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Article

Driving Thailand healthcare communication policy on e-cigarettes through social network analysis

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Abstract: E-cigarettes pose a significant public health concern, particularly for youth and young adults. Policymaking in this area is complicated by changing consumption patterns, diverse user demographics, and dynamic online and offline communities. This study uses social network analytics to examine the social dynamics and communication patterns related to e-cigarette use. We analyzed data from various social media platforms, forums, and online communities, which included both advocacy for e-cigarettes as a safer smoking alternative and opposition due to health risks. Our findings inform targeted healthcare policy interventions, such as educational campaigns tailored to specific network clusters, regulations based on user interaction and influence patterns, and collaborations with key influencers to spread accurate health information.

Keywords: e-cigarette; health-care policy; social network; dashboard; monitoring

1. Introduction

The increasing prevalence of e-cigarette use in Thailand has raised significant public health concerns, particularly among youth and young adults. Recent statistics from the National Health Examination Survey 2019–2020 reveal a substantial rise in e-cigarette use among Thai adolescents, with usage rates continuing to climb. E-cigarette advertising, especially targeted at teenagers active on social network platforms, is fostering a new generation addicted to e-cigarettes. This trend underscores the urgency of formulating timely and effective healthcare policies. Leveraging the continuous flow of information through social networks is crucial in shaping public attitudes and behaviors toward e-cigarettes and combating this public health issue.

Recent data from multiple national surveys in Thailand provide compelling evidence of the growing prevalence and impact of e-cigarette use, particularly among youth, underscoring the urgency of addressing this emerging public health issue. The National Statistical Office's 2021 health behavior survey, encompassing 84,000 households nationwide, revealed a significant increase in e-cigarette use. While traditional cigarette smoking rates among those aged 15 and above declined from 23.0% in 2004 to 17.4% in 2021, e-cigarette use surged dramatically, with 78,742 users recorded in 2021—A sevenfold increase from 2017. Notably, the majority of these users are young people, with 24,050 aged 15–24 and 13,875 aged 25–59. More recent data from the 1) Department of Health Service Support's 2023 surveillance study on e-cigarette use among Thai youth paints an even more alarming picture. In

a survey of 61,688 individuals aged up to 25 years, 25% were found to be e-cigarette users, representing one in four of the total population in this age group. This data aligns with the 2022 Global Youth Tobacco Survey (GYTS) data for Thailand, which reported a 17.6% e-cigarette use rate among students aged 13–15 years. Furthermore, long-term monitoring by the Tobacco Control Research and Knowledge Management Center at Mahidol University indicates that while overall smoking rates have declined over the past 30 years, this decline has slowed since e-cigarettes entered the market illegally in 2007. These findings collectively highlight the urgent need for comprehensive research and targeted interventions to address the rapidly evolving landscape of nicotine consumption in Thailand, particularly among youth and young adults.

The sharp increase in e-cigarette usage among teenagers and young adults is particularly alarming. This demographic is drawn to the enticing flavors and appealing packaging often featured in e-cigarette marketing. Addressing this issue requires a robust research foundation to understand the long-term health effects of e-cigarettes, which is vital for formulating evidence-based public health policies.

To enhance the monitoring and implementation of healthcare policies, this research advocates for the use of social analytics within the context of Thailand's regulatory framework on e-cigarettes. In 2015, the Thai government implemented a ban on the import and sale of e-cigarettes, which has been enforced through various public health campaigns and regulatory measures. Despite these efforts, e-cigarette use persists, particularly among youth. Analyzing data from social media platforms, online forums, and other digital sources can provide insights into public health trends, attitudes, and behaviors, offering a comprehensive understanding of the challenges in enforcing e-cigarette regulations. By employing social analytics, policymakers can make well-informed decisions, tailor health interventions more effectively, and engage with the public more efficiently. This research outlines several key strategies for utilizing social analytics to refine healthcare policies, including identifying health concerns and misinformation, engaging with the public, developing and adapting policies, evaluating these policies, and ensuring privacy and ethical considerations are upheld.

To address the challenge posed by e-cigarette use, this paper proposes adopting a social network analysis (SNA) framework as a pivotal instrument for monitoring and understanding the e-cigarette phenomenon in Thailand. This methodology can uncover critical relationships and insights essential for crafting effective healthcare policies aimed at reducing e-cigarette use. Essentially, social network analysis acts as a conduit between the dynamic world of e-cigarette consumption and the necessary healthcare interventions to counter its adverse effects.

The article is systematically organized as follows: Section Two Delves into related works and foundational theories pertinent to the study. Section Three: Outlines the research methodology employed. Section Four: Presents the core findings of the research, discussing the application of social network analysis in shaping healthcare policy regarding e-cigarettes in Thailand. Section Five: Concludes with a discussion of the challenges encountered and suggestions for future research directions. This structured approach aims to provide a comprehensive understanding of the e-cigarette issue in Thailand and proposes actionable insights

for effective policy intervention.

2. Literature review

In this section, we focus on two main research components: healthcare communication and social network analysis. The results of Social Network Analysis will have to be implemented into healthcare policy, which can be achieved through health communication policy. The World Health Organization states that health communication, or communication for health, encompasses several aspects of public health communication, including health promotion, health literacy, strategic communication, risk and community communication, and participation, enabling individuals to participate in protecting their health. However, making individuals aware of these requires both information and analysis, behavioral science, insights, storytelling, skills, other communication approaches, and strategic collaboration. These are the foundations of communication for health.

The American Association for Health Communication defines health communication as the science and art of using communication to develop health. The Department of Health Service Support defines health communication as the transmission of health information to the public through a structured health communication system, using technology and communication methods through appropriate media, reaching the target groups through transmission and exchange of health information between the sender and the recipient, who can be individuals, groups, or the masses, in various forms, to ensure that health information recipients receive the accurate and appropriate information.

Given the limited pages, we have not included literature reviews from the tobacco control field as there are quite a number of research studies in the area. These references offer a deeper comparison and contextualization of the findings within the broader discourse on tobacco control, enhancing the manuscript's credibility and relevance.

The Thai government maintains a stringent stance on e-cigarettes, categorizing them as "absolutely prohibited goods" under four key legislative instruments. The Ministry of Commerce's announcement in 2014 explicitly prohibits the import of e-cigarettes and related products into the kingdom. This policy is reinforced by the Customs Act B.E. 2560, which criminalizes the undeclared importation of these items. Furthermore, the Consumer Protection Board Order No. 9/2558 forbids the sale or provision of e-cigarettes, their components, and e-liquids. The Tobacco Products Control Act B.E. 2560 extends smoking prohibitions to include e-cigarettes in designated non-smoking areas. Enforcement of these regulations involves multiple government agencies, including customs officials and consumer protection authorities. Public health campaigns are spearheaded by organizations such as the Thai Health Promotion Foundation (ThaiHealth), working in collaboration with partners like the Division of Health Education, Department of Health Service Support, and Ministry of Public Health. These efforts are notably channeled through the "Youth Health Volunteer Network" and the Youth Institute of Thailand (YIT), which serve as crucial mechanisms for mobilizing health-literate youth leaders to prevent health risks in communities. This multi-faceted approach underscores the

government's commitment to maintaining a comprehensive ban on e-cigarettes while actively engaging in public education and youth-led initiatives to combat their use.

There are a few key works on e-cigarettes and healthcare communication policies. Ratzan (1996) state that health communication fundamentally comes from two disciplines: Communication and public health. Rimal and Lapinski (2009) suggest that health communication is a blend of theory and practice in understanding the process of communication and behavioral change in humans. Ishikawa and Kiuchi (2010) stated that health communication involves communication activities between individuals or masses aimed at improving health and skills in understanding and applying information about population health issues, which develop into health literacy.

By integrating the definition of health and well-being from the previous section with the definition of health communication, it can be concluded that health communication (health status) is the process of using all forms of media to communicate to individuals the importance of protecting their health, their families, and society to have good physical, mental, social, and intellectual health, ready for a good life, emphasizing not only treatment when illness occurs but also prevention before illness. The structure of communication to promote social health status is divided into two dimensions: the communication dimension and the content dimension. The components of health communication consist of five parts: sender, message, channel, receiver, and the effect of communication.

Bhalerao et al. (2019) underscored the enduring public health battle against tobacco, which continues to be responsible for nearly 480,000 American deaths every year, with a current smoker population of approximately 34.3 million individuals in the USA. Addressing this challenge requires a sophisticated and multi-layered strategy from federal, state, and local governments to formulate public health policies. Such policies must strategically position e-cigarettes as tools for smoking cessation, carefully designed to prevent contributing to the health decline of future generations by averting addiction and associated diseases.

Brady et al. (2019) delved into the complex and uncertain landscape surrounding the impact of electronic cigarettes (e-cigarettes) on established tobacco prevention strategies, underscoring the urgent need for a unified stance among health organizations. To shed light on this issue, they embarked on a comprehensive scoping review that sifted through both the published and gray literature to collate and analyze position statements on e-cigarette usage from a wide array of international health bodies. Klein et al. (2020) delved into the intricate dynamics surrounding electronic cigarettes (e-cigarettes), adeptly recognizing their paradoxical role in the public health sphere. They underscore the significant challenge posed by e-cigarettes, which can potentially lead to adverse effects among the youth while offering a less harmful alternative for adult smokers seeking cessation methods.

Helen and Eaton (2018) investigated the complex world of electronic cigarettes (e-cigarettes), devices designed to vaporize a nicotine-infused liquid for user inhalation. These devices harness a concoction of humectants, including propylene glycol and/or glycerin, combined with nicotine and various flavorings, which have propelled them to significant popularity since their debut in the U.S. market back in

2006. Doan et al. presented the intricate realm of policymaking in environments where electronic cigarettes (e-cigarettes) are subject to prohibition. The study leveraged data from Singapore, the USA, the UK, and Japan to construct models for various tobacco control strategies.

Jancey et al. (2018) delved into the polarized viewpoints regarding the ascendancy of electronic cigarettes (e-cigarettes) within the United States, tracing their journey from their inception in 2007 to the present day. This examination brings to light a dichotomy of opinions: on the one hand, there's an optimistic belief that e-cigarettes herald a new era in public health, potentially phasing out the harmful legacy of traditional tobacco cigarettes. Kurnia et al. delved into the transformative impact of Repetitive Transcranial Magnetic Stimulation (rTMS) on patients who have suffered ischemic strokes, with a particular focus on its ability to induce changes in brain activity and to facilitate motor function recovery. It is well-documented that strokes are a predominant cause of long-term disability across the globe, often leading to notable alterations in a patient's electroencephalography (EEG) patterns. These alterations typically manifest as a slowed background activity and an escalated delta + theta/alpha + beta ratio (DTABR), as captured by the quantitative electroencephalogram (qEEG).

Patanavanich et al. (2022) delved into the ramifications of the Thai government's decisive action in 2015 to prohibit the importation and sales of e-cigarettes and its subsequent impact on usage trends among middle school students. The dynamics influencing e-cigarette consumption among Thai youth resonate with patterns observed internationally, showcasing an uptick in 'ever-use' rates, albeit at a scale that is comparatively subdued relative to nations where no such prohibitory measures exist. The research shed light on the ramifications of the 2015 legislative action in Thailand aimed at curbing the importation and sales of e-cigarettes, with a specific focus on the middle school student demographic. Interestingly, despite the enforcement of this ban, the prevalence of current e-cigarette use within this young group has remained relatively high. This phenomenon underscores the ban's operational success.

Seeherunwong et al. (2023) ventured into understanding the consumption patterns and prevalence rates of both cigarette and e-cigarette use among Thai youths, ranging in age from 15 to 24 years, within the context of the socioecological model (SEM). This expansive research, spanning five geographical regions of Thailand and conducted from May to October 2021, capitalizes on an internet-based, self-administered questionnaire intricately designed around the SEM principles, drawing participation from a substantial cohort of 13,139 students. Upon refining the dataset to exclude participants lacking cigarette use status, the analysis unveiled that 4.3% of the respondents reported cigarette usage, 3.5% engaged in e-cigarette use, and 2.4% were identified as dual-users.

Benjakul et al. (2022) provided an insightful analysis of the prevalence and factors influencing e-cigarette usage among public health students in Thailand, recognizing the unique position of these students both as potential users and as role models for non-smoking behaviors. Employing an embedded mixed-methods design, the study incorporates a comprehensive cross-sectional online survey conducted between January and March 2021, which engaged 2302 third-year public health

students from 37 different institutions through a meticulously designed stratified two-stage cluster random sampling method complemented by self-administered questionnaires.

Sandhu et al. (2016) study presented a ground-breaking approach to the management and prediction of H1N1 outbreaks by harnessing the power of cloud computing to develop advanced healthcare support systems. By focusing on H1N1, an airborne virus known for its high contagion rate and significant mortality, the research introduces a meticulously designed cloud computing architecture aimed at swiftly identifying individuals infected with the virus and implementing preventive strategies to reduce the transmission rate. This innovative architecture incorporates four essential processing components alongside secure cloud storage dedicated to a medical database, ensuring both efficiency and data security.

For the initial assessment of infection based on symptomatic analysis, the architecture employs a random decision tree algorithm. It further enhances outbreak monitoring and management through the application of Social Network Analysis (SNA), which provides a dynamic visual representation of the outbreak's spread. The efficacy of this system was rigorously tested on synthetic data simulating two million users, where it demonstrated a remarkable 94% accuracy in disease classification and an 81% rate of resource utilization on the Amazon EC2 cloud platform, underscoring its potential for real-world application.

Hagaman et al. (2016) shed light on the formidable challenges associated with the collection and reporting of suicide data in low- and middle-income countries, spotlighting Nepal due to its alarmingly high suicide rates, as highlighted in the public health literature. The application of social network analysis (SNA) in this context unveils that the dominion over suicide data collection and dissemination predominantly resides with policing institutions, relegating health and community organizations to the periphery.

Stellefson et al. (2020) investigated the transformative potential of social media within the realm of public health education, underscoring its capacity to dismantle traditional hurdles to healthcare access and the availability of resources. As we venture further into an era dominated by Internet-based health promotion, it becomes imperative for health education specialists to cultivate expertise in navigating computer-mediated environments. The paper emphasizes the dual aspects of social media usage in public health—its advantages and its challenges—encouraging professionals to weigh its efficacy thoughtfully against potential obstacles.

Aiello et al. (2020) shed light on the pivotal role of disease surveillance systems within the public health arena, with a specific focus on the integration of social media and internet-based data collection techniques. This approach is poised to bolster surveillance capabilities significantly, offering both potential benefits and facing challenges, notably ethical dilemmas associated with the utilization of digital data for public health monitoring. The review further illuminates several promising advancements within the sphere, notably the advent of hybrid systems.

Dredze (2021) studied the progressive strides made in machine learning and natural language processing, specifically in their application to scrutinizing health-related discourse on Twitter. This examination brings to light the immense potential

harbored by aggregating tweets for the extraction of significant public health insights. The review methodically surveys a spectrum of health topics broached on Twitter, delineating how these virtual conversations can not only bolster existing public health capabilities but also pave the way for the inception of innovative strategies. Hadi and Fleshler (2016). work underscored the indispensable role that social media monitoring plays within the ambit of public health emergency response and recovery operations. It elucidates the bifurcated value that social media presents: on the one hand, serving as an expeditious conduit for the broad dissemination of critical and official incident information, and on the other, acting as a reservoir of incoming data poised to enrich leadership decision-making processes.

Teague et al. (2022) discussed the burgeoning potential and inherent challenges of leveraging social media for the surveillance of mental health in the wake of increasingly frequent and severe global disasters. The review critically addresses the difficulty of employing unstructured social media data to make clinically significant decisions, presenting a thorough scoping study that amalgamates research from various disciplines to shed light on the methodologies and applications pertinent to this field. Through an extensive search across six health and computer science databases, 47 studies were identified, published before 20 April 2021, that utilized social media data to delve into mental health amidst disasters or crises.

Moorhead et al. (2013) analyzed the multifaceted role of social media within the realm of health communication, addressing its interactions with the general public, patients, and health professionals while pinpointing areas ripe for further investigation. Leveraging a comprehensive search through nine electronic databases in addition to manual searches, the review encompasses a wide range of peer-reviewed studies published from January 2002 to February 2012, ultimately selecting 98 original research pieces for examination. The analysis identifies seven primary functions of social media in health communication, notably enhancing user interaction and aiding in both the dissemination and receipt of health-related messages.

In this context, the critical roles of healthcare communication and social network analysis become evident. These tools are essential for implementing the findings from social network analysis into actionable health policies. Effective health communication, as defined by organizations like the World Health Organization (2021) and the American Association for Health Communication (2017), involves using various media forms to educate and inform the public, thereby enhancing health literacy and enabling community participation in health promotion and disease prevention.

Health communication spans several key areas, including strategic communication, risk communication, and community involvement. These are fundamental in crafting policies that encourage healthy behaviors and manage public health risks. Insights from behavioral science, strategic storytelling, and collaborative efforts across different sectors bolster the effectiveness of these communications.

By integrating health communication strategies with findings from social network analysis, policymakers can effectively disseminate crucial information and

foster environments that support healthy choices and behaviors. This integration is pivotal in addressing the complex challenges posed by e-cigarettes, ensuring that health policies are informed by comprehensive data and executed through effective communication channels. This approach not only aims to reduce the prevalence of risky health behaviors but also enhances the overall health and well-being of the population.

The synthesis of existing literature on e-cigarettes, healthcare communication policies, and the emerging role of social media in public health surveillance underscores a multifaceted landscape of opportunities and challenges. E-cigarettes, as illustrated by Bhalerao et al. (2019), Brady et al. (2019), Klein et al. (2020), and St.Helen and Eaton (2018) present a complex public health challenge, balancing their potential as harm reduction tools for adult smokers against the risks of youth initiation and addiction. These works collectively highlight the need for nuanced, evidence-based regulatory approaches to manage the dual nature of e-cigarettes effectively. Furthermore, the insights from Jancey et al. (2018) emphasize the critical role of regulation and the potential effectiveness of targeted public health interventions in addressing the nuanced implications of e-cigarette use within different regulatory contexts.

In the realm of public health surveillance, the innovative application of social network analysis (SNA) and cloud computing provides compelling evidence of the potential to enhance disease outbreak management and suicide surveillance. These methodologies offer a promising avenue for capturing and analyzing complex data to inform public health strategies. Similarly, the integration of social media into health communication and emergency response operations, as discussed by Stellefson et al. (2020), Aiello et al. (2020), Dredze et al. (2012), and Hadi and Fleshler (2016) represents a pivotal shift toward leveraging digital platforms for health promotion, surveillance, and policy advocacy. The ability to monitor and analyze social media content in real time presents unprecedented opportunities to gauge public health trends, disseminate critical information, and engage with communities during health crises.

However, as Teague et al. (2022) and Moorhead et al. (2013) explain, the use of social media and digital data in health communication and surveillance has its limitations. Concerns regarding data quality, privacy, ethical considerations, and the need for robust methodological frameworks are recurrent themes. These reviews call for the establishment of standardized reporting guidelines and rigorous research methodologies to ensure the reliability, replicability, and clinical relevance of health communication and surveillance efforts using digital platforms.

3. Methodology

Social Network Analysis (SNA) is a multidisciplinary field that offers valuable tools and techniques for studying and understanding the intricate relationships and structures within social networks. Below are the five key technical fundamentals of SNA.

(1) Graph Theory: SNA relies heavily on graph theory, which provides the mathematical foundation for representing and analyzing networks. In this

context, nodes represent entities (e.g., individuals or organizations), and edges represent their relationships or connections. Understanding graph theory is crucial for defining and manipulating network structures.

(2) Centrality Metrics: Centrality measures are essential technical tools in SNA. They include various metrics such as degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality. These metrics help identify the most influential nodes, key connectors, and central actors within a network, allowing for a deeper understanding of network dynamics.

(3) Community Detection Algorithms: Community detection algorithms are used to identify clusters or groups of nodes within a network. These communities represent subsets of nodes that are more densely connected than to nodes outside the group. Algorithms like modularity optimization, Louvain, and hierarchical clustering are employed to uncover these substructures, revealing important insights into network organization.

(4) Network Visualization: Effective visualization is crucial for understanding and presenting the results of SNA. Tools like Gephi, Cytoscape, and networkX in Python enable researchers to create visual representations of networks, making it easier to interpret and communicate findings. Visualization techniques also help identify patterns, outliers, and structural characteristics within the network.

(5) Statistical Analysis: SNA often involves statistical analysis to test hypotheses and draw meaningful conclusions. Techniques such as exponential random graph modeling (ERGM) and network regression are used to assess the significance of network properties and relationships. Statistical analysis helps researchers validate their findings and make data-driven decisions based on network data.

These technical fundamentals are essential for conducting in-depth social network analysis, enabling researchers to gain valuable insights into the structure, behavior, and dynamics of complex networks. We give four common methodologies for collecting social network data.

(1) Surveys and Questionnaires: Conducting surveys and questionnaires is a traditional method of gathering social network data. Participants are asked to provide information about their connections, relationships, and interactions with others.

(2) Observational Data: Observational methods involve directly observing and recording interactions within a social network. Researchers may participate in the network themselves or observe from the outside.

(3) Archival Data: Archival data refers to existing records or data sources that contain information about social network interactions. This can include email logs, social media posts, communication logs, or historical records of relationships.

(4) Digital Trace Data: Digital trace data involves collecting data from online platforms and social media sites. This method leverages the vast amount of information generated by users' online activities, such as likes, shares, comments, and friend requests.

3.1. Selection of data sources

To identify and select our data sources, we focused on posts and websites rich in social interactions. The selection process was guided by the aim of finding sources that provide accurate insights into public perceptions and discussions around e-cigarettes. By focusing on social media platforms such as Twitter, Facebook, LinkedIn, Instagram, forums, blogs, and review websites, we aimed to gather a broad spectrum of viewpoints. Key considerations in this process included the volume of data, user demographics, content types, and data accessibility via APIs.

a) Initial Survey of Platforms: We began by cataloging an extensive list of social media platforms, forums, blogs, and review websites known for rich social interactions around health and lifestyle topics, particularly e-cigarettes.
b) Criteria Establishment: We then established a set of criteria for selecting these sources, including the volume of data (with a focus on platforms generating significant daily discussions), user demographics (to ensure a wide representation of viewpoints), content types (text, images, videos, and links), and data accessibility via APIs or web scraping tools.
c) Platform Evaluation: Each platform was evaluated based on these criteria, with an emphasis on identifying those that offer unique insights into public perceptions and discussions about e-cigarettes. This step involved analyzing sample data from each platform to assess its relevance.
d) Final Selection: The final selection of data sources was made to cover a broad spectrum of viewpoints, ensuring a comprehensive dataset that would support nuanced analysis.

3.2. Analysis goals

Clearly defined objectives drive our analysis. We aim to uncover specific insights from social network data about e-cigarette use and perceptions. We sought to answer pivotal questions and address significant problems related to e-cigarette discussions, aligning our data source selection with these analysis goals.

a) Defining Objectives: The first step was to clearly articulate the objectives of our analysis, focusing on extracting insights related to e-cigarette use, perceptions, and the public discourse surrounding them.
b) Question and Problem Identification: We identified key questions and problems to address, such as the factors influencing e-cigarette adoption, the impact of regulatory changes, and the sentiment toward health risks associated with e-cigarettes.
c) Alignment with Data Sources: With our objectives and questions in hand, we aligned our data source selection to ensure that the information we gathered was directly relevant to our analytical goals.

3.3. Data relevance and quality

We evaluated the relevance and quality of each potential data source in relation to our objectives. This involved assessing the types of content and user interactions present and considering the data's accuracy, completeness, and reliability. Our priority was to choose sources that offered relevant, high-quality information with

minimal irrelevant content.

a) Assessment Framework Development: We developed a detailed framework for assessing the relevance and quality of the data from each source, considering factors like content type, user interaction, and the potential for bias.
b) Content and Interaction Analysis: Using this framework, we analyzed the types of content and user interactions present in each data source to ensure they were pertinent to our study's focus.
c) Quality Checks: We also performed quality checks for data accuracy, completeness, and reliability, prioritizing sources that consistently offered high-quality, relevant information.

3.4. Ethical and legal considerations

We carefully reviewed the legal and ethical aspects of using data from social networks, ensuring compliance with regulations like GDPR or CCPA and adhering to each platform's data use policies. This step was crucial for using social data responsibly while respecting privacy and legal boundaries.

3.5. Data acquisition and storage

Data collection occurs weekly via scraping selected social networks, a frequency determined by the adequacy of interaction volume for meaningful analysis. The collected data are stored on Google's computing storage solutions, ensuring scalability and security.

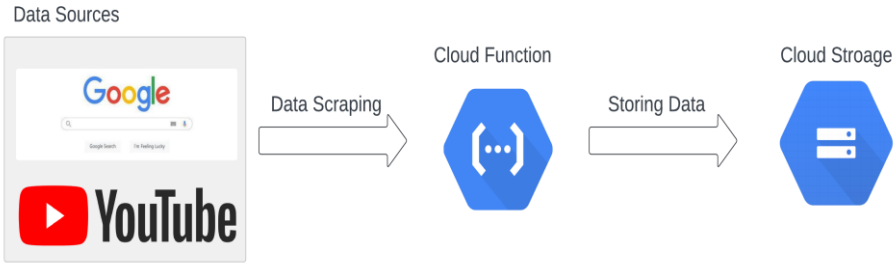

Figure 1. Data acquisition & storage.

This process, as shown in **Figure 1**, involves developing data collection and ingestion mechanisms, transforming and enriching the data, and organizing it in a scalable storage system. Regular backups and archiving are implemented to safeguard the data.

a) Collection Strategy Development: We established a data collection strategy that involved scraping selected social networks on a weekly basis, balancing the need for fresh data with the practicalities of data processing.
b) Data Ingestion and Transformation: Data collected from these platforms underwent ingestion and transformation processes to standardize formats and enrich the data with additional metadata.
c) Scalable Storage Solution: We chose Google's computing storage solutions for their scalability and security, and we developed a structured system for organizing the data effectively.

d) Backup and Archiving: We implemented regular backup and archiving procedures to protect the data's integrity and availability over time.

3.6. Data preparation

Data cleaning is performed using Python, which we utilize Google Cloud, as illustrated in **Figure 2**. It focuses on eliminating duplicates, preprocessing text, resolving entities to their canonical forms, and validating the accuracy of the dataset. These steps are critical for maintaining the integrity and usefulness of the social network data.

a) Cleaning and Pre-processing: We utilized Python to execute a comprehensive data cleaning process that included duplicate detection and removal, text pre-processing, entity resolution, and data validation.

b) Data Integrity Checks: We performed integrity checks to ensure the dataset's quality, making adjustments as necessary to resolve inconsistencies or inaccuracies.

c) Preparation for Analysis: The cleaned dataset was then prepared for analysis, with data structured and indexed to support efficient querying and analysis.

Figure 2. Data preparation.

3.7. Data analysis and policy formulation

Our analysis is presented through a smart dashboard, employing data science techniques to derive insights. These insights inform our healthcare policy framing, comparing current policies. Additionally, we engage stakeholders in the analysis process, fostering collaboration and ensuring that policies are well-informed and targeted.

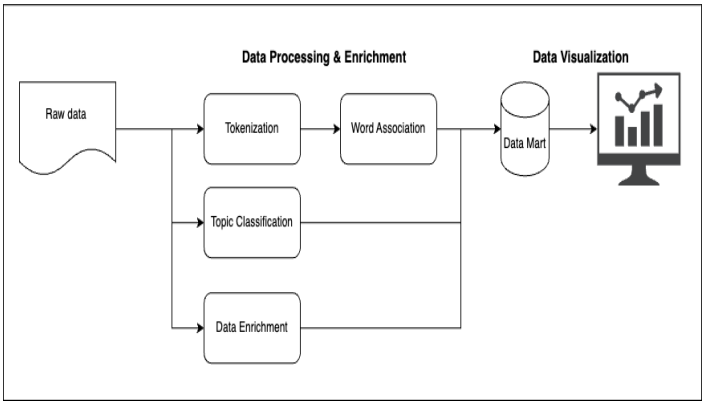

Figure 3. Data analytics process.

a) Analysis Execution: We employed advanced data science techniques, as

illustrated in **Figure 3**, to conduct a thorough analysis of the dataset, exploring network structures, information diffusion patterns, and public sentiment.

b) Dashboard Development: Insights derived from the analysis were visualized through a smart dashboard on Google Cloud, designed to present the findings in an accessible and actionable format.

c) Policy Comparison and Development: These insights informed our policy-framing efforts, allowing us to compare current e-cigarette policies with the new evidence and develop recommendations for policy adjustments.

d) Stakeholder Engagement: Throughout the analysis process, we engaged with stakeholders, incorporating their insights and feedback to ensure that the resulting policies were comprehensive, well-informed, and targeted toward relevant issues.

This comprehensive methodology enables a nuanced understanding of public discourse on e-cigarettes, guiding the formulation of health policies that are responsive to social network analyses and stakeholder inputs. The results are illustrated in **Figures 4–6**. **Figure 4** shows all of the analytic dashboards that we built to help track e-cigarette trends in Thailand. **Figure 5** shows a word cloud map of the Thai terms, which shows key frequent query terms. This demonstrated that the liquid for e-cigarettes is being queried rather often. Not only can these keywords tell us the trend of e-cigarettes in Thailand is increasing, but by comparing the larger word search for liquid vapor for e-cigarettes. **Figure 6** shows the ranking of different websites related to e-cigarettes, demonstrating that from March 2024 to April 2024, the government was very active in combating e-cigarettes.

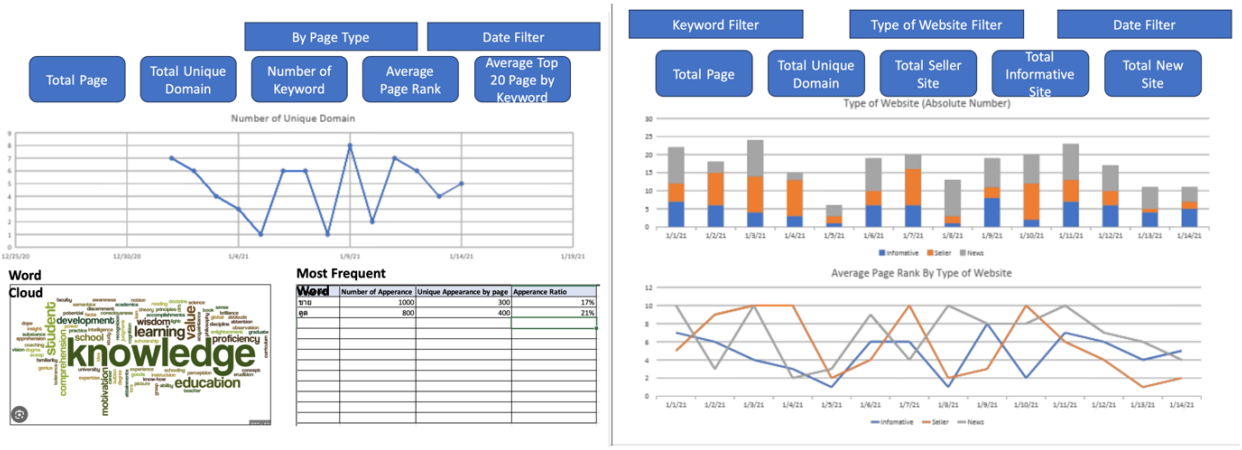

Figure 4. Analytics dashboard.

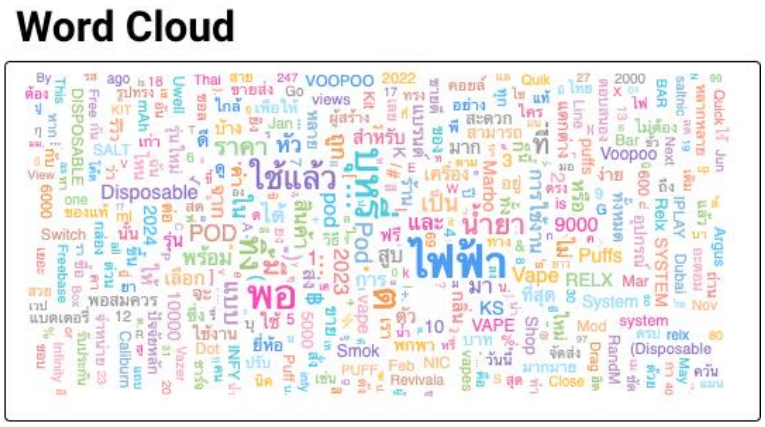

Figure 5. Active keywords.

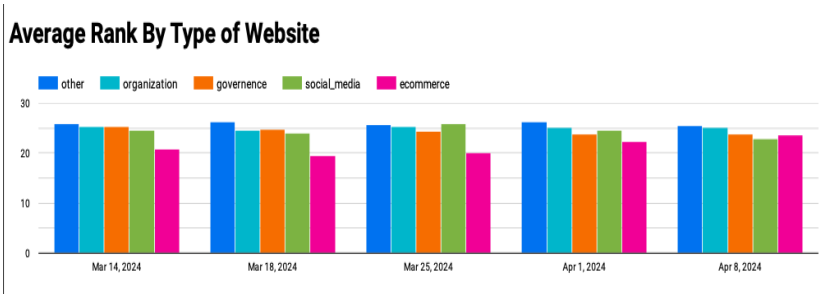

Figure 6. Website rank tracking by category.

4. Policy recommendations for applying research findings

The policy recommendations are well-founded and further strengthened by examples of successful approaches from other countries. For instance, Singapore and the UK have implemented targeted public health interventions and strict regulatory measures that have effectively reduced e-cigarette use among youths. These examples provide a stronger basis for the recommendations, demonstrating their potential for success in the Thai context.

International examples provide compelling evidence for the potential effectiveness of our proposed policies. The United Kingdom's "Stoptober" campaign exemplifies a comprehensive strategy utilizing various social media platforms to reach diverse segments of society, effectively promoting smoking cessation and raising awareness about both traditional smoking and vaping risks. Similarly, the United States FDA's "The Real Cost" campaign showcases the importance of data-driven approaches, with continuous monitoring and evaluation of the campaign's reach and effectiveness across multiple platforms. Australia's stringent regulations on e-cigarette imports and sales, coupled with targeted communication campaigns like "Don't Make Smokes Your Story," align closely with our recommendations for strict law enforcement and focused awareness efforts.

These examples demonstrate how integrated approaches, data-driven strategies, and strict regulations combined with targeted communication can contribute to successful tobacco control policies, including those addressing e-cigarette use. Furthermore, as highlighted by Dang et al. (2021) and Makkizadeh & Ebrahimi (2022), health communication research continues to grow rapidly, applying communication science to develop generalizable knowledge capable of improving

individual and community health. The FDA's Center for Tobacco Products has shown how such research can directly inform public health policies, actions, and practices, with real-world applications in areas such as communication campaigns, health warnings, and regulation of marketing claims (Noar et al., 2024).

By adapting these strategies to the Thai context, we believe there is strong potential for success in achieving the goals outlined in our policy recommendations. This approach aligns with the broader aim of contributing to Sustainable Development Goal 3—Good Health and Well-being, while also demonstrating the translatable nature of health communication research to other contexts beyond tobacco control.

The results highlight key influencers and network structures within the e-cigarette user community, revealing significant implications for policy formulation. For instance, the identification of central nodes within these networks suggests that targeted interventions through these key influencers could effectively disseminate accurate health information and counteract pro-e-cigarette messaging. This strategic approach can enhance the effectiveness of public health campaigns and regulatory measures. We summarize the findings as follows.

1) The research findings reveal that vaping-related communication occurs across all online social media platforms. Therefore, the concept of "health in all policies" should be promoted, with tobacco control being a crucial aspect of all significant national policies. Simultaneously, it is essential to continuously raise awareness and impart knowledge about the dangers of smoking to parents, guardians, teachers, children, youth, and all sectors of society through all online social media channels.
2) Studying potential obstacles to communication approaches reveals that the number of channels selling vaping products and accessories, particularly on e-commerce and dedicated vaping websites, is comparable to the amount of content from government agencies or relevant hospitals. Consequently, a data collection system should be developed to enable agencies responsible for anti-smoking communication campaigns to monitor and study the impact of the changing volume of information presented from both perspectives. This will help maintain a balance or ensure a higher volume and reach of health-promoting content over content that encourages vaping behavior, preventing unhealthy behaviors that hinder sustainable development in health and well-being.
3) Although importing vaping products and accessories is illegal in Thailand, the research findings reveal extensive information about their distribution across online social media landscapes, particularly on various websites. This highlights that vaping is a public health crisis in the country, especially for children and youth as new users. Thailand should maintain the import ban on vaping products coupled with strict law enforcement, which is the most effective measure to protect Thai youth. Additionally, efforts should be made to align with the World Health Organization's Framework Convention on Tobacco Control (FCTC), covering advertising, promotion, sales, or distribution through online platforms. Thailand should also consider joining the Protocol to Eliminate Illicit Trade in Tobacco Products.

4) The research findings identify government organizations, private entities, non-profit organizations, or channels with significant vaping-related communication and specific content direction. Consequently, government agencies such as the Ministry of Public Health, the Thai Health Promotion Foundation, and the anti-smoking advocacy foundation should establish collaborative networks, provide accurate information, disseminate knowledge, and offer communication guidelines to prevent vaping. These efforts should enable various communication channels to conveniently disseminate content that contributes to Sustainable Development Goal 3—Good Health and Well-being.

We discussed how the smart dashboard can be utilized to implement and monitor the E-cigarette Healthcare policy. We followed the criteria from the first section, where the data collection and analysis were discussed in the previous section. In this section, we present a discussion in conjunction with a smart dashboard introduced earlier that leads to the social network framework that can be utilized to help drive Healthcare Communication Policy.

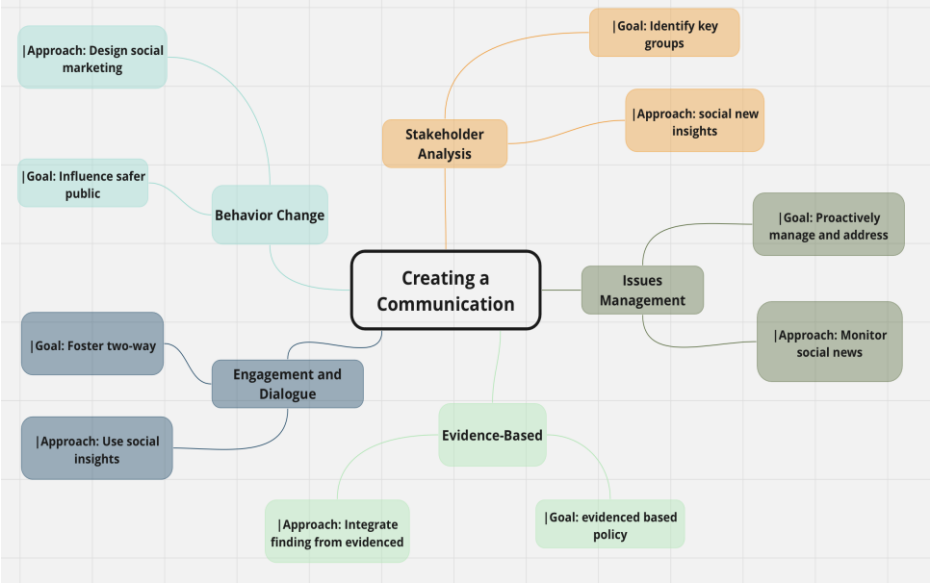

Figure 7. Framework.

Creating a communication policy on e-cigarettes using social news insights can be a strategic way to address public concerns and perceptions. Here are five frameworks illustrated in **Figure 7** that could guide this process:

(1) Stakeholder Analysis Framework:

- Goal: Identify key groups (e.g., e-cigarette users, healthcare professionals, regulators) and their sentiments and concerns regarding e-cigarettes.
- Approach: Use social news insights to analyze discussions and sentiments across different stakeholder groups. This helps in understanding diverse perspectives and tailoring communication to address specific concerns and misinformation.

(2) Issues Management Framework:

- Goal: Proactively manage and address emerging issues related to e-cigarettes that could impact public health or regulatory status.

- Approach: Monitor social news for real-time data on issues and trends. Use this information to predict potential crises or negative perceptions and develop responsive strategies to mitigate risks.

(3) Evidence-Based Communication Framework:
- Goal: Ensure that all communication policies are supported by credible evidence and scientific data.
- Approach: Integrate findings from reputable studies on e-cigarettes with insights gained from social news to craft messages that are factual and counteract prevailing myths. This could involve clarifying the risks and benefits of e-cigarette use compared to traditional smoking.

(4) Engagement and Dialogue Framework:
- Goal: Foster a two-way communication channel with the public and stakeholders.
- Approach: Use insights from social news to identify key concerns or questions the public has about e-cigarettes. Develop an interactive communication policy that includes Q&A sessions, public forums, and direct responses to public inquiries on social platforms.

(5) Behavior Change Communication Framework:
- Goal: Influence public behaviors and attitudes towards safer practices related to e-cigarette use.
- Approach: Apply social marketing principles using insights from social news to design targeted campaigns that encourage desired behavior changes (e.g., discouraging use among non-smokers, promoting cessation). This could involve testimonials, risk communication, and highlighting the benefits of quitting or switching from traditional cigarettes.

These frameworks can be tailored according to specific organizational goals and the regulatory environment, ensuring that the communication policy on e-cigarettes is both effective and socially responsible.

5. Discussion and conclusion

This study underscores the significance of social network analysis (SNA) as a potent tool for understanding and shaping healthcare policies concerning e-cigarettes in Thailand. By meticulously examining online platforms and social media discussions, we have gained invaluable insights into the intricate dynamics of e-cigarette use, perceptions, and communication patterns within the Thai context. These insights have the potential to inform evidence-based policy interventions that are both targeted and effective.

Our research findings highlight the need for a comprehensive and multi-faceted approach to address the complex issue of e-cigarette use in Thailand. This includes leveraging the power of social media for health communication, implementing stricter regulations on e-cigarette imports and sales, and fostering collaboration among government agencies, private entities, and non-profit organizations to disseminate accurate information and promote healthier alternatives. By integrating SNA with robust data collection and analysis methodologies, policymakers can develop a deeper understanding of the factors influencing e-cigarette adoption, the

impact of regulatory changes, and the evolving public sentiment towards these products. This knowledge can then be translated into actionable policies that prioritize public health, particularly among vulnerable populations such as youth and young adults.

The findings of this study can directly inform public health policies in Thailand. Specific policy recommendations include implementing targeted educational campaigns through identified key influencers, stricter enforcement of the existing e-cigarette ban, and the development of collaborative networks between government agencies, non-profits, and private entities to disseminate accurate information. These strategies align with Thailand's current regulatory framework and can significantly enhance public health outcomes.

In conclusion, this study serves as a stepping stone towards a more data-driven and socially informed approach to healthcare policymaking in Thailand. By harnessing the power of social network analysis and embracing a collaborative approach, we can pave the way for a healthier and more sustainable future for all Thai citizens.

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