mendez & Warner (2021)we discuss evidence that suggests the consumer benefits substantially outweigh the costs. We then turn to a prospective BCA of future anti-smoking Food and Drug Administration (FDA. After the age of 18 years, some smokers begin to quit smoking habit, and those who quit are former smokers. Also, it is assumed that the recurrence of initiation doesn’t happen.

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[4] STEPS-2019 is the survey of noncommunicable disease risk factors in Nepal, carried out from February to May 2019.

Table 3.1: Operations in STEPS - 2019

Never smokers	T1: Do you currently smoke? No T8: In the past, did you **ever smoke** any tobacco products?) No	Age: Current Age	**Proportion**: Never Smoker of an age / Total population of that age	
Current Smokers	T1: Do you **currently** smoke any **tobacco** products?) yes	Age: Current Age	**Proportion:** Current Smoker of an age / Total Population of that age	
Former Smokers	T1 & T8 T1 if no; T8 if Yes	Age: Current Age	**Proportion:** Former Smoker of an age / Total Population of that age.	
Initiation Rate	T3: How old were you when you started smoking?			If one has started at 0 -18 years, it is counted towards the initiation rate. The above quantity should then be divided by the population at risk.
Cessation Rate	T1: Do you currently smoke? No T8: In the past, did you ever smoke any tobacco products? Yes T11a: How long ago did you stop smoking? [If one year ago]		Cessation Rate= Number of those who quit in the last year/Number of smokers at the beginning of the last year	If one has stopped smoking in the last year and does not smoke currently, it should be used to calculate the cessation rate.

3.3.1 Death Rate Estimation

For estimation of the disease-specific death rate, the relative risk to adult mortality from smoking-related diseases, adults 35 years of age and older, based on Cancer Prevention Study II, United States, was taken, which lists the ICD code-wise smoking attributable diseases. Based on the ICD code and nature of the diseases, the death rate is extracted from the Global Burden of Disease Collaborative Network. The disease-specific death rate reported is the death per 100,000, which is converted to a unit rate to obtain the required death rate. This death rate is further used to estimate the death rate by age, sex, and smoking status. The formula used is as follows:

$$\mu_N(s,a,d)=\frac{\mu_P(s,a,d)}{\frac{N(s,a)}{P(s,a)}+\frac{S(s,a)}{P(s,a)}*RR_S(s,a,d)+\frac{F(s,a)}{P(s,a)}*RR_F(s,a,d)}$$

Where, $RR_S(s,a,d)$ and $RR_F(s,a,d)$ are sex-, age-group- and disease-specific relative rates for adult mortality from smoking-related diseases for current and former smokers, respectively;

$\mu_N(s,a,d)$, $\mu_S(s,a,d)$ are $\mu_F(s,a,d)$ the death rates of never-smokers, smokers, and former smokers of sex , age and the smoking-related disease category d ;

$\mu_P(s,a,d)$ is the sex-, age-, and disease-specific mortality rate for the general population (which includes never, current, and former smokers) obtained from the Global Burden of Disease Network.

$P(s,a)$ is the sex- and age-specific population.

$N(s,a), S(s,a)$ are $F(s,a,)$ the sex- and age-specific populations of never-smokers, current smokers, and former smokers, respectively.

After the calculation of the death rate for never smokers, it is multiplied by the relative risk to obtain the values of the death rate for current and former smokers, which is specified as follows:

$$\mu_S(s,a,d) = RR_S(s,a,d) * \mu_N(s,a,d)$$

$$\mu_F(s,a,d) = RR_F(s,a,d) * \mu_N(s,a,d)s$$

Finally, sex- and age-specific death rates by smoking status are calculated as follows:

$$\mu_N(s,a) = \sum_{d=1}^{19} \mu_N(s,a,d)$$

$$\mu_S(s,a) = \sum_{d=1}^{19} \mu_S(s,a,d)$$

$$\mu_F(s,a) = \sum_{d=1}^{19} \mu_F(s,a,d)$$

After obtaining the population by age, sex, and smoking status, and the death rate by age, sex, and smoking status, baseline calibration was done, which used the initiation and cessation rates calculated before.

1.1.1 Baseline Model Setup

For the baseline calibration, a series of linear formulas was applied, as specified below:

$P(s,0,t) = P(s,0,t-1)$,

$N(s,0,t) = P(s,0,t)$,

$N(s,a,t) = N(s,a-1,t-1) * \left(1-\mu_N(s,a-1)\right)$ for $a \neq 18$,

$N(s,18,t) = N(s,17,t-1) * \left(1-\mu_N(s,17)\right) * \left(1-\gamma(s)\right)$,

$S(s,a,t) = 0$ for $a < 18$,

$S(s,18,t) = N(s,17,t-1) * (1-\mu_N(s,17)) * \gamma(s)$,

$S(s,a,t) = S(s,a-1,t-1) * (1-\mu_S(s,a-1)) * \left(1-\rho(s)\right)$ for $a > 18$,

$F(s,a,t) = 0$ for $a < 19$,

$F(s,a,t) = F(s,a-1,t-1) * \left(1-\mu_F(s,a-1)\right) + S(s,a-1,t-1) * \mu_S(s,a-1) * \rho(s,a-1)$ for a ≥ 19,

where:

$P(s,a,t)$ is the population of sex s, age a, in year t,

$N(s,a,t)$, $S(s,a,t)$ are $F(s,a,t)$ the population of never-smokers, current smokers, and former smokers of sex s, age a, in year t,

$\mu_N(s,a)$, $\mu_S(s,a)$ are $\mu_F(s,a)$ death rates of never-smokers, smokers, and former smokers of sex s, age a,

$\rho(s)$ is the smoking cessation rate of smokers of sex s,

$\gamma(s)$ is the smoking initiation rate of smokers of sex s,

Using this model, it projects the population size by smoking status for each year and every year of age for 80 years starting from the baseline of 2019.

3.4 Simulation Strategy

In the first stage of simulation analysis, replication of the Nepalese population under two reference scenarios was done:

1. Status quo scenario: assuming a continuation of baseline smoking initiation and cessation rates for the following 80 years.
2. A never-smoking scenario: assuming no one ever smoked, nobody smokes in the baseline year or will smoke in the future. There is no smoking-related death, indicating all individuals are subject to the same death rates as never smokers.

Then, for simulation scenarios, vaping was introduced in the model with the assumption that vaping will change the smoking cessation rate and initiation rate, with consideration of the health risk of vaping. The scenario assumptions are as shown in *Table 3.2*. To evaluate the potential population health effects of e-cigarettes, the model incorporates assumptions regarding how vaping may influence smoking cessation, smoking initiation, and health risks relative to conventional smoking. These assumptions follow the scenario-based modeling framework developed by Mendez and Warner (2021) and applied in similar dynamic population simulation studies assessing tobacco harm-reduction policies.

First, the model assumes that e-cigarette use may increase smoking cessation among existing smokers. Specifically, the baseline cessation rate is allowed to increase by **5%, 10%, 25%, 50%, 100%, or 200%**, representing varying levels of effectiveness of vaping as a cessation aid at the population level. This range reflects evidence suggesting that e-cigarettes can improve the success rate of quit attempts among smokers (Hartmann-Boyce et al., 2021; Chambers, 2022). Second, the model allows vaping to affect smoking initiation rates. To capture uncertainty regarding the potential gateway or substitution effects of e-cigarettes, the annual smoking initiation rate is allowed to vary by **−20%, −15%, −10%, 0%, +10%, +15%, or +20%** relative to the baseline rate. Negative values represent scenarios in which vaping substitutes for combustible cigarettes and reduces initiation, whereas positive values represent scenarios in which vaping increases the likelihood of smoking uptake among non-smokers (Soneji et al., 2017; Kim & Selya, 2020).

Finally, the model incorporates uncertainty regarding the **relative health risks of vaping compared with cigarette smoking**. Individuals who quit smoking with the assistance of e-cigarettes are assumed to retain a residual mortality risk relative to those who quit without vaping. This additional risk is modeled as **0%, 2.5%, 5%, 10%, or 20% of the mortality risk associated with continued smoking,** reflecting the range of uncertainty surrounding the long-term health effects of vaping (Royal College of Physicians, 2016; McNeill et al., 2018).

Table 3.2 Scenario Assumptions

Impact of vaping on cessation rate	Impact of vaping on initiation rate	Health risk of vaping for former smokers
5%	-20%	0%
10%	-15%	2.50%
25%	-10%	5%
50%	0%	10%
100%	10%	20%
200%	15%	
	20%	

With the combination of these scenario assumptions, 210 different scenarios are developed, and the result is compared with the reference scenario mentioned above.

4. Baseline Result

The baseline year for this study is 2019. In this section, a brief overview of the data during the baseline year is reported. In the baseline year, we assume that there is no introduction of vapes or e-cigarettes.

4.1 Initiation Rate

The initiation rate among individuals aged 18–24 shows a substantial gender disparity. Males in this age group exhibit a markedly higher initiation rate (29.41%) compared to females (1.38%). This indicates that initiation into the studied behavior is overwhelmingly more common among young males than young females. Males in the 18–24 age range are often more exposed to peer influence, risk-taking behaviors, and social norms that encourage experimentation, thereby increasing the likelihood of initiation. In contrast, females may experience stronger social restrictions, greater parental supervision, or differing societal expectations that reduce initiation rates.

4.2 Cessation rate

The smoking cessation rates vary by both age group and gender, indicating distinct patterns in quitting behavior across the population. Among individuals aged **19–34 years**, the cessation rate is relatively low overall (2.18%). Females in this age group show a higher cessation rate (4.55%) compared to males (1.62%), suggesting that young adult females may be more inclined or motivated to quit smoking than their male counterparts.

In the **35–50 years** age group, the overall cessation rate is the highest (4.63%) among all age categories. Male cessation (5.00%) slightly exceeds female cessation (4.14%) in this group, which may reflect increased health awareness, family responsibilities, or the onset of smoking-related health concerns during mid-adulthood that encourage quitting, particularly among males.

For individuals aged **50 years and above**, cessation rates decline again, with an overall rate of 2.53%. Females (3.47%) continue to demonstrate higher cessation rates than males (1.72%), possibly indicating greater health-seeking behavior or responsiveness to medical advice among older women.

When considering the **average cessation rates,** females (3.86%) consistently show higher quitting rates than males (2.82%). The overall average cessation rate across all age groups is relatively low (3.11%), indicating that smoking cessation remains limited in the population.

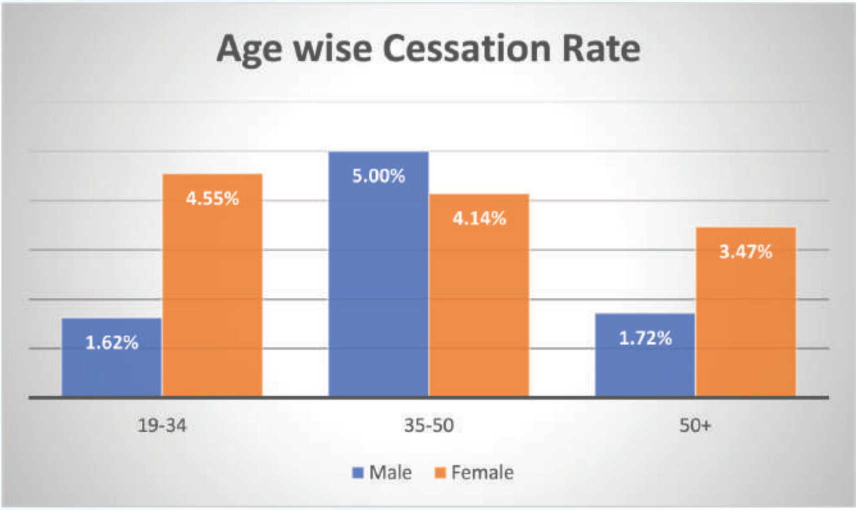

Figure 1: Age-wise Cessation rate

4.3 Population in Baseline Year by Smoking Status

In the baseline year, the distribution of smoking status shows clear differences between males and females in the study population. Among males, the majority are never smokers, accounting for 56.84% of the male population. However, a substantial proportion are current smokers (32.83%), indicating a high prevalence of active smoking among males. Former smokers constitute 10.33%, suggesting that while some males have successfully quit smoking, cessation remains relatively limited compared to the number of current smokers. In contrast, females show a markedly different pattern. A large majority of females are never smokers (83.04%), reflecting much lower initiation and uptake of smoking compared to males. Current smokers make up only 11.42% of the female population, while former smokers account for 5.54%, indicating both lower smoking prevalence and lower cessation experience among females.

Table 4.1 Population by Smoking Status

Smoking Status	Numbers		Percentage	
	Male	Female	Male	Female
Never Smokers	4624359.028	7958170.052	56.84	83.04
Current Smokers	2671459.68	1094890.26	32.84	11.42
Former Smokers	840452.30	530895.69	10.33	5.54
Total	**8136271**	**9583956**	**100**	**100**

5. Simulation Results

In the simulation analysis, there are 210 different combinations of the scenarios. The simulation scenarios are created based on assumptions. The results obtained from those simulation scenarios are presented in this section. The result consists of life years saved as the share of life years lost due to smoking, smoking prevalence, share of e-quitters in the former smokers, and the adult population. The results are reported for periods of 10, 30, 50, and 80 years.

5.1 Life years lost due to smoking

According to the estimation, smoking results in substantial losses of life expectancy over time. Based on the dynamic population model, the cumulative life-years lost (LYL) due to smoking for males amount to approximately 9.3 million after 10 years, 36.3 million after 30 years, 69.9 million after 50 years, and 121.4 million life-years after 80 years from the baseline shown in Table 5.1. These results illustrate how simulated changes in smoking behavior produce cumulative differences in projected life-years over time (Doll et al., 2004; Jha et al., 2013).

Table 5.1 Life Years Lost (in Millions) for Males

After 10 years	After 30 years	After 50 years	After 80 years
9.31	36.30	69.90	121.40

Similarly, Table 5.2 reports the estimated cumulative life years lost (LYL), measured in millions, due to smoking among females at 10, 30, 50, and 80 years after the baseline. The results indicate a strong increase in smoking-attributable health losses over time, reflecting the cumulative nature of smoking-related mortality. After 10 years, smoking among females results in 8.97 million life years lost, increasing to 31.5 million after 30 years. The burden rises at longer horizons, reaching 66.39 million life years lost after 50 years and 97.41 million after 80 years.

Table 5.2 Life Years Lost (in Millions) for Females

After 10 years	After 30 years	After 50 years	After 80 years
8.97	31.55	66.39	97.41

A comparison of cumulative life years lost due to smoking reveals pronounced gender differences in the magnitude and timing of health losses. Across all time horizons, males experience substantially higher life years lost than females, reflecting higher smoking prevalence, earlier initiation, and greater smoking-attributable mortality risks.

In the short term, female life years lost are considerably lower than male estimates, indicating that smoking-related mortality among women contributes less to population-level health losses in early projection periods. However, over longer horizons, the number of female life years lost increases sharply, narrowing the relative gender gap. This convergence reflects longer survival among women and the delayed manifestation of smoking-related diseases. Despite this narrowing over time, male life years lost remain higher at all horizons, underscoring the disproportionate contribution of male smoking to total population health losses. At the same time, the rapid long-term growth in female life years lost highlights that smoking among women generates substantial cumulative harm and should not be overlooked in long-term tobacco control strategies.

5.2 E-Cigarette Scenarios

The summary of all the e-cigarette scenarios is included in this section. The summary, based on cumulative life years saved and life years saved as a share of life years lost, is complete.

5.2.1 Cumulative Life Year Saved

Table 5.3 presents a summary of the simulation results for cumulative life years saved (LYS) across all modeled scenarios at 10, 30, 50, and 80 years after the baseline. The results show substantial variation in outcomes across scenarios, reflecting differences in underlying assumptions regarding the impact of vaping on smoking behavior and health risks.

Table 5.3 Summary of Cumulative Life Years Saved Over Different Scenarios for Males

Life Year Saved (males)	After 10 years	After 30 years	After 50 years	After 80 years
Mean Value	1048694.65	6700868.991	13553089	23485551.5
Median	655438.15	4651283.27	10423554.5	19754256.3
Max	3124115.59	19268576.53	39056707.6	69955022.8
Min	41711.17	-522792.23	-3849082.78	-12186268.5

On average, the estimated cumulative LYS increase markedly over time, rising from approximately 1.05 million life-years after 10 years to 6.7 million after 30 years, 13.6 million after 50 years, and 23.5 million life-years after 80 years. This pattern highlights the strongly cumulative nature of health gains associated with changes in smoking behavior, where benefits become increasingly pronounced over longer time horizons.

The median values are consistently lower than the corresponding means at all-time points, indicating a right-skewed distribution of outcomes. Specifically, the median LYS increases from 0.66 million after 10 years to 19.8 million after 80 years, suggesting that while most scenarios yield positive health gains, a smaller number of high-impact scenarios drive the higher mean values.

The maximum LYS reaches 3.1 million after 10 years and increases to nearly 70.0 million life-years after 80 years, reflecting scenarios in which vaping substantially increases smoking cessation and/or reduces smoking initiation without adverse health effects. In contrast, the minimum values indicate that some scenarios produce negative outcomes, with LYS declining to −12.2 million life-years after 80 years. These negative values arise in scenarios where increases in smoking initiation or elevated health risks among e-cigarette users outweigh the cessation benefits.

Similarly, Table 5.4 presents a summary of the simulation results for cumulative life years saved (LYS) among females across all modeled scenarios at 10, 30, 50, and 80 years after the baseline. As with the overall population, the estimated health gains increase substantially over time, reflecting the cumulative effects of smoking cessation and a reduction in smoking-related mortality. On average, cumulative LYS among females rises from approximately 0.37 million life-years after 10 years to 2.0 million after 30 years, 11.0 million after 50 years, and 20.8 million life-years after 80 years. This steady increase over time highlights the long-term nature of health benefits associated with changes in smoking behavior among women, despite their relatively lower baseline smoking prevalence.

Table 5.4 Summary of Cumulative Life Years Saved Over Different Scenarios for Females

Life Year Saved (females)	After 10 years	After 30 years	After 50 years	After 80 years
Mean Value	367588.744	2003994.573	10966577.8	20752059.5
Median	173151.03	1008272.165	5916207.67	11336609.4
Max	1286209.68	6788149.09	36017756.80	67990102.30
Min	14666.91	82216.79	321384.41	362080.54

The median values are consistently lower than the corresponding means, increasing from 0.17 million after 10 years to 11.3 million after 80 years, indicating a right-skewed distribution of outcomes. This suggests that while many scenarios yield moderate gains, a subset of higher-impact scenarios accounts for a disproportionate share of the overall average life years saved. The maximum estimated LYS reaches 0.22 million after 10 years and increases to 13.7 million after 80 years, reflecting scenarios in which vaping leads to sustained improvements in smoking cessation without significant adverse health effects. The minimum values, which remain positive across all time horizons, indicate that even under less favorable assumptions, most scenarios still generate net health gains among females. This contrasts with the results for the overall population, where some scenarios yield negative outcomes.

A comparison of the simulation results reveals pronounced gender differences in cumulative life years saved (LYS) across all time horizons. In absolute terms, the estimated LYS among males is consistently higher than that among females, reflecting the substantially higher baseline smoking prevalence and smoking-attributable mortality among men.

For males, the mean cumulative LYS increases from approximately 1.05 million after 10 years to 23.5 million after 80 years, whereas for females, the corresponding values rise from 0.37 million to 20.8 million life-years over the same period. Although the long-term gap narrows over time, male-specific gains remain larger at all horizons. Similarly, the median LYS is higher among males at each time point, indicating that typical scenarios yield greater health benefits for men.

The distribution of outcomes also differs markedly by gender. Male results exhibit a wider range, with both substantially higher maximum values and negative LYS in some scenarios, particularly at longer time horizons. This greater variability reflects the stronger sensitivity of male outcomes to assumptions regarding smoking initiation, cessation, and potential adverse health effects of vaping. In contrast, female results display a narrower distribution, and cumulative LYS remain positive across all scenarios and time horizons, indicating greater robustness to adverse assumptions.

5.2.2 Life year saved as a share of the life year lost

Table 5.5 summarizes the simulation results for life years saved (LYS) as a share of life years lost (LYL) due to smoking among males across all scenarios at 10, 30, 50, and 80 years after the baseline. This relative measure captures the extent to which vaping-related changes in smoking behavior offset the total health burden attributable to smoking.

Table 5.5 Summary of Life Year Saved as a share of Life Year Lost for Males

LYS as a share of LYL (males)	After 10 years	After 30 years	After 50 years	After 80 years
Mean Value	11.26%	18.45%	19.39%	19.34%
Median	7.04%	12.81%	14.92%	16.27%
Max	33.55%	53.07%	55.89%	57.62%
Min	0.45%	-1.44%	-5.51%	-10.04%

On average, the share of LYL offset by vaping increases rapidly over time, from 11.3% after 10 years to 18.5% after 30 years, reaching approximately

19.4% after 50 years and remaining stable at 19.3% after 80 years. This pattern indicates that the majority of relative health gains are realized within the first five decades, after which additional gains level off as cumulative benefits approach saturation.

The median values are consistently lower than the corresponding means, rising from 7.0% after 10 years to 16.3% after 80 years, suggesting a right-skewed distribution in which high-impact scenarios drive the average outcomes. The maximum values increase substantially over time, reaching 57.6% of smoking-related LYL offset after 80 years, reflecting scenarios with strong cessation effects and minimal adverse impacts.

In contrast, the minimum values become increasingly negative over longer time horizons, declining from 0.45% after 10 years to −10.0% after 80 years. These negative outcomes occur in scenarios where increases in smoking initiation and/or elevated health risks among e-cigarette users outweigh cessation benefits, particularly in the long run.

The distribution of positive and negative outcomes is shown in Table 5.6, which further highlights the time-dependent nature of these effects. While all 210 scenarios yield positive LYS after 10 years, the number of scenarios with negative outcomes increases over time, reaching 10 scenarios after 30 years, 25 after 50 years, and 32 after 80 years. Correspondingly, the number of scenarios with positive outcomes declines from 210 to 178 across the same horizons.

Table 5.6 Summary of the negative and positive outcomes of LYS as a share of LYL for males.

	After 10 years	After 30 years	After 50 years	After 80 years
Negative Value	0	10	25	32
Positive Value	210	200	185	178

Under the modeled assumptions, for males, some scenarios in which vaping affects cessation or initiation are associated with reductions in projected life-year losses from smoking. However, the emergence of negative outcomes in a growing subset of long-term scenarios underscores the sensitivity of male health outcomes to adverse assumptions and highlights the importance of sustained cessation benefits outweighing potential risks over extended time horizons.

Table 5.7 summarizes the simulation results for life years saved (LYS) as a share of life years lost (LYL) due to smoking among females across all scenarios at 10, 30, 50, and 80 years after the baseline. This relative indicator reflects the extent to which vaping-related changes in smoking behavior mitigate the smoking-attributable health burden among women.

Table 5.7 Summary of Life Year Saved as a share of Life Year Lost for Females

LYS as a share of LYL (females)	After 10 years	After 30 years	After 50 years	After 80 years
Mean Value	4.10%	6.35%	5.88%	4.17%
Median	1.93%	3.20%	3.17%	2.28%
Max	14.35%	21.52%	19.32%	13.67%
Min	0.16%	0.26%	0.17%	0.07%

The proportion of smoking-related life years offset by vaping remains positive across all time horizons, increasing from 4.1% after 10 years to 6.4% after 30 years, before gradually declining to 5.9% after 50 years and 4.2% after 80 years. This inverted U-shaped pattern suggests that relative health gains among females peak at intermediate horizons and diminish slightly in the long run, likely due to lower baseline smoking prevalence and the increasing influence of non-smoking-related mortality at older ages. The median values follow a similar trajectory, rising from 1.9% after 10 years to 3.2% after 30 years, and decreasing modestly to 2.3% after 80 years. The consistent gap between the mean and median indicates a right-skewed distribution, in which a subset of high-impact scenarios generates disproportionately large relative gains.

The maximum smoking-related LYL offset reaches 21.5% after 30 years, before declining to 13.7% after 80 years, reflecting scenarios with strong cessation effects and minimal adverse consequences. Importantly, the minimum values remain positive at all time horizons, with the lowest estimate at 0.07% after 80 years, indicating that none of the modeled scenarios produce net health losses among females. These results demonstrate that vaping-related changes in smoking behavior consistently reduce smoking-attributable life-year losses among females across all scenarios. Compared to males, the relative gains are smaller in magnitude but substantially more robust, as female outcomes remain positive even under unfavorable assumptions. This reflects lower smoking prevalence among women and greater resilience of female-specific health outcomes to adverse scenario parameters.

A comparison of the simulation results reveals clear gender differences in the relative health gains from vaping-related changes in smoking behavior. Across all time horizons, males exhibit substantially larger average and maximum shares of life years saved (LYS) relative to life years lost (LYL) than females, reflecting higher baseline smoking prevalence and smoking-attributable mortality among men.

For males, the mean share of LYL offset increases from 11.3% after 10 years to approximately 19.4% after 50 years, remaining close to this level at 80 years. In contrast, the corresponding female estimates are considerably lower, peaking at 6.4% after 30 years and declining to 4.2% after 80 years. Median values show a similar pattern, indicating that typical scenarios yield larger relative benefits for males than for females.

The distribution of outcomes differs markedly by gender. Male results display substantial variability, with maximum values exceeding 55% of smoking-related LYL offset in long-term projections, but also negative values in a growing number of scenarios at longer horizons. By the age of 80, 32 male scenarios produce negative outcomes, indicating that under certain adverse assumptions, vaping may increase the net health burden among men.

In contrast, female outcomes remain uniformly positive across all scenarios and time horizons. Although the maximum female LYS shares are lower than those observed for males, the absence of negative outcomes indicates a much greater robustness of female results to unfavorable assumptions regarding smoking initiation, cessation, and potential health risks of vaping.

5.3 Impact of Vaping on Cessation

In most of the literature, vapes are considered to increase the cessation rate. Given the impact of vaping on cessation, several scenarios are considered in this study. The result presented in this section simulates 'what will happen if initiation and health risk of vaping are considered 0%', with the cessation rate changed.

5.3.1 LYS as a share of LYL

Table 5.8 shows the simulated results for life years saved as a share of life years lost across different cessation scenarios for males. The results demonstrate the projected impact of vaping on smoking cessation among males, assuming that influences on initiation rate and health risk remain zero. The outcome is expressed as the percentage of life years saved across different time horizons (10, 30, 50, and 80 years) under varying cessation impact scenarios. Across all scenarios, life years saved increase both with higher cessation impact and longer time horizons. At a 5% cessation impact, the gains in life years saved are modest, increasing from 1.01% after 10 years to 2.49% after 80 years, indicating that small improvements in cessation yield limited long-term health benefits.

Table 5.8 LYS as a share of LYL in different cessation scenarios for males

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	1.01%	2.03%	2.37%	2.49%
10%	2.00%	4.01%	4.66%	4.89%
25%	4.93%	9.64%	11.08%	11.57%
50%	9.60%	18.08%	20.42%	21.15%
100%	18.24%	31.99%	34.96%	35.64%
200%	33.07%	51.08%	52.77%	52.29%

As the cessation impact increases to 10% and 25%, the number of life years saved rises substantially. For example, at 25% impact, life years saved increase from 4.93% after 10 years to 11.57% after 80 years, highlighting the cumulative health benefits of moderate increases in cessation over time. Under higher-impact scenarios (50% and 100%), the effect becomes pronounced. A 50% cessation impact results in 9.60% life years saved after 10 years, rising to 21.15% after 80 years, while a 100% impact leads to gains as high as 35.64% after 80 years. This suggests that widespread adoption of vaping as a cessation aid could significantly reduce smoking-related mortality among males.

The 200% scenario, representing a very large increase in cessation effectiveness, shows the greatest benefit, with life years saved exceeding 50% after 30 years and remaining above 52% at 80 years. The slight plateau observed between 50 and 80 years suggests diminishing marginal gains at very long-time horizons once a large proportion of smokers have already quit.

Table 5.9 LYS as a share of LYL in different cessation scenarios for females

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	0.24%	0.41%	0.43%	0.31%
10%	0.49%	0.83%	0.86%	0.62%
25%	1.28%	2.14%	2.17%	1.56%
50%	2.71%	4.46%	4.41%	3.17%
100%	6.02%	9.57%	9.09%	6.48%
200%	14.19%	21.24%	18.95%	13.35%

Table 5.9 presents the projected percentage of life years saved among females under varying cessation impact scenarios (5% to 200%), measured after 10, 30, 50, and 80 years, assuming other cessation influences remain constant. Across all scenarios, the life years saved among females increase with greater cessation impact, indicating that improved cessation rates contribute positively to long-term health outcomes. However, the magnitude of benefit is substantially lower than that observed among males, reflecting the lower baseline smoking prevalence among females. At the 5% cessation impact, gains in life years saved are minimal, increasing

from 0.24% after 10 years to 0.43% after 50 years, then declining to 0.31% after 80 years. This suggests that small improvements in cessation yield limited long-term benefits in populations with low smoking prevalence. As the cessation impact increases to 10% and 25%, life years saved rise more noticeably. For example, at a 25% impact, life years saved increase from 1.28% after 10 years to 2.17% after 50 years, before declining to 1.56% after 80 years.

This pattern indicates that benefits accumulate over time but may diminish in very long-term projections due to population aging and competing mortality risks. Under higher cessation impact scenarios (50% and 100%), the benefits become more pronounced. A 50% impact results in 4.46% life years saved after 30 years, while the 100% impact yields a peak of 9.57% after 30 years. However, in both cases, life years saved decrease by 80 years, suggesting diminishing marginal returns over extended time horizons. The 200% cessation impact scenario shows the greatest benefit, with 21.24% life years saved after 30 years, but this declines to 13.35% after 80 years. This decline likely reflects saturation effects and the influence of non-smoking-related mortality at older ages.

5.3.2 Smoking Prevalence

Table 5.10 presents projected smoking prevalence over time under different cessation impact scenarios (5% to 200%), measured after 10, 30, 50, and 80 years for males. The results show a consistent decline in smoking prevalence with both increasing cessation impact and longer time horizons.

Table 5.10 Smoking Prevalence for Males

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	25.93%	21.28%	20.76%	20.85%
10%	25.67%	20.92%	20.40%	20.50%
25%	24.88%	19.91%	19.42%	19.52%
50%	23.66%	18.44%	17.98%	18.08%
100%	21.47%	16.06%	15.69%	15.79%
200%	17.92%	12.84%	12.61%	12.70%

At the lowest cessation impact (5%), smoking prevalence decreases from 25.93% after 10 years to 20.85% after 80 years. This gradual reduction indicates that limited improvements in cessation lead to only modest long-term declines in smoking prevalence. As the cessation impact increases to 10% and 25%, smoking prevalence declines more noticeably. For example, at 25% impact, prevalence falls from 24.88% after 10 years to 19.52% after 80 years, demonstrating the cumulative effect of improved cessation on population-level smoking rates.

Under higher cessation impact scenarios (50% and 100%), the reduction in smoking prevalence becomes substantial. A 50% impact reduces prevalence from 23.66% after 10 years to 18.08% after 80 years, while a 100% impact leads to a sharper decline, reaching 15.79% after 80 years. This suggests that strong cessation interventions can significantly accelerate the reduction of smoking prevalence. The 200% cessation impact scenario produces the largest reduction in smoking prevalence across all time periods, decreasing from 17.92% after 10 years to 12.70% after 80 years. The slight stabilization observed between 50 and 80 years indicates a plateau effect, where most smokers susceptible to cessation have already quit, resulting in diminishing marginal reductions over time.

Table 5.11 Smoking Prevalence for Females

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	3.93%	1.52%	0.56%	0.57%
10%	3.85%	1.47%	0.54%	0.55%
25%	3.62%	1.32%	0.49%	0.49%
50%	3.27%	1.10%	0.41%	0.42%
100%	2.65%	0.77%	0.31%	0.31%
200%	1.74%	0.40%	0.20%	0.20%

Table 5.11 presents projected smoking prevalence among females over time under different cessation impact scenarios (5% to 200%), measured after 10, 30, 50, and 80 years. The results show a consistently low and declining smoking prevalence among females, with greater reductions observed under higher cessation impact scenarios and longer time horizons.

At the lowest cessation impact (5%), smoking prevalence declines sharply from 3.93% after 10 years to 0.56% after 50 years, then stabilizes at 0.57% after 80 years. This rapid decline reflects the already low baseline smoking prevalence among females and the cumulative effect of cessation over time. As the cessation impact increases to 10% and 25%, smoking prevalence decreases further at each time point. For example, under the 25% scenario, prevalence falls from 3.62% after 10 years to 0.49% after both 50 and 80 years, indicating that moderate improvements in cessation can substantially reduce smoking to very low levels in the long term.

Under higher-impact scenarios (50% and 100%), the reduction becomes more pronounced. A 50% cessation impact reduces smoking prevalence to 0.41% after 50 years, while the 100% impact lowers prevalence to 0.31%, suggesting that strong cessation interventions can nearly eliminate smoking among females. The 200% cessation impact scenario results in the lowest smoking prevalence across all time points, declining to 0.20% after 50 and 80 years. The minimal change between 50 and 80 years indicates a plateau effect, where smoking prevalence approaches a residual minimum driven by persistent or hard-to-reach smokers.

5.3.3 Adult Population

Table 5.12 presents projections of the adult population size over time under different cessation impact scenarios (5% to 200%), measured after 10, 30, 50, and 80 years. The results indicate that increases in cessation impact are associated with gradual growth in the adult population, particularly over longer time horizons.

Table 5.12 Adult Population for Males

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	7.94	8.95	8.97	8.9
10%	7.95	8.95	8.97	8.9
25%	7.96	8.96	8.98	8.91
50%	7.99	8.98	8.99	8.92
100%	8.03	9	9	8.93
200%	8.1	9.01	9.01	8.94

At the lowest cessation impact (5%), the adult population increases from approximately 7.94 million after 10 years to 8.97 million after 50 years, then declines slightly to 8.90 million after 80 years. This pattern reflects normal demographic dynamics, where population growth eventually stabilizes or declines due to aging and mortality.

As cessation impact increases to 10% and 25%, the adult population becomes moderately larger at each time point. For instance, under the 25% scenario, the adult population rises from 7.96 million after 10 years to 8.98 million after 50 years and remains higher than the lower-impact scenarios at 80 years. This suggests that improved cessation contributes to reduced smoking-related mortality, allowing more individuals to survive into older adulthood.

Under higher cessation impact scenarios (50%, 100%, and 200%), the increase in adult population size is more pronounced. The 100% impact scenario results in an adult population of approximately 8.03 million after 10 years, increasing to 9.00 million after 50 years, and remaining close to 8.93 million after 80 years. The 200% scenario shows the highest population levels across all time points, reaching over 9.0 million after 50 and 80 years.

Table 5.13 Adult Population for Females

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	0.01	0.02	0.03	0.03
10%	0.02	0.04	0.06	0.06
25%	0.06	0.11	0.14	0.14
50%	0.12	0.22	0.27	0.27
100%	0.25	0.44	0.55	0.55
200%	0.5	0.88	1.09	1.09

Table 5.13 presents projections of the adult female population size under different cessation impact scenarios (5% to 200%), measured after 10, 30, 50, and 80 years. The results show a strong positive association between increased cessation impact and adult population size, with the effect becoming more pronounced over longer time horizons.

At the lowest cessation impact (5%), the adult female population increases from approximately 12,082 after 10 years to 27,534 after 50 years, with a slight stabilization by 80 years. This pattern reflects natural population growth and survival dynamics in the absence of substantial cessation-driven reductions in mortality. As the cessation impact increases to 10% and 25%, the adult female population grows more rapidly. For example, under the 25% scenario, the population rises from 60,726 after 10 years to 137,527 after 50 years, remaining relatively stable at 80 years. This suggests that improved cessation leads to reduced smoking-related mortality, allowing more females to survive into older adulthood.

Under higher cessation impact scenarios (50%, 100%, and 200%), the increase in the adult population becomes substantial. A 50% impact results in an adult population of approximately 274,720 after 50 years, while the 100% scenario more than doubles this figure to 548,323. The 200% scenario produces the largest population sizes, exceeding 1.09 million after 50 and 80 years. The slight plateau observed between 50 and 80 years across all scenarios suggests that demographic factors such as aging and non-smoking-related mortality eventually limit further population growth, even under strong cessation impacts.

5.3.4 E-quitters as a share of all former smokers

Table 5.14 presents the projected proportion of quitters (who used vapes/e-cigarettes to quit) for males over time under different cessation impact scenarios (5% to 200%), measured after 10, 30, 50, and 80 years. The results demonstrate a strong, consistent increase in the proportion of quitters with both greater cessation impact and longer time horizons.

Table 5.14 Share of E-quitters among former smokers for males

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	3.92%	9.57%	10.81%	10.88%
10%	7.39%	17.00%	18.99%	19.11%
25%	15.79%	31.97%	34.95%	35.12%
50%	25.46%	45.58%	48.97%	49.15%
100%	36.86%	58.88%	62.39%	62.55%
200%	47.98%	71.16%	74.74%	74.86%

At the lowest cessation impact (5%), the proportion of quitters remains relatively small, increasing from 3.92% after 10 years to 10.88% after 80 years. This indicates that limited improvements in cessation lead to only gradual accumulation of ex-smokers over time.

As the cessation impact increases to 10% and 25%, the proportion of quitters rises substantially. For example, under the 25% scenario, quitters increase from 15.79% after 10 years to 35.12% after 80 years, reflecting the cumulative effect of sustained cessation over multiple decades.

Under higher-impact scenarios (50% and 100%), the growth in the proportion of quitters becomes pronounced. A 50% cessation impact results in nearly half of the population being quitters after 80 years (49.15%), while the 100% scenario increases this proportion to 62.55%. These results suggest that strong cessation interventions can dramatically shift smoking status distributions at the population level.

The 200% cessation impact scenario produces the largest effect, with quitters accounting for 47.98% after 10 years and rising to 74.86% after 80 years. The slight leveling-off observed between 50 and 80 years indicates a saturation effect, where most smokers have already quit, leading to diminishing marginal increases in the quitter population over time.

Table 5.15 Share of E-quitters among former smokers for females

Impact of Vaping on Cessation	After 10 years	After 30 years	After 50 years	After 80 years
5%	3.00%	6.81%	20.54%	20.93%
10%	5.74%	12.55%	33.54%	34.07%
25%	12.77%	25.49%	54.26%	54.85%
50%	21.66%	39.03%	68.72%	69.22%
100%	33.49%	53.71%	79.98%	80.34%
200%	46.97%	67.39%	88.00%	88.23%

Table 5.15 presents the projected proportion of quitters (who used vapes/ e-cigarette for quitting) among females under different cessation impact

scenarios (5% to 200%), measured after 10, 30, 50, and 80 years. The results show a strong and consistent increase in the proportion of quitters with both higher cessation impact and longer time horizons. At the lowest cessation impact (5%), the proportion of quitters is relatively small in the short term (3.00% after 10 years), but increases substantially over time, reaching 20.93% after 80 years. This indicates that even modest improvements in cessation accumulate gradually among females over multiple decades.

As the cessation impact increases to 10% and 25%, the proportion of quitters rises more rapidly. For example, under the 25% scenario, quitters increase from 12.77% after 10 years to 54.85% after 80 years, demonstrating the long-term cumulative effect of sustained cessation on smoking status distribution. Under higher cessation impact scenarios (50% and 100%), the growth in the quitter population becomes pronounced. A 50% cessation impact results in nearly 69.22% of females being quitters after 80 years, while the 100% scenario increases this proportion to 80.34%. These results suggest that strong cessation interventions can substantially shift the majority of female smokers into the ex-smoker category over time. The 200% cessation impact scenario produces the highest proportion of quitters across all time points, with 46.97% after 10 years and 88.23% after 80 years. The slight plateau observed between 50 and 80 years indicates a saturation effect, where most smokers susceptible to cessation have already quit, leaving a small residual group of persistent smokers.

These findings indicate that enhanced smoking cessation effectiveness among females leads to a dramatic increase in the proportion of ex-smokers over time. When combined with the already low smoking prevalence among females, these results suggest that high-impact cessation strategies can drive smoking toward near elimination in the long term. The findings reinforce the importance of sustained cessation support alongside prevention strategies to maintain low smoking initiation among women.

5.4 Most Plausible E-cigarette Scenarios

Population-level modeling of tobacco harm reduction necessarily requires explicit assumptions about behavior, risk, and market dynamics in the absence of definitive long-term epidemiological evidence. Following the approach articulated by Mendez and Warner (2021), the objective of scenario selection in this study is not to identify the most optimistic or pessimistic outcome, but to construct the **most plausible scenario**, one that reflects the central tendency of current empirical evidence while acknowledging residual uncertainty.

Consistent with Mendez and Warner's modeling philosophy, this analysis rejects extreme assumptions at both ends of the spectrum. Scenarios in which reduced-risk products produce no effect on smoking cessation, or substantially increase smoking initiation, are difficult to reconcile with the growing body of population studies and randomized trials demonstrating that non-combustible nicotine products like e-cigarettes can meaningfully increase cessation among adult smokers (Hajek et al., 2019; Beard et al., 2016; Zhu et al., 2017). At the same time, scenarios assuming near-complete substitution of cigarettes or negligible health risk from long-term alternative product use are equally implausible given ongoing dual use, imperfect switching, and unresolved questions regarding chronic exposure.

The plausible scenario adopted here, therefore, aligns closely with the mid-range assumptions explored by Mendez and Warner (2021) and Mzhavanadze and Yanin (2023). Mendez and Warner demonstrate that across hundreds of modeled combinations, scenarios with these characteristics overwhelmingly produce net life-years saved, even when conservative assumptions about initiation effects and residual risk are imposed.

Crucially, this modeling rationale treats uncertainty as a structural feature rather than a methodological flaw. As Mendez and Warner (2021) argue, the absence of long-term disease endpoints does not justify inaction or extreme pessimism; instead, it necessitates scenario-based modeling that transparently varies key parameters and evaluates the robustness of outcomes across plausible ranges. By anchoring assumptions in convergent empirical evidence and avoiding reliance on best-case projections, the most plausible scenario presented here aims to provide a credible basis for policy-relevant inference rather than advocacy.

In this study, selected plausible scenarios assume a moderate to substantial increase in smoking cessation, ranging from 25% to 50%, combined with a reduction in smoking initiation of 10%. At the same time, recognizing that e-cigarette use is not risk-free, these scenarios incorporate positive health risks associated with vaping, set at 5% and 10%, respectively.

Table 5.16 Plausible E-cigarette Scenarios

Initiation	Cessation	Vaping Risk
Decrease by 10%	Increase by 25%	5%
	Increase by 50%	10%

These scenarios illustrate outcomes under moderate assumptions regarding cessation, initiation, and vaping-related health risks. This section presents results for the four most plausible e-cigarette scenarios for males, defined by a 10% reduction in smoking initiation, 25% or 50% increase in smoking cessation, and vaping-related health risks of 5% or 10%. Outcomes are reported for smoking prevalence, share of e-quitters among former smokers, adult population size, and life years saved as a share of life years lost due to smoking.

5.4.1 LYS as a share of LYL

The relative health benefits of vaping are captured by life years saved (LYS) as a share of life years lost (LYL) due to smoking, and the result of the simulation for males is shown in Table 5.17. Under the 25% cessation scenario, LYS increases from approximately 5–6% after 10 years to 15–16% after 80 years. When cessation increases to 50%, relative gains are substantially larger, rising from about 9–10% after 10 years to approximately 23–24% after 80 years.

Table 5.17 LYS as Share of LYL due to smoking for Males (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	5.12%	10.80%	13.79%	16.18%
Cessation 50%	9.73%	18.82%	22.19%	24.49%
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	5.06%	10.49%	13.28%	15.57%
Cessation 50%	9.62%	18.23%	21.23%	23.35%

Higher vaping risk assumptions slightly reduce the share of life years saved, particularly at longer horizons, but do not alter the overall conclusion that strong cessation effects generate substantial long-term health gains, even when vaping is assumed to carry non-negligible health risks.

Table 5.18 LYS as Share of LYL due to smoking for Females (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	1.30%	2.19%	2.27%	1.66%
Cessation 50%	2.73%	4.50%	4.50%	3.26%
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	1.29%	2.17%	2.24%	1.64%
Cessation 50%	2.70%	4.45%	4.45%	3.22%

Table 5.18 shows relative health gains among females remain positive across all scenarios and time horizons. Under the 25% cessation scenario, life years saved increase from approximately 1.3% after 10 years to about 1.7% after 80 years. When cessation increases to 50%, relative gains are larger, reaching around 3.3% after 80 years.

Assuming a 10% vaping risk slightly attenuates these gains, particularly at longer horizons, but does not change the overall conclusion that vaping-related increases in cessation generate net health benefits among females.

5.4.2 Smoking Prevalence

Under all selected scenarios, smoking prevalence among males declines over time as shown in Table 5.19. With a 25% increase in cessation, smoking prevalence decreases from approximately 23.8% after 10 years to about 17.4% after 80 years, largely independent of whether vaping risk is assumed to be 5% or 10%. When cessation increases to 50%, the decline is more pronounced, with smoking prevalence falling to approximately 16.2% after 80 years.

Differences between the 5% and 10% vaping risk assumptions are minimal, indicating that changes in cessation rates dominate prevalence outcomes, while moderate vaping-related health risks have limited influence on smoking prevalence itself.

Table 5.19 Smoking Prevalence for Males (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	23.84%	18.00%	17.35%	17.44%
Cessation 50%	22.64%	16.65%	16.07%	16.16%
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	23.84%	18.01%	17.36%	17.44%
Cessation 50%	22.64%	16.66%	16.08%	16.17%

Across all selected scenarios, smoking prevalence among females declines rapidly over time, as shown in Table 5.20. With a 25% increase in cessation, smoking prevalence falls from approximately 3.6% after 10 years to 0.44% after 80 years. When cessation reaches 50%, prevalence declines further, to around 0.38% after 80 years.

Table 5.20 Smoking Prevalence for Females (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	3.59%	1.28%	0.44%	0.44%
Cessation 50%	3.24%	1.06%	0.37%	0.38%
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	3.59%	1.28%	0.44%	0.44%
Cessation 50%	3.24%	1.06%	0.37%	0.38%

Differences between the 5% and 10% vaping risk assumptions are negligible, indicating that smoking prevalence outcomes among females are driven primarily by changes in cessation and initiation rather than by moderate vaping-related health risks.

5.4.3 Adult Population

Adult population projections for males increase gradually over time across all scenarios, reflecting reduced smoking-related mortality as depicted in Table 5.21. With 25% cessation, the adult male population grows from approximately 7.97 million after 10 years to about 8.01 million after 80 years. Under 50% cessation, population size is consistently larger, reaching approximately 9.08 million after 80 years.

Table 5.21 Adult Population (in Millions) for Males (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	7.97	7.97	7.99	8.01
Cessation 50%	9.04	9.04	9.05	9.08
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	9	9	9.01	9
Cessation 50%	8.97	8.97	8.99	8.98

Differences between the 5% and 10% vaping risk assumptions are small, suggesting that mortality reductions from smoking cessation outweigh moderate vaping-related risks in shaping long-term population size.

The projected adult female population increases steadily across all scenarios, reflecting reductions in smoking-related mortality, which is shown in Table 5.22. Under 25% cessation, the adult population grows from approximately 0.060 million after 10 years to about 0.137 million after 80 years. With 50% cessation, population size is consistently larger, reaching approximately 0.273 million after 80 years.

Table 5.22 Adult Population (in Millions) for Females (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	0.06	0.11	0.14	0.14
Cessation 50%	0.12	0.21	0.28	0.25
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	0.06	0.11	0.14	0.14
Cessation 50%	0.12	0.21	0.23	0.28

Differences between vaping risk assumptions are small, indicating that long-term survival gains from smoking cessation outweigh moderate vaping-related health risks in shaping female population outcomes.

5.4.4 E-quitters as a share of all former smokers

The share of former smokers who quit using e-cigarettes increases substantially with higher cessation rates for males, as in Table 5.23. Under the 25% cessation scenario, the share of e-quitters rises from approximately 15–16% after 10 years to around 34–35% after 80 years. When cessation increases to 50%, this share grows much more rapidly, reaching approximately 48–49% after 80 years.

Table 5.23 Share of E-quitters among former smokers for Males (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	15.41%	30.82%	34.34%	34.52%
Cessation 50%	24.91%	44.27%	48.31%	48.51%
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	15.27%	30.30%	33.76%	33.95%
Cessation 50%	24.71%	43.68%	47.68%	47.89%

Assuming a higher vaping risk slightly reduces the share of e-quitters at each time horizon, but the overall pattern remains unchanged. These results indicate that higher cessation effectiveness leads to a significant long-term shift toward e-cigarette–assisted quitting among former smokers.

Table 5.24 shows the share of female former smokers who quit using e-cigarettes, and it increases substantially with higher cessation rates. Under the 25% cessation scenario, the share of e-quitters rises from approximately 12.78% after 10 years to about 57% after 80 years. With a 50% increase in cessation, this share grows more rapidly, exceeding 70% after 80 years.

Table 5.24 Share of E-quitters among former smokers for Females (Decrease initiation by 10%)

Vaping Risk - 5%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	12.78%	25.63%	56.78%	57.36%
Cessation 50%	21.67%	39.21%	70.87%	71.35%
Vaping Risk - 10%				
	After 10 years	After 30 years	After 50 years	After 80 years
Cessation 25%	12.76%	25.58%	56.69%	57.27%
Cessation 50%	21.64%	39.15%	70.79%	71.28%

Higher vaping risk assumptions lead to only marginal reductions in the share of e-quitters, suggesting that cessation effectiveness dominates patterns of quitting behavior among females.

6. Conclusion And Discussions

6.1 Key Empirical Findings

This study assessed the long-term population health impacts of e-cigarette use by modeling its effects on smoking cessation, smoking initiation, and mortality using a dynamic population framework. By comparing a large set of e-cigarette scenarios against a no-vaping baseline, the analysis quantified smoking-attributable life years lost (LYL), life years saved (LYS), and changes in smoking prevalence over short-, medium-, and long-term horizons.

In the absence of e-cigarettes, smoking was found to impose a substantial and cumulative health burden on the population, resulting in large life-year losses over time. While these losses were considerably higher among males due to higher smoking prevalence and earlier initiation, the burden among females increased sharply in the long run, reflecting delayed disease onset and longer survival. These findings underscore the persistent and long-term nature of smoking-related mortality for both genders.

Across the full set of modeled scenarios, the majority produced positive health outcomes, with most e-cigarette scenarios generating net life years saved. However, the magnitude and direction of these effects varied widely depending on assumptions regarding smoking cessation, smoking initiation, and vaping-related health risks. Scenarios characterized by modest increases in cessation and unfavorable assumptions regarding initiation and health risks yielded limited or even negative outcomes, particularly among males in long-term projections.

More specifically, scenarios that assume substantial increases in smoking cessation tend to yield net life-years saved relative to the baseline. These findings are consistent with prior modeling studies conducted in high-income and upper-middle-income countries (Mendez & Warner, 2021; Mzhavanadze & Yanin, 2023), while also revealing important contextual and demographic heterogeneity that has received limited attention in existing literature.

At a conceptual level, our findings closely align with those of Mendez and Warner (2021), who conclude that e-cigarettes are “highly likely” to reduce smoking-attributable mortality under a wide range of plausible assumptions. In both studies, the primary mechanism driving population benefit is increased cessation among existing smokers rather than reductions in initiation alone (Mendez & Warner, 2021). Similarly, in our Nepal model, scenarios that assume modest but sustained increases in cessation consistently outperform those that rely on changes in initiation, reinforcing the centrality of cessation effects in determining long-run outcomes.

However, the magnitude and temporal profile of benefits differ between the two studies. Whereas Mendez and Warner (2021) project that vaping could avert a substantial fraction of smoking-related life-years lost in the United States by the end of the century under favorable assumptions, our model suggests more gradual gains in Nepal, particularly in the early decades of implementation. This difference likely reflects Nepal’s lower baseline smoking prevalence, different age structure, and the fact that a significant share of future smoking-related mortality is already determined by past smoking exposure—a point emphasized by Mendez and Warner (2021) when noting that only a fraction of future smoking-attributable life-years lost remains avoidable.

Our findings also parallel those of Mzhavanadze and Yanin (2023), who apply a similar dynamic population simulation framework to the Russian Federation. As in our study, they report that the majority of plausible harm reduction scenarios yield positive net life-years saved and that negative outcomes arise primarily under extreme and arguably unrealistic assumptions—such as negligible cessation effects combined with large increases in smoking initiation. The convergence of results across such distinct national contexts supports the robustness of the conclusion that harm reduction is more likely than not to reduce population harm when evaluated under realistic behavioral assumptions.

Quantitatively, Mzhavanadze and Yanin (2023) estimate that harm reduction could avert a modest but meaningful proportion of smoking-related life-years lost under their most plausible scenarios. Our Nepal model produces effects of similar conceptual magnitude, though the absolute scale differs due to population size and baseline smoking patterns. Importantly, both studies demonstrate that even relatively small proportional reductions in smoking-attributable mortality translate into substantial absolute public health gains, given the size of the smoking burden.

A key methodological and substantive extension of prior modeling work is our explicit gender-wise analysis. While Mendez and Warner (2021) stratify smokers by difficulty quitting, their primary outcomes are not reported separately for men and women. Similarly, although the Russian model incorporates sex-specific mortality and smoking prevalence, its discussion focuses primarily on aggregate outcomes.

In contrast, our results demonstrate that the population-level benefits of harm reduction in Nepal are overwhelmingly concentrated among men. This pattern reflects Nepal's highly skewed smoking epidemiology, in which smoking prevalence among men far exceeds that among women (WHO, 2019). Consequently, even when harm reduction produces positive effects for both sexes, the absolute gains in life-years saved are substantially larger among men. This heterogeneity would be obscured in aggregate analyses, highlighting the value of gender-disaggregated modeling.

More broadly, these findings underscore the importance of contextualizing harm reduction within local epidemiological realities rather than assuming uniform effects across populations. In Nepal, reductions in smoking-related harm primarily affect men due to their substantially higher smoking prevalence, while the projected benefits for women remain smaller but still positive.

6.2 Implications for Research

From a policy perspective, this insight has several implications. First, it suggests that harm reduction strategies in Nepal are likely to yield their greatest benefits among male smokers who are unable or unwilling to quit using existing methods. Second, it reinforces the importance of maintaining strong prevention efforts among women and youth, particularly to avoid future increases in female smoking prevalence that could erode long-term gains (Thakur et al., 2013; WHO, 2019). Finally, it highlights the need for future modeling studies to routinely report sex-disaggregated outcomes, especially in low- and middle-income countries where gender norms strongly shape tobacco use.

Taken together, the comparisons across studies support a consistent interpretation of the role of harm reduction in tobacco control. As emphasized by Mendez and Warner (2021), harm reduction is unlikely to replace established tobacco control measures such as taxation, smoke-free policies, and cessation support, but it may meaningfully complement them. Our Nepal-specific results reinforce this conclusion, suggesting that harm reduction could accelerate declines in smoking prevalence and mortality when layered onto existing control efforts, rather than deployed in isolation.

From a research standpoint, this study strengthens the case for transparent, scenario-based modeling that explicitly acknowledges uncertainty and heterogeneity (Lee et al., 2021). By incorporating gender-disaggregated outcomes and situating results within a low-income country context, our analysis extends the external validity of prior modeling work and identifies new directions for future research, including the integration of relapse dynamics, dual use, and differential adoption patterns by age and sex.

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