การพัฒนาสถานการณ์จำลองสำหรับภาคพลังงานและสิ่งแวดล้อมของเมืองอัจฉริยะเทศบาลนคร เชียงใหม่ด้วยกระบวนการมีส่วนร่วมทางสังคม

The scenario development for the Energy and Environment Sector of Chiang Mai Municipality Smart City is based on social engagement

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Abstract

Chiang Mai, Thailand's second-largest city, faces challenges from rapid urban growth, traffic congestion, and pollution, threatening its livability and sustainability. This study aims to develop a sustainable smart city scenario for Chiang Mai Municipality through participatory engagement and strategic planning. By examining urban development trends and formulating energy and environmental scenarios, the research seeks to create a framework that integrates ecological sustainability, technological innovation, and resident well-being. The methodology involves two key components: reviewing smart city development case studies and conducting stakeholder meetings and group interviews to facilitate social engagement processes. A SWOT analysis and scenario development are employed to evaluate actionable strategies. The study emphasizes infrastructure development, online networks, cultural preservation, economic growth, renewable energy adoption, intelligent power distribution, clean transportation, green spaces, and modernization.

The research outlines four scenarios for Chiang Mai's energy and environmental sectors: Scenario 1, "Smart City Plus," promotes low-carbon activities; Scenario 2, also "Smart City Plus," focuses on green actions; Scenario 3, "Smart City Innovation," advances technological leadership; and Scenario 4, "Global Smart City," emphasizes comprehensive technology standardization. These scenarios aim to address critical issues such as air pollution, water quality degradation, and inefficient energy use. The proposed smart city framework integrates digital technology and innovation to alleviate energy and environmental challenges. Strategies include maximizing energy efficiency, encouraging economic growth through sustainable energy adoption, and implementing environmental technologies for water quality improvement. Smart governance enhances public service delivery, infrastructure adaptability, and environmental management, while a smart economy fosters growth, improves transit systems, and elevates residents' quality of life. This research provides actionable insights for sustainable urban development in Chiang Mai.

Keywords: Smart City, Scenario, Chiang Mai Municipality, Social engagement

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บทคัดย่อ

เซียงใหม่เมืองที่ใหญ่เป็นอันดับสองของประเทศไทยและกำลังมีความต้องการพัฒนาไปสูงเมืออัจฉริยะและ ้ประสบปัญหาการขยายตัว การจราจร และมลพิษส่งผลต่อความน่าอยู่และความยั่งยืน การวิจัยนี้มีความต้องการพัฒนา ้โครงการริเริ่มเมืองอัจฉริยะที่ยั่งยืนของพื้นที่เทศบาลนครเชียงใหม่โดยการมีส่วนร่วมทางสังคม ผ่านการศึกษาการ ้เติบโตของเมืองและการพัฒนาสถานการณ์จำลองสำหรับภาคพลังงานและสิ่งแวดล้อมของเมืองอัจฉริยะเทศบาลนคร เชียงใหม่ โดยวิธีการวิจัยแบ่งออกเป็นสองส่วน ประกอบด้วยการศึกษาเอกสารและงานวิจัยที่เกี่ยวข้องด้านการพัฒนา ้เมืองอัจฉริยะ และการใช้กระบวนการทางสังคมผ่านการประชุมและการสัมภาษณ์กลุ่ม จากนั้นทำมาวิเคราะห์ SWOT ์ และสร้างสถานการณ์จำลอง พบว่าเชียงใหม่ให้ความสำคัญกับโครงสร้างพื้นฐาน เครือข่ายดิจิทัล การอนุรักษ์วัฒนธรรม การเติบโตทางเศรษฐกิจ และการมีส่วนร่วมของผู้มีส่วนได้ส่วนเสีย พลังงานที่ยั่งยืน เครือข่ายการกระจายพลังงาน ้อัจฉริยะ การขนส่งและการก่อสร้างที่เป็นมิตรต่อสิ่งแวดล้อม และพื้นที่สีเขียวในเมือง เชียงใหม่ต้องการเป็นเมืองที่ ้ทันสมัย เป็นมิตรกับสิ่งแวดล้อม และก้าวหน้าทางเทคโนโลยี โดยให้ความสำคัญกับผู้อยู่อาศัยและสิ่งแวดล้อม การ ้วิเคราะห์สถานการณ์ภาคพลังงานและสิ่งแวดล้อมสำหรับการพัฒนาเมืองอัจฉริยะของเทศบาลนครเชียงใหม่ ้ประกอบด้วยสถานการณ์ที่ยั่งยืน นวัตกรรม และเทคโนโลยีขั้นสูงสี่สถานการณ์ สถานการณ์ที่ 1 "เมืองอัจฉริยะบวก" ้ส่งเสริมแนวทางปฏิบัติที่มีคาร์บอนต่ำ ฉากที่ 2 "เมืองอัจฉริยะอันทรงเกียรติ" เน้นย้ำถึงความเป็นผู้นำด้านเทคโนโลยี ้ฉากที่ 3 "นวัตกรรมเมืองอัจฉริยะ" นวัตกรรม และฉากที่ 4 "เมืองอัจฉริยะสากล" ความครอบคลุมและเทคโนโลยีที่ได้ มาตรฐาน ความตระหนักรู้ด้านสิ่งแวดล้อม นวัตกรรมทางเทคโนโลยี และการเติบโตที่ครอบคลุม เป็นส่วนหนึ่งของ ้กรอบการทำงานเมืองอัจฉริยะของเชียงใหม่ ส่วนประกอบของเมืองอัจฉริยะในเชียงใหม่ใช้เทคโนโลยีดิจิทัลและ ้นวัตกรรมเพื่อแก้ไขปัญหาพลังงานและสิ่งแวดล้อม การพัฒนาเมืองที่ยั่งยืนรวมถึงการปรับปรุงคุณภาพน้ำในพื้นที่เสื่อม ์ โทรม การใช้พลังงานให้เกิดประโยชน์สูงสุด ส่งเสริมการเติบโตทางเศรษฐกิจ ปรับปรุงธรรมาภิบาล และเพิ่มความ ้คล่องตัวด้วยเทคโนโลยีด้านสิ่งแวดล้อม[์]และการตรวจวัดคุณภาพน้ำ, การเลือกใช้พลังงานสะอาดเพื่อลดมลพิษทาง อากาศ, เศรษฐกิจอัจฉริยะช่วยเพิ่มการเติบโตทางเศรษฐกิจ, ระบบธรรมาภิบาลอัจฉริยะปรับปรุงโครงสร้างพื้นฐานการ ้บริการสาธารณะ และปรับปรุงการขนส่งและความพึงพอใจของผู้อยู่อาศัย งานวิจัยนี้ให้แนวทางที่สามารถนำไปใช้ได้ จริงเพื่อการพัฒนาเมืองอย่างยั่งยืนในจังหวัดเชียงใหม่

ดำสำคัญ: เมืองอัจฉริยะ สถานการณ์จำลอง เทศบาลนครเชียงใหม่ การมีส่วนร่วมทางสังคม

Introduction

Thailand's digital economy-focused Smart City policy uses big data analytics to improve transportation, utilities, healthcare, and other public services. Thailand's second-largest city, Chiang Mai, wants to become a smart city due to rapid economic and tourist growth. Sprawl, traffic, and pollution have plagued urban livability and sustainability due to this growth. The city wants to use technology and innovation to overcome these issues and stay a top tourist destination. City leaders worldwide use "Smart City" to describe the use of ICT to improve efficiency and quality of life. Some smart cities prioritize economic competitiveness, while others prioritize livability [1-3]. However, a smart city uses data and analysis for urban management, integrates ICT into services, and encourages community participation. Thailand's second-largest city is Chiang Mai. It actively seeks smart city status. Commerce and tourism have made the city a regional hub for transportation, education, wellness, and hospitality for two decades. Rapid urban development has caused sprawl, poor land use planning, strained public services, traffic congestion, and pollution, affecting livability and environmental sustainability. Chiang Mai is using technology and innovation to improve livability, sustainability, energy efficiency, and public services to stay a top tourist destination. The 98 communities of Chiang Mai represent various residential areas. The 40.216 square kilometers includes residential, commercial, and infrastructure zones. With 130,000 people, this area is densely populated. Community involvement is there crucial for the success of smart city initiatives, necessitating partnerships between governments, academia, businesses, and local communities. This research aims to develop bottom-up strategies for smart city development, engaging stakeholders at all levels. The

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scenario approach utilized data from public consultations, interviews, and community engagement to ensure the sustainability and effectiveness of smart city strategies [4-6]. Ultimately, the research aims to contribute to a broader sustainable smart city agenda beyond Chiang Mai, supporting capacity building and technical assistance for smart city initiatives. By fostering innovation and collaboration, the outcome of this research will sustain efforts to implement smart city strategies and improve urban quality of life.

Research Methodology

Chiang Mai Municipality context review

The Chiang Mai context data is collected by categorizing information from various sources such as the existing database, which includes Thailand's national strategy (2018-2037), the Chiang Mai provincial smart city plan, articles, publications, annual reports, and journals from the Digital Economy Promotion Agency, National Innovation Agency, and affiliated organizations. Additionally, legislation and regulations related to the support of Chiang Mai Municipality Smart City are also considered. In addition, internet or online media were taken into account, along with a comprehensive analysis of the literature review pertaining to the notion of smart cities [7].

Document analysis for Chiang Mai Municipality Smart City

Energy and Environment Sector document analysis for Chiang Mai Municipality's Smart City development emphasizes social engagement and community involvement in sustainable initiatives. It evaluates stakeholder engagement, community participation, capacity building, social inclusion, and monitoring frameworks. This study examines how the municipality empowers stakeholders and the community in decision-making and project implementation. The effectiveness of current approaches and areas for improvement for genuine community involvement in sustainable urban development are revealed by assessing these elements.

Utilizing social engagement methodologies

Chiang Mai Municipality Smart City's Energy and Environment Sector collected primary data through interviews, focus groups, and surveys. Government agencies, community leaders, volunteers, visitors, nonprofits, and allies were contacted via phone, email, and in person. Focus Group Discussions (FGDs) and Group Interviews (GIs) were used to gain feedback from communities, authorities, companies, volunteers, academics, and policymakers. Representative Chiang Mai citizens were randomly or stratified sampled, open-ended talks on environmental issues and smart city initiatives were held, and qualitative data was analyzed for themes. In semi-structured interviews, GIs selected experts and stakeholders to discuss policy frameworks, issues, and future orientations. These interviews revealed themes and insights using thematic analysis. These methods provide complete stakeholder knowledge and participation for sustainable urban development in Chiang Mai.

Scenario analysis

The Scenario Analysis methodology, incorporating SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, systematically evaluates potential scenarios and their implications for Chiang Mai Municipality Smart City's Energy and Environment Sector. It begins with identifying key factors such as regulatory

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frameworks, technological advancements, and community programs. SWOT analysis, informed by stakeholder input from interviews and discussions, assesses internal strengths and weaknesses, as well as external opportunities and threats. Based on these findings, multiple scenarios are developed to explore various outcomes for the sector. Stakeholders participate in workshops to evaluate scenarios and select a preferred one aligned with city objectives. Action plans are then formulated to implement strategies outlined in the chosen scenario, ensuring effective execution and progress monitoring. This approach integrates SWOT analysis and scenario planning to anticipate and address future trends, enabling stakeholders to capitalize on opportunities and mitigate threats for sustainable urban development in Chiang Mai Municipality Smart City [8-10].



Figure 1 Research methodology framework

Result and Discussion

Documentary study of smart city frameworks and best practices for energy and environment

In smart city frameworks across Singapore, Bandung, Taiwan, and Kuala Lumpur, common themes emerge in energy and environmental initiatives. Each city emphasizes governmental commitment and policies, such as Singapore's Green Plan 2030, Bandung's thematic parks, Taiwan's Climate Change Response Act, and Kuala Lumpur's Green Blueprint. Technological innovation is pivotal, with Singapore investing in Grid 2.0 research, Bandung fostering startups like Smash.id for waste management, Taiwan creating the Smart Green Energy Science City, and Kuala Lumpur implementing intelligent technologies like cloud computing and IoT. Urban planning and sustainable infrastructure are also key, seen in Singapore's parkland initiatives, Bandung's restoration projects, Taiwan's green supply chain focus, and Kuala Lumpur's Sunway City development. These efforts collectively drive progress towards smart energy and environmental objectives, prioritizing sustainability and innovation for long-term urban resilience.

Ultimately, every city showcases a unique combination of governmental policies, technological advancements, and urban planning approaches that are focused on promoting smart energy and environmental initiatives. Although different methods may be used, the main objective remains the same: to develop intelligent

and environmentally-friendly cities that improve the well-being of residents and support global sustainability goals.

Social engagement information for Chiang Mai Municipality Smart City

Table 1 are the summary of the smart city perspectives from 6 stakeholder group which are Chiang Mai citizens, Government, Business, Community, Academia and Policy maker. The data are extracted from the organized focused group and/or interviews. The perspectives of smart city are categorized into 7 topics which are 1) The meaning of Chiang Mai smart city; 2) The Direction of Chiang Mai Smart City Developments; 3) The benefits from the development of Chiang Mai Smart City; 4) Key players for the development of smart cities; 5) The indicators of sustainable smart city development; 6) Needs and supporting for sustainable smart city development; and 7) Chiang Mai's Unique style and smart city development.

Overall, the perspectives indicated that Chiang Mai should leverage technology and innovation to enhance services, administration, and economic growth, fostering creativity and progress among residents. Key elements include renewable energy, efficient transportation, and advanced technologies to improve urban life and promote sustainable development. Achieving this requires robust regulatory frameworks and significant investments in digital infrastructure and economic development. A city that prioritizes overall well-being, safety, community engagement, and happiness. Chiang Mai's journey towards smart city status underscores its commitment to sustainability, innovation, and public participation to enhance residents' quality of life. Advancing into a smart city offers various benefits. , including modernized administration, expanded services, improved security, and increased citizen empowerment. Stakeholder collaboration is crucial, with the municipality playing a central role in leading initiatives across multiple sectors for smart city development include resident well-being, environmental sustainability, investment attractiveness, and tourism potential. Maximizing smart city potential involves utilizing local resources, allocating funds to sustainable initiatives, and ensuring timely growth in Chiang Mai requires cultivating innovation, raising awareness, and fostering community participation. in leveraging local assets, implementing sustainable practices, and collaborating with stakeholders to create a comprehensive urban environment aligned with national and global policy objectives..

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 Table 1
 Comparison of Smart City Perspectives from focus group and stakeholder engagement from Citizens, Government, Business, Community, Academics and Policy maker.

Tania	Stakeholder Group						
Горіс	Chiang Mai citizens	Government	Business	Community	Academic	Policy Makers Interview	
The meaning of Chiang Mai smart city	Modern, technologically advanced city that prioritizes convenience, safety, accessibility, and fairness for its residents and visitors alike.	The urban center's strategic emphasis on harnessing technology and innovation not only bolsters the efficacy of its services and administration but also catalyzes economic expansion, generates avenues for employment, and cultivates a milieu conducive to innovation and advancement among its populace.	Clean energy, efficient transportation, and cutting- edge technologies are needed to improve urban livability and well-being and promote sustainable urban growth. Coherent policy frameworks and significant investments in digital infrastructure and economic advancement are essential to achieving these goals.	Clean energy, efficient transportation, and advanced technology are needed to improve residents' quality of life and promote sustainable urban development in a comfortable, happy city. Clear policy frameworks and large investments in digital infrastructure and economic development are needed to achieve these goals.	A smart city transcends mere technological deployment; it prioritizes the enhancement of holistic quality of life, the advancement of safety measures, and the cultivation of community engagement and well-being.	Thai smart cities improve public service efficiency and quality of life with digital technology. This modernization uses technology and social capital to improve convenience, safety, and infrastructure. Development addresses social issues and improves life through technology. health of citizens.	
The Direction of Chiang Mai Smart City Developments	Forward-thinking city that values sustainability, innovation, and citizen engagement in its efforts to create a better quality of life for its residents.	Chiang Mai's goal is to showcase how innovative technologies and strategies can be effectively implemented to improve the quality of life for its residents, enhance sustainability, and position the city as a leader in the global smart city movement.	Modern, sustainable, and livable cities require efficient transportation, infrastructure development, environmental management, data-driven decision-making, and technology accessibility. These initiatives improve residents' quality of life and the city's global competitiveness.	The vision for developing Chiang Mai into a smart city focuses on leveraging technology and sustainable practices to enhance urban mobility, accessibility, environmental sustainability, and quality of life for residents and visitors.	The vision for Chiang Mai is to create a vibrant, modern, and sustainable city that offers a high quality of life and encourages repeat visits from all who come.	Tourism and housing development increase diversity, economic growth, and cultural preservation. Sustainable development is emphasized to promote tourism and income for entrepreneurs and communities. By integrating neighboring communities and improving infrastructure, traffic, and essential services, everyone benefits from regional prosperity and quality of life.	

_ .	Stakeholder Group					
Горіс	Chiang Mai citizens	Government	Business	Community	Academic	Policy Makers Interview
The benefits	Commitment to leveraging		Smart cities require	Tthe transformation into a	The aim is to create a smart	Becoming a smart city offers
from the	technology to modernize		government support for	smart city is envisioned to	city in Chiang Mai that is	multifaceted benefits spanning
development of	governance, enhance		commercial activities,	bring about numerous	competitive, safe,	economic, social,
Chiang Mai	service delivery, improve		innovation, project quality,	benefits, including improved	convenient, inclusive, and	environmental, and
Smart City.	security, and promote		data utilize, and digital	quality of life, better health	environmentally sustainable,	administrative realms. By
	citizen engagement and		platforms. They can make	and environment, economic	with a strong emphasis on	harnessing digital technology,
	empowerment in the city.		high-living-standard cities	growth, enhanced security,	leveraging technology to	innovation, and streamlined
			more efficient, sustainable,	and increased attractiveness	improve the overall quality of	communication, this transition
			and livable for residents and	to both residents and	life for its residents.	elevates living standards for
			visitors.	tourists.		both residents and visitors.
Key players for	Significance of	For integrated and	Innovation and technology	The government, private	This statement emphasizes	The Chiang Mai Municipality
the development	cooperation among local	sustainable smart city	companies, supported by	sector, education sector, and	the importance of	plays a central role in the
of smart cities	government, the	development, government,	government and business,	specialized agencies like	compliance with regulations	development of smart cities
	commercial sector, and	educational, and private	drive smart city	DEPA must collaborate	and laws by various	within its jurisdiction,
	educational institutions in	sector entities must	development. Their	when developing smart	agencies involved in the	leveraging its legal powers and
	promoting the	collaborate. These	innovative solutions, along	cities. Smart city initiatives	development of a specific	duties to spearhead initiatives
	advancement of smart	stakeholders may pool their	with government support,	can create sustainable,	area, particularly Chiang Mai	across various sectors.
	cities.	abilities and resources to	create sustainable and	inclusive, and innovative	Municipality and Province,	
		solve challenging urban	habitable cities.	cities by leveraging	private organizations, and	
		problems and stimulate		stakeholder expertise and	city administrators.	
		innovation-driven growth.		resources.		
The indicators of	Smart city development	Multisector stakeholders,	Corporate innovation,	This statement outlines key	Improved quality of life,	The smart city will provide high
sustainable	improves quality of life,	international smart city	competitiveness, validation,	indicators for measuring	economic progress, and	public standards and quality
smart city	environmental	indicators, and academic	big data use, and	sustainable smart city	agency collaboration are	delivery services. However,
development	sustainability, revenue,	engagement boost Chiang	comprehensive applications	development, with a focus	indicators of Chiang Mai's	main indicator is the happiness
	investment appeal, and	Mai's innovation ecosystem	should be encouraged by	on people's happiness,	smart city development.	of populations in the city.
	tourism potential. These	and speed its smart city	the government to establish	household income, carbon	These indicators measure	
	advantages boost urban	transformation.	smart cities. These steps	emissions, technology	smart city progress and	
	well-being, prosperity,		can accelerate smarter,	adoption, and investment	success, benefiting Chiang	
	and appeal.		more efficient, livable city	levels.	Mai inhabitants and	
			goals.		stakeholders.	

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Торіс	Stakeholder Group						
	Chiang Mai citizens	Government	Business	Community	Academic	Policy Makers Interview	
Needs and	Leverage local human	Every organization can	Successful urban	The declaration emphasizes	Foundational elements	Chiang Mai Municipality serves	
supporting for	resources, allocating	participate in developing and	development in Chiang Mai	human resources, funds	necessary for the	as the driving force behind	
sustainable	resources towards	promoting the innovation	requires collaboration among	allocation, and timely growth	development of Chiang Mai,	smart city development,	
smart city	sustainable initiatives,	ecosystem. To achieve the	stakeholders, including the	in Chiang Mai smart city	emphasizing the importance	leveraging its legal powers and	
development	and ensuring timely	development of Chiang Mai	private sector, civil society,	development. Chiang Mai	of efficient communication	collaborating with diverse	
	development to effectively	to be a smart city In the role	and government agencies.	can manage smart city	systems, digital	stakeholders to create a	
	harness the potential of	of facilitator in creating	Raising awareness,	growth while creating a	infrastructure, transportation	comprehensive and inclusive	
	smart city initiatives,	innovation for local networks	leveraging technology, and	more profitable and livable	management, and	urban environment that aligns	
	particularly in Chiang Mai.	With the goal of creating	fostering community	urban environment by	environmental sustainability.	with national and global policy	
		SME/Startup entrepreneurs	participation are essential for	utilizing local strengths,		objectives.	
		or communities to be strong	creating a smart city that	engaging in sustainable			
		through the use of	meets the needs of its	practices, and adapting to			
		innovation.	residents and adapts to	technological advances.			
			changing circumstances.				
Chiang Mai 's	To create inclusive,	The importance of	Transforming Chiang Mai's	Vision for Chiang Mai that	The declaration promotes	Emphasizing Chiang Mai's	
Unique style and	vibrant, and sustainable	establishing a distinct identity	Walking Street into an online	prioritizes urban	cultural acceptance and	cultural identity and integrating	
smart city	cities, the statement	for the public transportation	format presents an	development, economic	technology to build smart	tradition with technology. The	
development	emphasizes diversity,	system within the area,	opportunity to modernize the	growth, sustainability, and	municipalities in Chiang Mai.	goal is to improve digital	
	local heritage, technology	especially in the context of	market and adapt to	safety. By focusing on	Combining tradition and	services, income, and tourism	
	for cultural preservation,	integrating existing mass	changing consumer	infrastructure improvements,	innovation may create a	value while including local	
	and public participation in	transit systems with future	preferences while preserving	investment, job creation,	dynamic, integrated city that	citizens in the development	
	urban development.	transportation infrastructure.	its cultural heritage and	transportation	respects its heritage and	process. Understanding	
			economic significance.	enhancements, and safety	embraces the digital age.	potential challenges helps	
				measures.		manage cultural preservation	
						and modernization.	



Figure 2 The DNA of Chiang Mai Municipality Smart City

From the perspectives of the stakeholder engagement, the DNA or unique characteristic of Chiang Mai was developed as the aspiration toward the future Smart City of Chiang Mai in Figure 2. In order to achieve the unique character of Chiang Mai with the Smart City Concept. The Smart city scenario planning was performed. Smart city scenario planning involves the exploration and assessment of potential futures for a city, considering various assumptions, drivers, and trends. This method assists planners and policymakers in identifying the opportunities, challenges, and trade-offs associated with different smart city solutions and services. It aids in designing and implementing solutions that are both desirable and sustainable. In this research, the focus is on the energy and environment sector including energy, water, waste, land, and human capital. Implementing the energy and environment scenario can enhance the city's efficiency, resilience, and environmental quality, while concurrently reducing costs and emissions.

Scenario of Chiang Mai Municipality Smart City in Energy and Environment Sector

When analysing the SWOT data for the Energy and Environment Sector of Chiang Mai Municipality's Smart City development, it was discovered that scenario planning for a smart city involves examining and evaluating possible future outcomes for a city (Table 2). This process considers different assumptions, factors, and trends. This approach aids in the identification of the opportunities, problems, and trade-offs linked to various smart city solutions and services, benefiting planners and policymakers. The summary of the SWOT analysis are

Strengths: Chiang Mai demonstrates strong multisector innovation to address energy and environmental challenges, supported by national and international recognition. Government commitment to innovation, regulatory reform, and investment drives these initiatives, with collaboration across government, education, and business sectors. The city emphasizes digital innovation infrastructure and integrated public transportation networks as critical enablers of sustainable development.

Weaknesses: While the initiatives outline broad objectives and strategies, they lack detailed implementation and monitoring plans. Financial and human resource requirements for introducing innovative technologies and infrastructure improvements pose challenges. Policy execution and enforcement mechanisms are not robust, and public involvement lacks clear mechanisms for engagement in planning and execution.

Opportunities: Advancements in renewable energy and smart grid systems offer innovative solutions to energy and environmental issues. Chiang Mai's regional and global significance positions it for collaborations with similar smart cities, enabling knowledge sharing and resource pooling. Investments in energy and

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environmental initiatives can drive economic growth, create jobs in renewable energy, and attract investments in sustainable infrastructure projects.

Threats: Chiang Mai faces increasing vulnerabilities from climate change, such as extreme weather events and water scarcity, which threaten sustainability efforts. Rapid urbanization and population growth strain resources and infrastructure, complicating the implementation and maintenance of initiatives. Political instability or shifts in government priorities could disrupt continuity, hindering long-term sustainability goals.

Strengths	Weaknesses	Opportunities	Threats	
The emphasizes multisector	The scenario outlines	The rapid advancement of	Chiang Mai faces	
innovation to solve energy and	overarching objectives and	technology, including renewable	escalating vulnerabilities due to	
environmental issues.	strategies for energy and	energy solutions and smart grid	climate change, including	
National and international	environmental initiatives but lacks	systems, presents opportunities for	increased occurrences of extreme	
recognition for Chiang Mai's	detailed specifics on	Chiang Mai to address energy and	weather events and water scarcity,	
initiatives shows strong local and	implementation and monitoring.	environmental challenges	which jeopardize sustainability	
global support.	Introducing innovative	innovatively.	efforts.	
Energy and environmental	technologies and improving	Chiang Mai's regional and	Rapid urbanization and	
projects are supported by	infrastructure may require	global significance not only	population growth intensify strains	
government commitment to	significant financial and human	highlights its potential but also	on existing resources and	
innovation, regulatory reform, and	resources, posing challenges for	facilitates collaborations with	infrastructure, posing significant	
investment.	Chiang Mai.	similar smart cities and relevant	challenges to implementing and	
Sustainable solutions	The effectiveness of policy	organizations, enabling knowledge	maintaining energy and	
adoption requires government,	execution and enforcement	sharing and resource pooling.	environmental initiatives.	
educational, and business sector	mechanisms may vary, potentially	Investment in energy and	Political instability or	
collaboration.	impacting the success of energy	environmental initiatives has the	changes in government priorities	
Digital innovation	and environmental efforts.	potential to stimulate economic	may disrupt the continuity of	
infrastructure and integrated public	While public involvement is	growth, including job creation in	energy and environmental	
transportation networks are	recognized, the scenario does not	renewable energy sectors and	programs, hindering the	
stressed to enable sustainable	provide clear mechanisms for	attracting investments in	achievement of long-term	
development.	engaging residents in the	sustainable infrastructure projects.	sustainability goals.	
	formulation and execution of			
	initiatives.			

Table 2 SWOT for Chiang Mai Municipality Smart City Development in the Energy and Environment Sector

From the SWOT analysis and the categorization of stakeholder perspectives and Chiang Mai's unique characteristics, the scenario can be categorized into three types: Smart City Plus, Smart City Prestige, and Smart City Innovation. The details are as follows:

Scenario 1 Smart City Plus: Chiang Mai, northern Thailand, is promoting sustainability and low-carbon development through the Sustainable Urban Tourism Project. With partners like the Hue City Centre for International Cooperation, the project promotes sustainable tourism and reduces carbon emissions through traffic-calmed zones and e-mobility. This effort is part of "Achieving Low Carbon Growth in Cities through Sustainable Urban Systems Management in Thailand," a UNDP-Greenhouse Gas Management Organization partnership. To improve Chiang Mai's climate resilience and promote low-carbon practices, the Integrated Urban Climate Action for Low-Carbon & Resilient Cities Project develops climate services and comprehensive land use planning. These projects show Chiang Mai's dedication to sustainable urban development and environmental awareness.

Scenario 2 Smart City Prestige: Chiang Mai is actively transforming into a smart city by investing in cutting-edge technologies for transportation, energy, and waste management. Digital innovation hubs promote the development of new businesses and encourage cooperation, while intelligent mobility solutions tackle issues related to transportation. Information technology is essential for effective city management and the provision of digital services, with a particular emphasis on establishing connectivity through public Wi-Fi networks. Electronic

government services optimize administrative procedures. Sustainability is given priority through the implementation of green initiatives, which include environmental monitoring.

Scenario 3 Smart City Innovation: Chiang Mai is making significant progress in becoming a Smart and Innovation City. It is implementing various initiatives such as establishing digital innovation hubs for startups, implementing Smart City projects to improve urban services, and providing support for a thriving startup ecosystem through events and incubation programs. The objective of education and research collaborations is to enhance the development of STEM fields, while efforts are being made to modernize E-Government services for improved efficiency. In addition to fostering collaboration with international partners to access global expertise and resources, Chiang Mai also prioritizes cultural innovation. This strategic approach positions Chiang Mai as a vibrant hub within the innovation ecosystem.

The key differences between the three scenarios lie in their primary focus, scope, partnerships, and level of technological and innovative integration. Smart City Plus centers on sustainability and climate resilience, with a narrower scope that prioritizes urban tourism and environmental projects, relying on international partnerships such as those with the UNDP for implementation. In contrast, Smart City Prestige adopts a more balanced approach, combining advanced technology with sustainability to improve urban services like transportation, energy, and waste management. This scenario emphasizes IT-driven solutions, including e-government services and public Wi-Fi, while fostering public-private collaborations to achieve its goals. Smart City Innovation stands out for its comprehensive strategy that integrates technological advancement, startup ecosystem development, STEM education, cultural transformation, and international collaboration. It positions Chiang Mai as a global innovation hub with a strong focus on leveraging digital technologies, fostering creativity, and building partnerships that span multiple sectors. The progression across the scenarios illustrates a shift from an emphasis on environmental sustainability (Scenario 1) to a broader focus on integrating technology and sustainability (Scenario 2), culminating in a forward-looking approach that champions innovation and global competitiveness (Scenario 3).

Since the three scenarios encompass different aspects of Chiang Mai's uniqueness and direction, it is essential to ensure inclusivity and incorporate stakeholder participation, reflecting the perspectives of Chiang Mai's people. As a result, the research has developed an integrated scenario titled "Chiang Mai Universal Smart City."

Scenario for Chiang Mai as Universal Smart City

The term "Universal" within the realm of smart cities can be construed in several ways. It may denote inclusivity and accessibility, ensuring that the advantages of smart city endeavors are widely distributed and beneficial to all residents. Alternatively, it could signify the integration of universal design principles, creating environments and services accessible to individuals of all ages and abilities. In a broader context, "Universal" might imply the utilization of standardized technologies and practices that can be widely adopted and replicated across diverse urban landscapes, contributing to a more universally applicable approach to smart urban development. The fusion of "Universal" with "City" in the context of smart cities suggests the integration of inclusive and accessible smart technologies that can be universally embraced by urban centers. This could encompass initiatives prioritizing equitable access to digital services, sustainable practices, and innovation, rendering them relevant and advantageous on a global scale. Ultimately, the concept of a "Universal Smart City" proposes a comprehensive and inclusive approach to urban development that considers the varied needs and characteristics of cities worldwide while leveraging standardized, widely applicable technologies and practices.

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The objective of the Chiang Mai municipality is to position the city as a leading model of sustainable urban development. This will be accomplished by prioritizing infrastructure enhancement, digital network improvement, cultural heritage preservation, economic expansion, and active stakeholder engagement. The city acknowledges the significance of integrating energy and environmental considerations into its smart city initiatives, pursuing development with a focus on achieving enduring sustainability and enhancing the welfare of its populace. These development objectives are delineated into five distinct categories: firstly, emphasizing the integration of renewable energy sources such as solar, wind, and hydro power into urban infrastructure; secondly, implementing a smart grid system to enhance energy distribution effectiveness and optimize usage patterns; thirdly, promoting the adoption of eco-friendly transportation options to alleviate traffic congestion and diminish air pollution; fourthly, encouraging the adoption of environmentally sustainable construction techniques to mitigate the ecological impacts of urban expansion; and lastly, implementing measures to preserve and expand urban green spaces to promote biodiversity and improve overall quality of life. Collaboration among diverse stakeholders, including government agencies, businesses, academia, and civil society organizations, is imperative to achieve these objectives. Through fostering alliances and collaboration, Chiang Mai can leverage collective knowledge and resources to effectively address energy and environmental challenges. Additionally, initiatives such as the Community Energy Transition and Sustainable Living Program empower residents to actively participate in sustainability endeavors, nurturing social cohesion and environmental stewardship within the community. By adopting these measures and incorporating them into its smart city development strategy, Chiang Mai can realize its vision of becoming a contemporary, eco-friendly, and technologically advanced city, prioritizing the well-being of its citizens and preserving its natural surroundings.

Chiang Mai Municipality Smart City development initiative

The Smart City Initiatives in the energy and environment area was developed from the scenarios. The implementation of smart city components in Chiang Mai involves a range of activities that attempt to tackle energy and environmental issues by utilizing digital and innovative technologies. Chiang Mai's commitment to tackling energy and environmental challenges is evident via these initiatives, which involve innovative solutions and active community participation. These endeavors encompass:

1. Smart Environment initiative aims to address environmental concerns, specifically in degraded areas such as Mae Kha Canal, by leveraging community-driven efforts. Implementation encompasses the development of wastewater collection infrastructure and the incorporation of aesthetic improvements to increase the quality of water. This process is facilitated by the use of sensors to test water quality and the real-time reporting of data.

2. Smart Energy Solutions are designed to optimize energy use in households and daily routines, with the goal of mitigating air pollution and addressing climate change. The endeavor entails incorporating energy management technologies into both traditional Lanna-style homes and modern constructions in order to achieve a tangible decrease in habitable temperature of 10%.

3. The focus is on utilizing digital technology to increase profits, particularly in the agriculture and tourism industries that have been affected by the COVID-19 pandemic. Initiatives such as the Fresh Market app enable the safe acquisition of fresh goods, with the goal of stabilizing businesses and promoting economic growth after the pandemic.

4. The Intelligent Governance System aims to leverage digital technology to improve public service infrastructure, namely by implementing a comprehensive animal data and stray registration system.

Thairabies.net facilitates pet owners in adhering to regulations and preventing the transmission of rabies by offering services such as microchipping and sterilization.

5. Intelligent Mobility is a field that aims to use technology to oversee and improve public transportation. This includes monitoring the transportation network, managing parking systems, and enhancing transportation standards to increase resident satisfaction and accessibility.

Conclusion

In this work, the analysis of Chiang Mai plan and context integrated with the perspectives of Chiang Mai stakeholders were taken into account in the development of Chiang Mai Smart City scenarios. Chiang Mai aims to lead sustainable urbanization by enhancing infrastructure, digital networks, cultural preservation, economic growth, and stakeholder engagement. Key objectives include adopting sustainable energy, intelligent power distribution, eco-friendly transportation, and expanding green spaces. Programs like the Community Energy Transition empower residents to promote sustainability and social harmony.

The city's smart city initiatives, categorized into four scenarios, focus on diverse priorities:

Scenario 1 (Smart City Plus): Low-carbon practices and climate resilience.

Scenario 2 (Smart City Prestige): Technology-driven solutions for transportation, energy, and waste management.

Scenario 3 (Smart City Innovation): Fostering startups, education collaborations, and economic growth through innovation.

Scenario 4 (Universal Smart City): Inclusivity, accessibility, and standardized technologies to address diverse urban needs.

Chiang Mai integrates smart technologies to address energy and environmental challenges, improve governance, and boost economic resilience. Efforts include improving water quality, mitigating air pollution, enhancing public transportation, and promoting renewable energy. Recommendations emphasize smart grids, renewable energy incentives, real-time emissions monitoring, EV infrastructure, and community education. By combining environmental consciousness, technological innovation, and inclusive strategies, Chiang Mai aspires to become a sustainable, eco-friendly, and technologically advanced city.

In addition, to advance the Chiang Mai Smart City project in energy and environment, practical and innovative solutions should be implemented. Key recommendations include developing smart grids, installing smart meters, and promoting renewable energy adoption through incentives. Real-time monitoring of greenhouse gas emissions and investment in energy storage systems can enhance sustainability. Smart building technologies, such as energy-efficient materials and automated systems, should be prioritized alongside public transport electrification and EV infrastructure. Community education on energy conservation and data-driven decision-making using IoT devices will support informed urban planning. Finally, supportive policies and regulations, like green building standards and clean energy incentives, are essential for long-term success.

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