A COMPREHENSIVE FRAMEWORK AND GUIDELINES FOR SUSTAINABLE CITY DEVELOPMENT IN CHIANG MAI, THAILAND

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Abstract
Purpose: The purpose of this work is to provide practical guidelines for policymakers, urban planners, and stakeholders in Chiang Mai and to ensure that the city grows in a manner that preserves its environmental integrity, enhances the well-being of its residents, and fosters economic prosperity. **Design/Methodology/Approach:** The research adopts a comprehensive approach to studying sustainable city development in Chiang Mai. It utilizes a combination of qualitative and quantitative methods, including data analysis. These methods enable a holistic understanding of the current state of the city and its sustainability challenges. **Findings:** The framework for the development of the city of Chiang Mai was proposed. Future urban Chiang Mai development should focus mainly on increased utilization of renewable energy in relation to total energy consumption, improving air quality, improving waste management, and implementing sustainable transport options. **Research Limitations:** Certain limitations were encountered, such as time constraints and data availability. These limitations may have influenced the scope and depth of the study. **Practical Implications:** The guidelines derived from the study will serve as a practical tool for policymakers, urban planners, and stakeholders in Chiang Mai, enabling them to make informed decisions and take effective actions to promote sustainable city development. **Value:** This research presenting a comprehensive framework for evaluating cities using indicators. The framework developed in this study can be adapted and applied not only to Chiang Mai but also to other cities globally.

Keywords: Sustainable cities and communities; Urban development plan; City indicator; Clean energy

Introduction

The Sustainable Development Goals (SDGs) are a set of global objectives adopted by the United Nations in 2015 to address the most pressing economic, social, and environmental challenges facing the world (Pradhan et al., 2023; Breuer et al., 2023). As cities around the world grapple with the challenges of rapid urbanization, sustainable urban development emerges as a critical concept for promoting long-term environmental, social, and economic well-being (Asadzadeh et al., 2022; Yang and Qian, 2022). Chiang Mai, a bustling city in Thailand, has embarked on a transformative journey towards sustainability (Pongruengkiat et al., 2022).

The research conducted in Chiang Mai, which focuses on promoting sustainable development through indicators and guidelines, aligns with the SDGs (Blasi et al., 2022; Sucupira Furtado et al., 2023). The SDGs provide a comprehensive framework for sustainable development, encompassing goals such as affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), and climate action (SDG 13), among others (Grossi and Trunova, 2021; Greenland et al., 2023). By addressing sustainability challenges in areas such as air pollution, water quality, energy consumption, transportation, and waste management, the research in Chiang Mai contributes to multiple SDGs. For example, efforts to increase the utilization of renewable energy and improve air quality contribute to SDG 7 and SDG 13, respectively. Enhancing waste management practices aligns with SDG 12, while

implementing sustainable transportation options supports SDG 11(Obaideen et al., 2022; Saiu et al., 2022; Hussain et al., 2023).

In previous research (Pongruengkiat et al., 2023a; 2023b), we delve into the state of sustainable urban development in Chiang Mai, employing a comprehensive multi-dimensional framework that examines various indicators, shown in Figure 1. The analysis reveals that Chiang Mai has made commendable progress in certain areas. However, pressing challenges in transportation, waste management, air pollution, and energy consumption demand urgent attention. The research underscores the significance of sustainable urban development and offers valuable insights for policymakers, urban planners, and stakeholders seeking to shape a sustainable future for the city.

The previous research work also introduces a comprehensive framework for evaluating cities through expert-selected indicators, which can be adapted and applied to other urban centers worldwide. In evaluating Chiang Mai, a set of 35 indicators was used whose 28 indicators surpassed the assessment criteria. The overall score of 2.69 out of 3 indicates commendable progress towards sustainable development. However, certain indicators fell short, emphasizing the ongoing need for concerted efforts to achieve sustainability goals.

The purpose of this work is to offer practical guidelines for policymakers, urban planners, and stakeholders in Chiang Mai, aiming to ensure that the city's growth aligns with the preservation of its environmental integrity, the enhancement of residents' well-being, and the promotion of economic prosperity. Based on the research findings, a comprehensive framework for the development of Chiang Mai has been proposed. The future urban development of Chiang Mai should primarily prioritize increasing the utilization of renewable energy in relation to total energy consumption, improving air quality, enhancing waste management practices, and implementing sustainable transportation options. By focusing on these key areas, Chiang Mai can make significant strides towards becoming a sustainable and livable city, setting an example for other urban centers to follow.

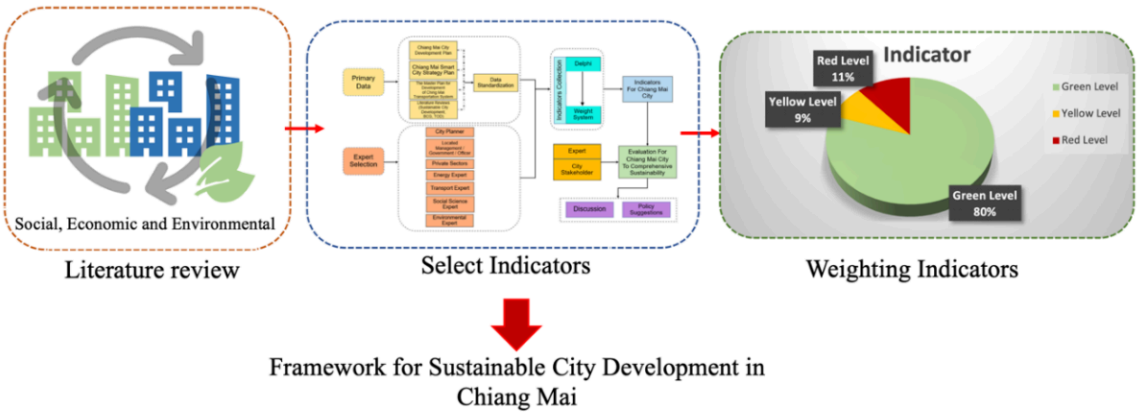

Figure 1: Research framework

Materials and Methods

Based on our prior research, a sustainability guideline for Chiang Mai has been established, incorporating concise indicators (Pongruengkiat et al., 2022; 2023a; 2023b). Consequently, this study aims to propose a development guideline for Chiang Mai. The indicators presented in this research comprise a selection of indicators previously categorized as yellow and red. Yellow-rated indicators encompass water quality, population density, and number of crimes, while red-rated indicators include the proportion of renewable energy usage to total energy, air quality, waste management, and transportation type. The scores of indicators are displayed in Figure 2. The yellow and red graded indicators identified in the research play a crucial role in guiding efforts towards achieving sustainable development in Chiang Mai. These

indicators highlight areas that require further attention and improvement to elevate their performance to the green level. By focusing on addressing the challenges represented by the yellow and red graded indicators, Chiang Mai can work towards finding sustainable solutions to enhance its overall sustainability. For example, for indicators such as water quality, population density, and number of crimes falling within the yellow level, specific measures can be implemented to improve their performance. This may involve implementing stricter regulations to minimize pollution, implementing urban planning strategies to manage population density effectively, and enhancing law enforcement and community engagement to reduce crime rates. Similarly, for indicators in the red level, such as proportion of using renewable energy to total energy, air quality, waste management, and type of transport, concerted efforts are needed to address the significant areas of concern. This may include implementing policies and incentives to promote the use of renewable energy sources, adopting stricter emission standards to improve air quality, enhancing waste management infrastructure and practices, and investing in sustainable and efficient public transportation systems.

By actively addressing these yellow and red graded indicators and finding sustainable solutions, Chiang Mai can strive towards achieving the green level across all indicators for sustainable development. This holistic approach will contribute to creating a more resilient, livable, and environmentally friendly city for its residents while also serving as a model for other cities seeking sustainable development.

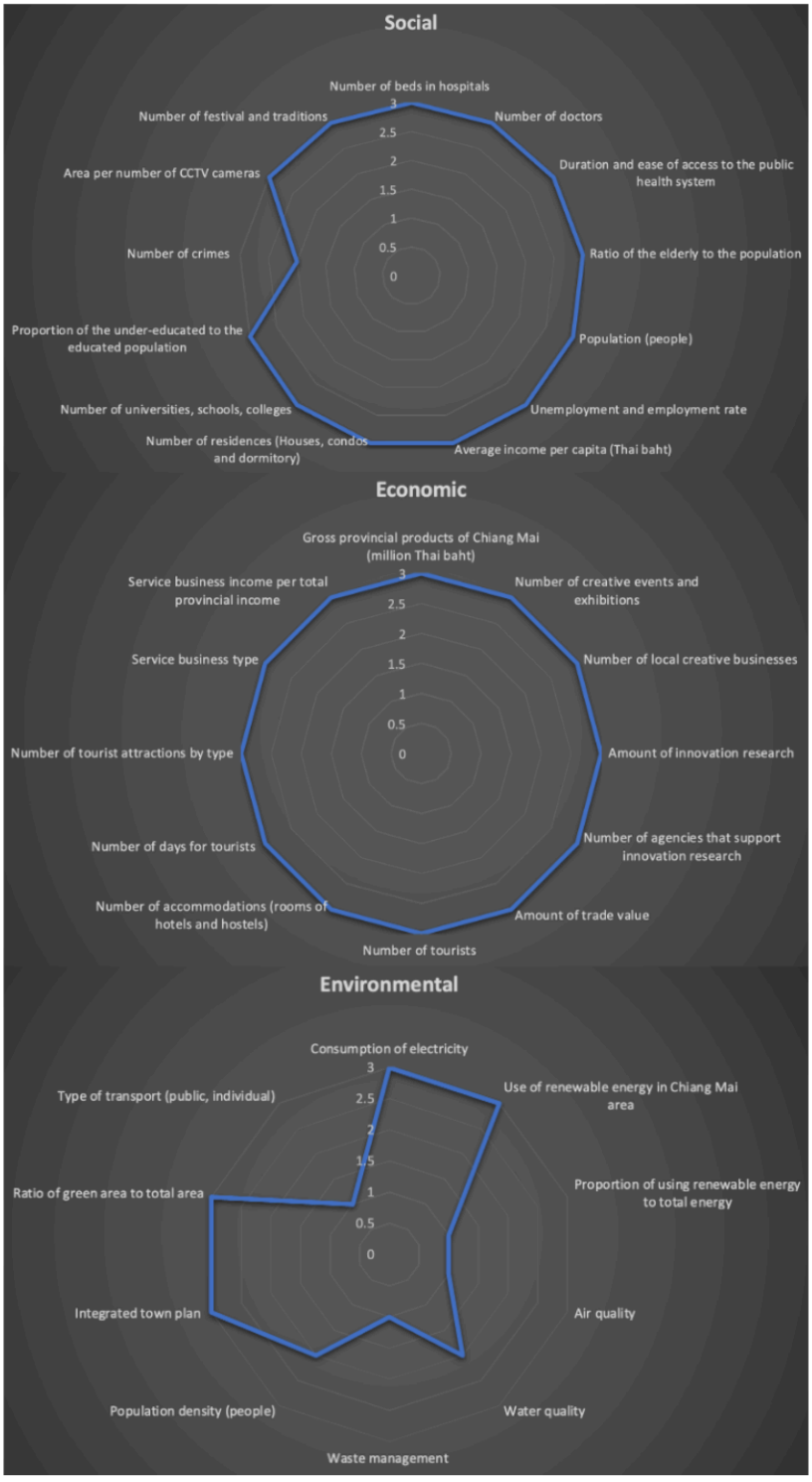

Figure 2: Scores of indicators separated by Social, Economic and Environmental groups

Results and Discussion

Based on the study of various aspects of Chiang Mai and the indicators that have not met the evaluation criteria, several methods and guidelines can be proposed to improve these indicators and promote sustainable development in the city.

Water quality

Improving water quality in Chiang Mai is a critical step towards achieving sustainable development and ensuring the well-being of its residents. To address this challenge, a multi-faceted approach is needed. First and foremost, comprehensive wastewater treatment measures should be implemented, requiring industries to treat their wastewater before it enters water bodies. Furthermore, promoting sustainable agricultural practices that minimize chemical runoff and encourage responsible irrigation techniques can help safeguard water quality. Regular monitoring of water sources is essential to identify contamination sources promptly and take corrective actions. Engaging and educating local communities about the importance of clean water and involving them in monitoring initiatives can foster a sense of ownership and responsibility. Upgrading water treatment facilities and protecting water catchment areas, such as forests and wetlands, are vital steps in ensuring clean and safe water for the population. Lastly, collaborative governance and regulation, involving government agencies, water management authorities, and environmental organizations, can support the development and enforcement of effective policies and practices. By implementing these measures, Chiang Mai can effectively tackle its water quality issues, paving the way for a sustainable future for the city and its residents.

Population density

To address Chiang Mai's population density challenges, the following strategies can be implemented: prioritizing compact and mixed-use development through smart growth principles, investing in efficient public transportation systems, developing satellite towns and decentralized employment centers, promoting affordable housing and mixed-income neighborhoods, and fostering citizen participation and engagement. These measures aim to distribute the population more evenly, reduce congestion, improve land use efficiency, and enhance the overall livability and sustainability of the city. By implementing these strategies, Chiang Mai can effectively manage its population density and create a more balanced and inclusive urban environment.

Number of crimes

To address the issue of high crime rates in Chiang Mai, several strategies can be implemented. First and foremost, enhancing law enforcement efforts and increasing police presence in high-crime areas can help deter criminal activities and improve public safety. Additionally, investing in community policing initiatives and fostering strong relationships between law enforcement agencies and local communities can promote trust, cooperation, and timely reporting of crimes. Implementing targeted crime prevention programs, such as neighborhood watch programs and youth engagement initiatives, can also play a significant role in reducing criminal activities. Furthermore, improving street lighting and implementing effective urban design strategies, such as creating well-lit public spaces and improving the overall physical environment, can help enhance surveillance and discourage criminal behavior. Finally, providing support and resources for rehabilitation and reintegration programs for offenders can contribute to reducing recidivism and promoting long-term community safety. By implementing these comprehensive approaches, Chiang Mai can effectively address the challenges associated with the number of crimes and create a safer and more secure city for its residents and visitors.

Proportion of renewable energy usage to total energy

To address the challenge of increasing the proportion of renewable energy usage to total energy in Chiang Mai, several measures can be implemented. Firstly, it is crucial to establish supportive policies and regulations that incentivize the adoption and integration of renewable energy sources. This can include feed-in tariffs, tax incentives, and subsidies for renewable energy projects. Encouraging investment in renewable energy infrastructure, such as solar and wind farms, can also help boost the overall capacity of renewable energy generation in the city. Additionally, promoting energy efficiency measures and raising awareness about the benefits of renewable energy among the public can encourage individuals and businesses to transition to clean energy sources. Collaborating with local and international partners to access expertise, technology, and funding for renewable energy projects can also accelerate progress in this area. Furthermore, conducting research and development activities to explore innovative solutions, such as energy storage technologies, can enhance the reliability and stability of renewable energy systems. By implementing these strategies, Chiang Mai can significantly increase the proportion of renewable energy usage and reduce its dependence on fossil fuels, leading to a more sustainable and environmentally friendly energy future.

Air quality

To tackle the issue of air quality in Chiang Mai, comprehensive measures need to be taken. Firstly, reducing sources of air pollution is crucial. This can be achieved through stricter regulations on industrial emissions, enforcing vehicle emission standards, and promoting cleaner transportation options such as electric vehicles or improved public transportation. Additionally, addressing the problem of open burning, particularly during the agricultural season, is essential. Implementing effective policies and awareness campaigns to discourage this practice and provide alternative solutions can significantly improve air quality. Furthermore, promoting green spaces and urban forestry can help mitigate air pollution by absorbing pollutants and improving air circulation. Enhancing monitoring systems and establishing early warning systems can provide real-time data on air quality, allowing for prompt actions and public awareness. Lastly, public engagement and education initiatives are vital to raise awareness about the importance of clean air and encourage individuals to adopt sustainable practices. By implementing these measures, Chiang Mai can effectively address air quality issues and create a healthier living environment for its residents.

Waste management

To address Chiang Mai's waste management problem, a multi-faceted approach is necessary. Firstly, promoting waste reduction and recycling initiatives can significantly reduce the amount of waste generated. This can be achieved through public awareness campaigns, educational programs, and incentivizing recycling and composting practices. Implementing a comprehensive waste segregation system is crucial, ensuring that different types of waste are properly sorted and disposed of. Developing efficient waste collection and transportation systems, including regular pickups and designated collection points, can help prevent waste accumulation and illegal dumping. Investing in modern waste treatment facilities, such as waste-to-energy plants or anaerobic digestion facilities, can provide sustainable solutions for managing the remaining waste. Collaboration with local communities, businesses, and organizations is vital to create a sense of responsibility and ownership in waste management efforts. Finally, implementing stricter regulations and enforcement measures, along with penalties for improper waste disposal, can help ensure compliance and accountability. By adopting these measures, Chiang Mai can work towards a more sustainable and efficient waste management system, minimizing environmental impacts and promoting a cleaner city.

Transportation type

To address Chiang Mai's transportation challenges, a comprehensive strategy focused on sustainable and efficient modes of transportation is crucial. Firstly, promoting the use of public transportation, such as buses and trains, can help reduce the reliance on private vehicles and alleviate traffic congestion. Enhancing the public transportation infrastructure by expanding routes, increasing frequency, and improving accessibility can make it a more attractive option for residents and visitors. Encouraging active modes of transportation, such as walking and cycling, through the development of pedestrian-friendly infrastructure and dedicated cycling lanes can promote a healthier and greener city. Implementing intelligent transportation systems and technologies, such as traffic management systems and real-time information services, can improve traffic flow and optimize transportation routes. Furthermore, incentivizing the adoption of electric and hybrid vehicles through subsidies, tax incentives, and the development of charging infrastructure can contribute to reducing air pollution and carbon emissions. Collaborating with stakeholders, including transportation providers, urban planners, and the community, is essential to ensure the effective implementation of these measures. By prioritizing sustainable transportation options and reducing reliance on private vehicles, Chiang Mai can create a more efficient, environmentally friendly, and people-centric transportation system.

Towards sustainability

This research study focuses on promoting sustainable development in Chiang Mai, Thailand, while aligning with the goals of the SDGs (Biermann et al., 2017). By evaluating various aspects of the city, including water quality, population density, number of crimes, proportion of renewable energy usage to total energy, air quality, waste management, and transportation, practical guidelines and solutions are proposed to address these challenges.

To enhance water quality, the study emphasizes the importance of implementing robust water treatment systems, promoting responsible agricultural practices to reduce pollution, and raising awareness about water conservation among residents and businesses. In addressing population density concerns, the research highlights the need for strategic urban planning, including the development of satellite towns, affordable housing projects, and efficient land use practices. Additionally, investment in infrastructure and amenities, such as schools, healthcare facilities, and recreational spaces, is essential to support the growing population.

To tackle the issue of high crime rates, the study recommends strengthening law enforcement measures, enhancing community policing initiatives, and fostering social programs that address the root causes of crime, such as poverty, unemployment, and inequality. In terms of renewable energy, the research emphasizes the need for promoting clean energy sources, including solar and wind power, through incentives, regulations, and partnerships with energy providers. Increasing the proportion of renewable energy usage to total energy can significantly reduce carbon emissions and contribute to mitigating climate change. Addressing air quality concerns involves adopting stricter emissions standards, promoting green technologies, and encouraging the use of electric and hybrid vehicles. Additionally, the research emphasizes the importance of tree planting and green spaces to improve air quality and enhance urban resilience.

Regarding waste management, the study proposes a comprehensive waste management strategy that includes waste reduction, recycling, and the implementation of efficient waste disposal systems. Public education campaigns, community involvement, and collaborations with waste management companies are essential to achieve sustainable waste management practices. Lastly, in addressing transportation challenges, the research suggests promoting sustainable modes of transportation, such as public transit, walking, and cycling. This involves expanding public transportation networks, developing pedestrian-friendly

infrastructure, and incentivizing the use of electric and hybrid vehicles. Additionally, implementing intelligent transportation systems can optimize traffic flow and reduce congestion.

By implementing the recommendations provided in this research, Chiang Mai can progress towards achieving the SDGs, particularly Goal 6 (Clean Water and Sanitation), Goal 7 (Affordable and Clean Energy), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), Goal 13 (Climate Action), and Goal 16 (Peace, Justice, and Strong Institutions) (Subramaniam et al., 2023). The findings of this study can guide policymakers, urban planners, and stakeholders in their efforts to ensure a sustainable and prosperous future for Chiang Mai, while contributing to the global agenda of sustainable development.

Framework for Chiang Mai sustainable city

For the city to achieve sustainability, it requires three essential elements: livability, viability, and fairness. These elements stem from the development of environmental, social, and economic indicators, totaling 7, which Chiang Mai must improve upon. Figure 3 illustrates these indicators. The challenges faced by Chiang Mai are denoted by red and yellow circles and encompass waste management and water management, both crucial for a healthy environment. Additionally, addressing crime indicators contributes to the betterment of society and the economy. While implementing air policy and renewable energy measures may involve expenses, they lead to cleaner air. Furthermore, the transport indicator significantly impacts various aspects like affordable reduce private vehicle, public and green area, reduced congestion, and supports tourism. Population density indicators also influence congestion and land use. By improving clean air, reducing congestion, and efficient land use, the city can enhance its environment, society, and economy, ultimately driving Chiang Mai towards sustainability. The interplay between transport and population density indicators becomes evident as they impact various dimensions. This relationship needs to be cultivated initially. Simultaneously, the aforementioned indicators necessitate concurrent management.

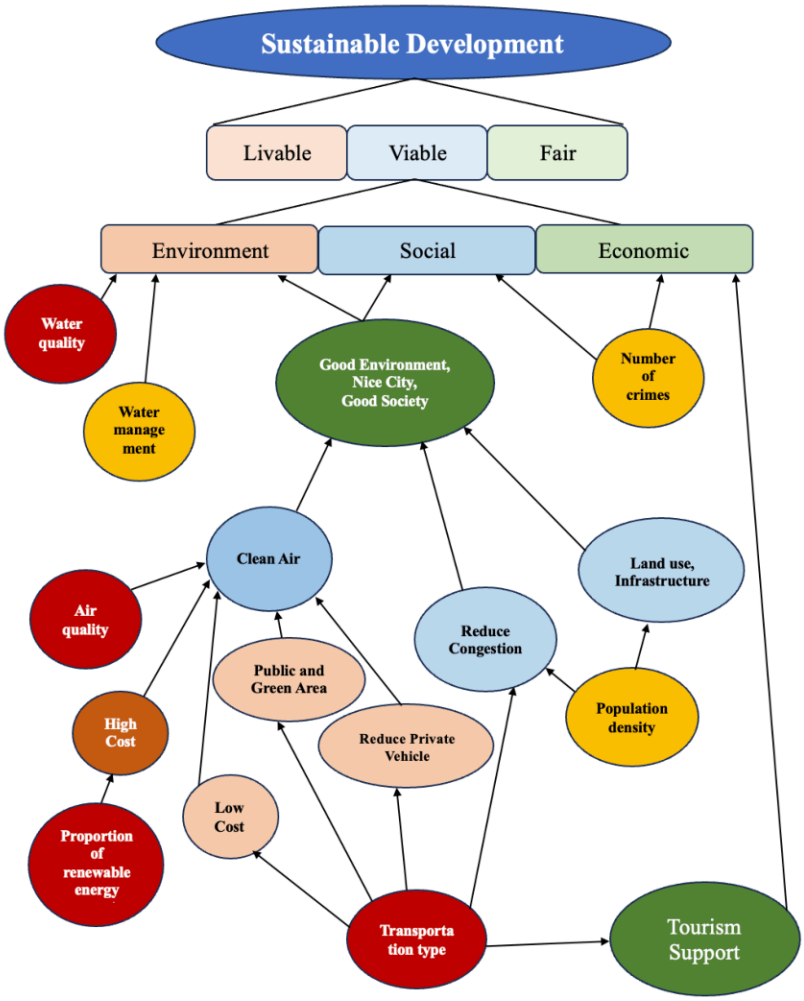

Figure 3: Framework for Chiang Mai sustainable city

Conclusions

This research study provides a comprehensive approach to promoting sustainable development in Chiang Mai, Thailand, aligned with the SDGs. By addressing key indicators such as water quality, population density, crime rates, renewable energy usage, air quality, waste management, and transportation, the study offers practical solutions and guidelines to overcome these challenges. By adopting the recommendations of this research, Chiang Mai can make significant progress towards achieving the SDGs, particularly in the areas of clean water and sanitation, affordable and clean energy, sustainable cities and communities, responsible consumption and production, climate action, and peace, justice, and strong institutions. The findings of this study provide valuable guidance to policymakers, urban planners, and stakeholders in their efforts to ensure a sustainable and prosperous future for Chiang Mai, while contributing to the global agenda of sustainable development.

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References

Asadzadeh, A., Kotter, T., Fekete, A., Moghadas, M., Alizadeh, M., Zebardast, E., Weiss, D., Basirat, M., and Hutter, G. (2022), "Urbanization, migration, and the challenges of resilience thinking in urban planning: Insights from two contrasting planning systems in Germany and Iran", *Cities*, vol. 125, article no. 103642.

Biermann, F., Kanie, N., and Kim, R. E. (2017), "Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals", *Curr Opin Environ Sustain*, vol. 26–27, pp. 26–31.

Blasi, S., Ganzaroli, A., and De Noni, I. (2022), "Smartening sustainable development in cities: Strengthening the theoretical linkage between smart cities and SDGs", *Sustain Cities Soc*, vol. 80, article no. 103793.

Breuer, A., Leininger, J., Malerba, D., and Tosun, J. (2023), "Integrated policymaking: Institutional designs for implementing the sustainable development goals (SDGs)", *World Dev*, vol. 170, article no. 106317.

Greenland, S. J., Saleem, M., Misra, R., Nguyen, N., and Mason, J. (2023), "Reducing SDG complexity and informing environmental management education via an empirical six-dimensional model of sustainable development", *J Environ Manage*, vol. 344, article no. 118328.

Grossi, G., and Trunova, O. (2021), "Are UN SDGs useful for capturing multiple values of smart city?", *Cities*, vol. 114, article no. 103193.

Hussain, S., Ahonen, V., Karasu, T., and Leviäkangas, P. (2023), "Sustainability of smart rural mobility and tourism: A key performance indicators-based approach", *Technol Soc*, vol. 74, article no. 102287.

Obaideen, K., Shehata, N., Sayed, E. T. Abdelkareem, M. A., Mahmoud, M. S., and Olabi, A. G., (2022), "The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline", *Energy Nexus*, vol. 7, article no. 100112.

Pongruengkiat, W., Pichayapan, P., Tippayawong, K. Y., and Tippayawong, N., (2022), "Applying sustainable city assessment framework for Chiang Mai's future urban development", *AIP Conference Proceedings*, vol. 2681, no. 1, article no. 020015.

Pongruengkiat, W., Tippayawong, K. Y., Aggarangsi, P., Pichayapan, P., Katongtung, T., and Tippayawong, N. (2023a). "Applying Delphi method to develop sustainable city indicators. A case study of Chiang Mai, Thailand", *TEMA J Land Use, Mobility Environ*, vol. 16, no. 1, pp. 165-182.

Pongruengkiat, W., Tippayawong, K. Y., Aggarangsi, P., Pichayapan, P., Katongtung, T., and Tippayawong, N. (2023b). "Assessing sustainability of Chiang Mai urban development", *Discover Sustainability*, accepted for publication.

Pradhan, B. K., Yadav, S., Ghosh, J. and Prashad, A. (2023), "Achieving the sustainable development goals (SDGs) in the Indian State of Odisha: challenges and opportunities", *World Dev*, vol. 3, article no. 100078.

Saiu, V., Blečić, I., and Meloni, I. (2022), "Making sustainability development goals (SDGs) operational at suburban level: Potentials and limitations of neighbourhood sustainability assessment tools", *Environ Impact Assess Rev*, vol. 96, article no. 106845.

Subramaniam, N., Akbar, S., Situ, H., Ji, S., and Parikh, N. (2023), "Sustainable development goal reporting: Contrasting effects of institutional and organisational factors", *J Clean Prod*, vol. 411, article no. 137339.

Sucupira Furtado, L., da Silva, T. L. C., Ferreira, M. G. F., de Macedo, J. A. F., and de Melo Lima Cavalcanti Moreira, J. K. (2023), "A framework for digital transformation towards smart governance: using big data tools to target SDGs in Ceará, Brazil", *J Urban Manag*, vol. 12, pp. 74-87.

Yang, C. and Qian, Z. (2022), "Urbanization through resettlement and the production of space in Hangzhou's concentrated resettlement communities", *Cities*, vol. 129, article no. 103846.