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Thailand's Green Transportation Revolution: Creating Diverse Business Opportunities

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Introduction

Thailand, often celebrated as the "Detroit of the East," stands as a linchpin in the global automotive industry. As Southeast Asia's second-largest economy, it boasts a high level of international integration and serves as an essential manufacturing hub for top automakers from Europe, America, Japan, and Korea. In response to global trends toward net-zero carbon emissions and sustainable development, the Thai government has proactively spearheaded a transformative agenda for its transportation sector. This initiative includes the implementation of numerous incentives and subsidies designed to promote electric vehicles (EVs) and green transport technologies. These efforts are strategically aimed at reinforcing Thailand's leadership position in new energy and EV manufacturing, setting the stage for a robust expansion throughout Southeast Asia and beyond. This commitment to green transportation is expected to unlock diverse business opportunities, enhancing Thailand's role in the international market while supporting its environmental objectives.

Advancing Thailand's Electric Vehicle Revolution

The electric vehicle market has garnered substantial attention and growth, especially following the 2015 Paris Climate Agreement's global call to phase out fuel vehicles to mitigate climate change and reduce air pollution. Recognizing transportation as a significant contributor to carbon emissions, the Thai government has strategically prioritized EV adoption, encapsulated in the "3030" policy. This ambitious policy targets that by the year 2030, at least 30% of all vehicles manufactured in Thailand will be electric. Thailand's robust automotive industry, which produced roughly 1.9 million vehicles in 2022, and favorable government policies, suggest that the country is poised to become a key hub for EV components in Southeast Asia. The nation's strategy includes not only producing these vehicles but also boosting their daily use for commuting, underlining Thailand's potential leadership in the EV sector.

Analysts foresee this move as creating a ripple effect that could accelerate the adoption of EVs across the region, further establishing Thailand as an influential player in the global shift towards sustainable transportation.

Besides hosting enterprises from traditional Japanese and German automakers, and significant entries by Chinese manufacturers like BYD and Great Wall, the Thai government is propelling this with tax reductions, import duty exemptions on machinery, and allowing 100% foreign land ownership. Moreover, it offers subsidies for locals purchasing EVs. However, merely having vehicles is insufficient for leading Southeast Asia's EV market; robust and accessible infrastructure is also crucial. Efficient operation of EVs on the roads requires a well-developed network of charging stations and an effective electric vehicle operating system (EVOS).

Since 2022, Bangkok's streets have increasingly seen electric buses and tuk-tuks. In early 2023, Tesla's online presale of the Model 3 saw nearly 40,000 orders within just two hours, signaling the EV era's arrival in Thailand. By 2025, it is estimated that the number of private EVs will reach 400,000, with public transport vehicles exceeding 30,000, growing annually by double digits. While the EV industry involves a massive upstream and downstream supply chain and significant capital investment, the infrastructure for EV services and charging stations presents many opportunities for innovative startups, preparing to tap into Southeast Asia's most promising EV market.

More Than Just EVs – Infrastructure and Services are Necessary

Electric vehicle (EV) charging infrastructure in Thailand is categorized into AC (Alternating Current) and DC (Direct Current) systems, reflecting distinct charging speeds and costs. AC chargers, often rated at 7kw or 22kw, typically require between 4 to 8 hours to fully charge an EV, making them more suitable for residential use where vehicles can be charged overnight. On the other hand, DC chargers are more powerful, usually around 50kw, and are capable of charging an EV battery to over 80% within just an hour, although they come at a higher operational cost.

The landscape of EV charging stations in Thailand, as per data from the Thailand Electric Vehicle Association in early 2023, includes approximately 4,000 charging points. These are predominantly concentrated in urban areas like Bangkok, with a composition of about two-thirds AC and one-third DC chargers. This distribution underscores the strategic placement of fast chargers in high-density areas to cater to rapid charging needs, while slower AC chargers are more dispersed for longer, less urgent charging sessions.

The current ratio of electric vehicles to charging stations in Thailand stands at approximately 20:1, which serves as a bellwether for the pressing demand for a more capacious charging infrastructure. Anticipated to widen to 30:1 by the year 2024, this trend underscores an escalating urgency to augment the charging network to accommodate the swelling fleet of EVs. In an active response, the Thai government is diligently crafting policies to bolster the national EV charging grid. These strategic policies are intended to proliferate the network well beyond the confines of urban locales, stretching into tourist hotspots, highway rest areas, and even the most secluded regions. This expansive coverage is critical for fostering widespread EV adoption throughout the country. The government's foresight in this domain is not solely a matter of convenience for EV users but is intrinsically linked to Thailand's environmental objectives, which include slashing carbon emissions and endorsing sustainable transportation modalities. This commitment, reflective of a harmonious blend of practicality and environmental stewardship, positions Thailand as

a forerunner in the global pursuit of sustainable transport ecosystems.

In the burgeoning field of EV infrastructure, private sector entities are pioneering innovative business models to capitalize on this dynamic market. One prevalent model is based on electricity revenue, where EV owners pay a fee per unit of electricity used, which is subsequently shared among the power company, property owners hosting the stations, and the charging station operators. This revenue might also be shared with hardware and software suppliers, contingent on the specific agreements in place. Such a model emphasizes the strategic acquisition of prime locations—akin to the 'Starbucks model'—where securing high-traffic areas early on establishes a dominant presence and ensures profitability. Another integral model is the maintenance of these charging stations, which ensures their operational efficiency and reliability, providing a steady revenue stream similar to the maintenance contracts in the elevator industry.

Additionally, the Engineering, Procurement, and Construction (EPC) model is gaining traction, offering a turnkey solution for the installation and setup of charging stations, appealing to government entities, businesses, and property developers seeking comprehensive project management. Lastly, the data monetization model is emerging as a critical strategy, leveraging the vast data collected from smart charging stations to enhance customer service, tailor marketing strategies, and create new revenue streams through targeted advertising and partnerships. Together, these models not only enhance the economic feasibility of EV infrastructure projects but also align with global sustainability goals by promoting cleaner transportation solutions.

The maintenance strategy for EV infrastructure, adopting a model reminiscent of 'elevator sales,' emphasizes sustained service and systematic updates over initial unit sales. This approach yields a consistent revenue stream from regular maintenance, ongoing system upgrades, and necessary repairs—factors that are essential for long-term operational reliability and efficiency. Particularly pertinent in the residential sector where AC (slow charging) units dominate, this strategy ensures that home-based charging solutions maintain optimal functionality. Homeowners benefit from dependable and efficient charging systems, which are crucial for supporting the daily use of electric vehicles. This maintenance-centric model not only enhances customer satisfaction but also solidifies the infrastructure needed for a sustainable transition to electric mobility.

Key Factors of EV Infrastructure

In Thailand, the collaboration between infrastructure providers and real estate developers has emerged as a key strategy for incorporating EV charging facilities into new residential projects. This partnership takes advantage of local building regulations, which typically require a minimum of one parking space per household, creating a prime opportunity to integrate advanced EV technology directly into residential areas. Strategically, about 10%-15% of these parking spaces are equipped with charging stations, significantly increasing the property's value and ensuring it is well-prepared for the broader adoption of electric vehicles in the future. This approach not only enhances the appeal of the properties but also contributes to the infrastructure needed for a sustainable, EV-friendly environment.

This integration not only aligns with Thailand's regulatory framework but also sets a benchmark for sustainable property development. Similar models can be observed in other markets, such as in Norway and the Netherlands, where government incentives and partnerships with property developers have successfully accelerated the adoption of EV infrastructure. These examples underscore the

effectiveness of integrating EV charging solutions in residential and commercial developments, facilitating broader adoption of electric vehicles and contributing to national goals for reducing carbon emissions.

Continuing the discussion on effective business models for EV infrastructure, the EPC model plays a pivotal role by streamlining the installation process. This model focuses primarily on the delivery of installation services, with the client specifying the hardware requirements. Commonly utilized in partnerships with leading automakers and EV dealers, such as Tesla or BYD, the EPC model ensures that the hardware and installation standards meet the manufacturers' stringent requirements. When a customer purchases an EV, they benefit from a seamless installation process handled by a locally designated EPC team, which operates under the direct guidelines provided by the vehicle manufacturer. This approach not only simplifies the customer's transition to electric vehicles but also maintains high standards of quality and efficiency in the installation of necessary charging infrastructure.

Transitioning from the various business models emerging in the EV sector, we turn our attention to the wealth of data generated by EVs and their users—a rich vein of information that, when mined and analyzed, holds immense potential for innovative business applications. Indeed, the potential for data monetization extends significantly beyond basic operational metrics. Connected EVs generate a vast array of data points, from charging patterns and durations to precise location usage. This wealth of information is invaluable for creating refined user profiles, which can be leveraged for highly targeted advertising campaigns or to enhance other consumer services. Furthermore, strategic partnerships with entities in the insurance and financial sectors can utilize this daily data to tailor more personalized product offerings or to assess risks more accurately. This integration can lead to the development of innovative insurance models or financing options that are specifically adapted to the usage patterns of EV owners, thereby creating additional value streams. As the EV market continues to expand, the opportunities for sophisticated data-driven services will only grow, making data monetization an increasingly lucrative component of the EV ecosystem.

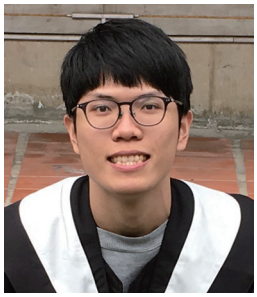
Greener Transportation for Net-zero Future

Thailand's advancement in electric vehicle development closely aligns with its ambitious goals for a sustainable, electrified transportation system. The country's efforts to enhance its EV infrastructure and services are key to becoming a leader in the global green transportation revolution. As Thailand extends its capabilities in this sector, it provides fertile ground for investors and innovators to contribute meaningfully to eco-friendly transportation advancements.

The government of Thailand supports these endeavors with clear policies and goals aimed at achieving net-zero emissions. This strategic support is designed to stimulate economic growth, propel technological innovation, and enhance environmental sustainability. Such initiatives are expected to attract significant investment, encouraging further innovations in both the EV sector and related industries like renewable energy and advanced automotive technologies.

Looking ahead, Thailand's ongoing commitment to expanding its EV infrastructure is set to solidify its position as a pioneer in green transportation, both regionally and globally. This proactive stance not only aims to transform the urban mobility landscape but also significantly contributes to the global effort to combat climate change. As Thailand continues to push forward with these initiatives, it ensures its place at the forefront of sustainable transportation, promising a greener and more sustainable future for generations to come.

Balanced Development of Digital Economy and Society in the Asia-Pacific Region



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Introduction

The rise of the digital economy has emerged as a primary driver of global economic growth. According to data from the McKinsey Global Institute, global data flows increased by over 40% annually from 2010 to 2021.[1] Faced with these transformative opportunities, the Asia-Pacific region, leveraging its vast population and resource advantages, has entered a golden age of the digital economy. The rapid growth of consumers' and enterprises' digital demands has brought huge development potential to the region's digital economy. According to data from the Asia-Pacific Economic Cooperation (APEC), the value of digital trade in 2018 was estimated at around $1.68 trillion, accounting for 20% of intra-regional trade, with a compound annual growth rate of 7.8% from 2000 to 2018.[2] With the rise of ASEAN (Association of Southeast Asian Nations) countries, it is expected that by 2030, ASEAN will become the world's fourth-largest economy, with the regional internet economy market size reaching $1 trillion.[3] Data from the telecommunications market research firm TeleGeography indicates that international bandwidth usage in Asia and Oceania increased by 32% and 29%, respectively, in 2023,[4] reflecting the rapid development and potential of the region in the digital economy.

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Taking Into Account Economic Development and Social Inclusion

The rapid development of innovation and widespread adoption of digital technologies in the Asia-Pacific region have brought profound changes to the economic and social landscape. However, along with these advancements come unprecedented challenges that require serious consideration and concerted efforts from all stakeholders. Despite significant progress in digitalization, there still exists a considerable digital divide in the region, particularly in developing countries. According to World Bank data, as of 2021,[5] significant portions of the population in countries like Myanmar and the Philippines still lack access to basic internet services, let alone benefiting from distance education, remote work, or telemedicine.

It must be recognized that while developing the digital economy, addressing social issues is equally crucial. Ensuring equitable access to digital opportunities for everyone is not only a matter of social justice but also critical for sustainable economic growth. Failure to address these social disparities may lead to social instability, exacerbate existing economic inequalities, and pose long-term challenges to the region's economic development. Efforts to close the digital divide and measures to address broader social issues are therefore crucial. For example, through investment in education, countries can provide individuals with the digital literacy and skills needed to effectively participate in the digital economy and improve people's quality of life. Similarly, measures to improve the accessibility of healthcare services through digital technologies can enhance overall public health outcomes, contributing to a healthier and more efficient workforce. Likewise, leveraging digital platforms for social welfare programs can ensure that vulnerable groups have access to basic services and support, thereby mitigating the impact of economic disparities.

Harnessing Digital Innovation

Digital innovation stands as a transformative force with the potential to advance the United Nations Sustainable Development Goals (SDGs)[6] across the Asia-Pacific region. Through technological innovation, countless opportunities are provided to address pressing social challenges and promote progress in sustainable development. Firstly, digital innovation can revolutionize education, contributing to Goal 4: Quality Education. The region's talent in software development, data analytics, and digital content creation enables the development and deployment of diverse digital teaching platforms. Online education, digital learning materials, and distance learning programs enhance educational accessibility and quality, raising standards across the region.

Secondly, digital innovation can spur economic growth, aligning with Goal 8: Decent Work and Economic Growth. The region's abundant data resources and skilled workforce support the development of technologies like artificial intelligence and big data analytics. Fostering a supportive ecosystem for digital innovation enterprises can catalyze job creation, enhance productivity, and drive economic growth across various sectors. Furthermore, digital innovation has the capacity to mitigate social

5.World Bank, "Individuals using the Internet (% of population) - East Asia & Pacific (excluding high income)," https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=4E

6.United Nations, "Sustainable Development Goals," https://sdgs.un.org/goals

and economic inequalities, contributing to Goal 10: Reduced Inequality. Given the diverse socio-economic landscape of the region, with a mix of developing countries and emerging markets, promoting the widespread adoption of digital technologies can enhance opportunities for marginalized groups. Digital innovation can bridge the digital divide and foster inclusion, reducing inequality in the region.

Moreover, in light of the region's demographic challenges, including aging populations and health issues, digital innovation presents an invaluable opportunity to enhance healthcare provision and management, aligning with Goal 3: Good Health and Well-being. Technologies such as telemedicine, smart medical devices, and big data analytics revolutionize healthcare delivery, improving efficiency, reducing costs, and promoting better health outcomes and well-being for individuals. In conclusion, digital innovation represents a powerful driver for sustainable growth and development in the Asia-Pacific region. The stakeholders must collaborate effectively to harness the full potential of digital innovation, collectively working towards the realization of the SDGs and fostering comprehensive development across economic, social, and environmental dimensions in the region.

Stakeholders for Sustainable Digital Growth in the Region

Collaboration among governments, businesses, and civil society is crucial for promoting sustainable development in the digital realm. These stakeholders can combine their expertise and resources to tackle the challenges and opportunities of digitalization. Governments play a central role by facilitating collaboration and coordination across sectors. Bringing together policymakers, regulators, technical experts and industry representatives can ensure digital policy is comprehensive and inclusive.

Furthermore, governments can collaborate with businesses and academia to enhance digital education and skills training initiatives. By equipping the workforce with the necessary digital skills, governments can ensure that individuals are prepared to navigate the digital landscape effectively. This may involve providing support for on-the-job training initiatives and integrating digital technology education into school and university curricula. In addition to fostering human capital development, governments should also focus on creating an enabling environment for digital innovation. This includes providing financial support for startups, reducing bureaucratic hurdles to entrepreneurship, establishing incubators and accelerators, and promoting digital transformation across industries.

By enhancing the visibility of domestic digital initiatives in international markets, governments can attract investment and facilitate cross-border collaboration, driving sustainable growth in the digital economy. Collaboration between governments and businesses can also extend to the development of smart city infrastructure. By jointly investing in projects and involving civil society organizations in planning and oversight processes, governments can ensure that smart city initiatives are implemented in a transparent and accountable manner. Civil society can contribute their expertise and insights to accelerate the digitization process, ensuring that digital services are accessible to all segments of society. In summary, collaboration among governments, businesses, and civil society is essential for promoting sustainable development in the digital domain. By leveraging their respective strengths and resources, these stakeholders can work together to build a resilient and inclusive digital ecosystem that benefits society as a whole.

Several successful cases of digital innovation and social impact in the Asia-Pacific region highlight the benefits of collaboration between

the public and private sectors. In Singapore, the government is committed to building a smart city to improve urban efficiency and residents' quality of life. The smart transportation system uses data analysis and intelligent monitoring to optimize traffic flow, reduce congestion, and lower emissions. This initiative, involving regulatory measures and collaboration with enterprises and startups, has enhanced both urban operations and residents' lives. Taiwan's government has subsidized small and medium-sized enterprises (SMEs) to promote digital transformation, yielding significant results. Taiwan's SME-dominated economy benefits from flexibility and rapid response. Government support through financial aid and reduced barriers has fostered technological innovation in cloud computing and data analysis, increasing the use of digital tools like tablet computers. South Korea has established a national digital education system, offering comprehensive digital education and encouraging corporate involvement in employee training. This policy has driven educational innovation, creating a digital talent cultivation system and digital research institutes through partnerships between enterprises, universities, and government support. These efforts have nurtured a rich pool of digital talent. These cases demonstrate how public and private sector collaboration can drive digital innovation and transformation, contributing significantly to sustainable development in the region.

Driving Sustainable Digital Development

Achieving sustainable growth in the digital economy is paramount, not merely for driving economic development but also for ensuring that such progress yields positive societal and environmental outcomes. The Asia-Pacific region, renowned for its dynamism and promise, stands at the forefront of this digital evolution, with implications extending far into the future. However, the challenges posed by digitization are multifaceted, demanding collaboration among diverse stakeholders to navigate effectively. Governments play a pivotal role in setting conducive policy frameworks and regulations that foster innovation while safeguarding societal well-being and environmental sustainability. Simultaneously, businesses drive much of the digital innovation, leveraging technology to enhance productivity, create new markets, and improve customer experiences.

Collaboration between government and industry is crucial, ensuring alignment between regulatory goals and market needs, thereby facilitating a conducive environment for sustainable digital growth. Civil society advocates for equitable access to digital opportunities, ensuring that the benefits of digitization reach all segments of society, particularly marginalized communities. Collaboration across these sectors is essential, leveraging collective expertise and resources to address complex challenges such as digital inclusion, data privacy, and cybersecurity. By viewing digital development from the perspectives of innovation and social impact, stakeholders can collaborate to research solutions and promote sustainable practices. This collaboration transcends national borders and recognizes the interconnectedness of economies and the importance of regional cooperation. By pooling resources, sharing best practices, and adjusting strategies to address the multifaceted challenges of digitalization, stakeholders can fully harness the positive social and environmental impacts of the digital economy in driving positive societal and environmental changes in the Asia-Pacific region and beyond, paving the way for a prosperous and inclusive digital future.

Sustainability and Resilience Policy in Transportation Systems

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Introduction

Transportation resilience has normally been defined as the ability of the transportation system to maintain its normal functions through its resistance, mitigation, and absorptive capability under interruptive conditions, or the ability to restore the original equilibrium or reach a new equilibrium condition within a reasonable time and with limited resources (Hsieh and Feng, 2016; IOT, 2019; Weilant, Strong and Miller, 2019).

Global warming, climate change, motorization, and rapid urbanization all increase the risk of complex extreme weather events, presenting even serious challenges for the operation and maintenance of transportation infrastructures and services in Taiwan. A hazard exposure analysis conducted by The Work Bank has shown that more than 73% of lands and populations in Taiwan threatened by three major nature disasters while 99% of populations threatened by two major nature disasters, including typhoons, drought, earthquakes, floods, and landslides (The World Bank, 2005; National Fire Agency, 2018).

This paper conducts an overview on concepts of transportation resilience and presents related policy in Taiwan. It also presents contents and challenges in net zero and vision zero policies considering sustainable development goals. With evidence-based decision and technology-based approach, this paper summarizes findings and proposed further strategies for enhancing resilient transportation systems.

Concept and Policy Framework on Transportation Resilience

Transportation sector faces various challenges while the inadequacy of preparation for natural and human-made disasters has been identified as one of priority areas. Among variety of definitions and frameworks of resilience (for examples, Mattsson and Jenelius, 2015; Chan and Schofer, 2016; Cheng, Zai, Di, et al., 2017; Fletcher and Ekern, 2017; Markolf, Hoehne, Fraser, et al., 2019; Goncalves and Ribeiro, 2020), a clear framework has been proposed for formulating transportation resilience policy, which is known as AREA Framework: (1) Absorptive capacity, (2) Restorative capacity,

(3) Equitable access, and (4) Adaptive capacity (Weilant, Strong and Miller, 2019).

In this framework, absorptive capacity is the ability of the system to absorb disruptions and maintain normal functioning. Restorative capacity is the ability of the system to recover quickly following a disruption and return to normal functioning. Adaptive capacity is the ability of the system to change in response to disruption to maintain normal functioning. Equitable access is the ability of the system to provide opportunity for access across the entire community during a disrupted and undisrupted period (Weilant, Strong and Miller, 2019).

This AREA approach to transportation resilience is quite informative and useful in project evaluation. For example, these AREA capacities represent strategies of alternative investments should be considered when aiming to enhance the resilience of the transportation systems. It is helpful of making decision on whether it is more cost-effective to invest in adaptive or restorative capacity than in absorptive capacity to maintain system functions in normal and disrupted times.

Investments in absorptive capacity could be for hardening the transportation infrastructure. Investments in restorative capacity could be investments in equipment, crews, and collaborative schemes so that the infrastructure is repaired more quickly right after a disrupted event. Adaptive capacity investments could include adding road spaces and reducing congestion during both disrupted and normal conditions. Investments in equitable access could include increasing public transport service by increasing operation frequency or by providing multimodal access to vulnerable users and remote areas. These assessments should be applied to identify resilience strategies for mid- and long-term planning and investment decision (Azolin, Silva and Pinto, 2020).

Transportation resilience has also been referred to serviceability of transportation network in a micro-aspect. The microscope disruptions are normally caused by accidents, concurrent incidents due to congestions, and cyberattacks. Therefore, recovery capacity become essential in resilience planning for these microscope disruptions.

Based on the national guidelines on adaption of climate change (Sustainable Development Committee, 2017), Ministry of Transportation and Communications came out a series of strategies on resilient highway and railway systems accordingly (Chen, 2023; Wu, Tseng, et al., 2021).

The latest transportation resilience policy consisted of 15 strategies within four aspects of enhancement, including Absorptive Capability, Adaptive Capacity, Restorative Capacity, and Decision Supporting Capacity, as shown in Table 1.

Challenges in Two Zero Goals: Vision Zero and Net Zero

In addition to resilient transportation policy, two strategic objectives highly-related to sustainability and resilience have been proposed and prioritized: Vision Zero and Net Zero. In terms of vision zero policy, Taiwan faces crucial challenges of enhancing its transportation safety. In the past 10 years, more than 30,000 fatalities and 3.5 million injuries due to transportation accidents, which caused social economic loss of more than USD15 billions per year which is 3.172% of GDP (Chang, 2024).

Development of human-centered environment and enhance of road safety have become a top priority in national sustainable transportation policy. In terms of net zero transportation policy, (1) electrified and zero-emission mobility, (2) green transportation, and (3) management of motorized vehicles are the three main strategies

Table 1. Strategies of Transportation Resilience

Aspects	Strategies	Type*
Absorptive Capacity	1.To avoid high risk and environmentally sensitive areas.	A
	2.To revise guidelines for planning, design, construction and operation management.	C
	3.To apply new materials, engineering approach and equipment for enhancing absorptive capacity.	A
	4.To refine facility inspection approach.	B
	5.To strength intermodal interfaces and vital infrastructures.	C
Adaptive Capacity	6.To apply technologies for enhancing capability of prediction and hazard warning.	B
	7.To provide transportation alternatives and options (modes, routes, destinations).	C
Restorative Capacity	8.To apply technologies, materials and engineering approaches for enhancing recovery efficiency.	A
	9.To develop classification schemes for proper scheduling of infrastructure recovery.	A
Decision Supporting Capacity	10. To develop safety and risk assessment methods for transportation systems.	B
	11. To develop necessary assessment scheme for infrastructure investments.	B
	12. To develop datasets for risk management and assessment.	B
	13. To formulate necessary authority and training programs for resilience policy.	B
	14. To facilitate multidisciplinary platform and information sharing scheme.	B
	15. To enhance dialog on climate risk among stakeholders.	B

* Category A: Infrastructure Construction; B: Operation & Management; C: Both Construction and Operation & Management.
Source: modified from IOT (2019) and Wu, Tseng et al. (2021).

under the authority of Ministry of Transportation and Communications while Transit-oriented Development (TOD) and behavior change are another two strategies under the authority of Ministry of Interior and Ministry of Environment, respectively.

These vision zero challenges and the "3+2 Net Zero" transportation strategies are all highly related to sustainability and resilience in transportation systems. Therefore, electrified mobility needs sustainable charging infrastructure and smart grid design while bicycle facilities, one of nature-based solutions should be actively developed and integrated with public transportation systems.

Enhancement of Transportation Systems Sustainability and Resilience

In addition to those strategies proposed by MOTC, it is necessary to have further actions with considering roadmap of net zero 2050 and SDGs 2030. Followed the principles of technology-based approach and evidence-based decision, the following actions are proposed for enhancement of transportation sustainability and resilience.

(1)More Investments on Digital Infrastructures

In the past few years, MOTC has planned, designed and developed Transportation Data Exchange Platform (TDX) (MOTC, 2023). Main strategic objectives of TDX include: (i) increase service quality for passengers, (ii) increase productivity for operators, and (iii) enhance decision making quality of governments. It is also having industry benefits since innovative services and products may be created based on full information with data analytics and other ITS technologies.

First, digital technologies shall be widely applied to transportation system planning, design, construction and operation. For examples, applications of geo-information systems and digital twin will be able to assess the necessary integration of land use and public transportation. VR and AR technologies will be able to enhance e-governance capability through visualized information. The big data mining technology and AI deep learning

methods will enhance prediction capability and provide tools for evaluating network vulnerability and generating alternatives for achieving resilience in transportation systems. A digital twin can also be applied in the design and construction phases to simulate designs and monitor construction progress. Applications of sensors, 5G and AIoT technologies in users, vehicles, and infrastructures of highway, harbor, airport and railway will increase not only transportation safety and operation efficiency but also prediction capability for unexpected interruptions. Cybersecurity is also critical issue for preventing transportation networks and operation from cyberattacks.

(2)Incorporating Resilience into System Planning and Project Evaluation

Planning of transportation systems is crucial for providing appropriate infrastructures and services to meet future mobility needs. One of the first and necessary steps of incorporating resilience into planning process involves vulnerability assessment for framing planning around mitigating and adapting to vulnerabilities of the existing networks and infrastructures.

Second, incorporating resilience and TOD objective into integration of land use and transportation planning is another challenging work (Wang, 2015; Chang, 2023). Additionally, alternatives analysis is a crucial element in transportation planning. Therefore, adsorptive capacity, restorative capacity, equitable access, and adaptive capacity must be incorporated into formulation of alternatives and cost benefit evaluation in the system planning process.

(3)Development of Nature-based Solutions in Transportation Systems

Considering both net zero goals and resilient transportation systems, 15 minute city has been proposed and active mobility become an essential part of sustainable transportation (Funk and Glickman, 2023). The concept of the 15-minute city is based on the idea that residents are able to cover the majority of their daily needs within a 15 minute radius, by walking and cycling, while traveling to further districts and longer distances by other forms of sustainable modes.

Therefore, under the concept of nature-based solutions, friendly environment and infrastructure for cycling and walking are most important and top priority for implementation. Taiwan has developed more than 7,000 km of bicycle lanes in the past 15 years while most of the bicycle lane and facilities are for recreation, leisure and sport purposes. Although the funding for the enhancement program of bicycle facilities has been raised from US$82 millions to US$170 millions for the budget years of 2025~2028, it is highly suggested that friendly environment for cycling to work and cycling to school needs to be included in the national program while overall investment needs to be increased accordingly. Other NBSs in transportation sector, for examples, from urban design along mother river Cheonggyecheon in Seoul green corridor to the permeable pavement in London streets well summarized by Baskin (2023) are good reference for policy formulation.

(4) Collaborative Platform for Stakeholders

Resilient transportation systems involved different stakeholders having various objectives and resources. It is therefore necessary to have a dialog for stakeholders from both private and public sectors (Chen, 2019; Fletcher and Ekern, 2017). This collaborative platform will be beneficial for formulating resilience policy and roadmap through exchanging information, understanding personal objectives and mutual benefits, discussing legal and institutional barriers. This platform will also be able to facilitate collaborations between central and local governments.

Conclusion

Facing the climate challenges, transportation sector needs to take quick actions to incorporate resilience into lifecycle of transportation infrastructures. This paper conducts an overview on the concepts of transportation resilience and strategies in Taiwan. It also presents challenges of the net zero and vision zero goals. The following perspectives for enhancing transportation system sustainability and resilience are proposed: (1) More investments on digital infrastructures, (2) Incorporating resilience into system planning and project evaluation, (3) Development of comprehensive nature-based solutions in transportation systems, and (4) Formulation of collaborative platform for stakeholders. It is shown that the proposed strategies will be beneficial to not only Taiwan but also to those regions and cities in development of strategies for resilient transportation systems.

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