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Integrating Artificial Intelligence and Strategic Policy in Maritime Logistics: The Singapore Model and Lessons for Developing Economies

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ARTICLE INFO	ABSTRACT
Article History: Received 5 December 2025 Received in revised form 26 January 2026 Accepted 9 February 2026 Available online 15 March 2026 Keywords: Artificial intelligence; Maritime logistics; Singapore model; Port digitalisation; Logistics policy; ASEAN; Developing economies	Since its independence in 1965, Singapore has turned its logistics industry into a global hub despite its small territory and lack of natural resources, by combining state-led planning, foreign direct investment, investment in infrastructure and the early adoption of digital technologies. This paper is a qualitative policy case study based on official statistics and reports of Singapore agencies and international organisations for 1961–2025. It examines the historical evolution, governance frameworks, key indicators and role of artificial intelligence (AI) in Singapore's logistics sector. In 2024 transportation and storage accounted for 9.1% of Singapore's nominal value added, the ports handled a record 41.12 million TEU, and Singapore ranked first in the World Bank Logistics Performance Index 2023. Since the National AI Strategy (2019) and its update NAIS 2.0 (2023), AI has been applied to predictive maintenance, automated terminal operations at Tuas Port and the optimisation of truck and vessel movements; operator-reported effects include more than 50% fewer empty truck trips, although system-wide effects have not been measured independently. The paper identifies the main challenges — land scarcity, shortages of skilled workers, global disruptions, climate risks and regulatory barriers — and derives lessons for developing economies, particularly ASEAN member states: long-term planning, public-private partnerships, investment in skills and the separation of regulation from operation. Policy recommendations cover investment in digital infrastructure and AI, regional cooperation, support for small and medium-sized enterprises, environmental sustainability and workforce development, each with indicators for monitoring.

1. INTRODUCTION

Since its independence in 1965, Singapore has used deliberate state policy, foreign direct investment (FDI) and sustained investment in infrastructure to turn its location on one of the world's busiest sea lanes into an economic advantage, and logistics has become one of the pillars of its economy. Nominal gross domestic product (GDP) rose from about USD 1 billion in 1965 to about USD 501 billion in 2023 and USD 547 billion in 2024 [1], and in 2024 transportation and storage accounted for 9.1% of nominal value added [2]. The container ports of Singapore handled

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a record 41.12 million twenty-foot equivalent units (TEU) in 2024, 5.4% more than the 39.0 million TEU of 2023 [3], and Singapore ranked first in the World Bank's Logistics Performance Index 2023 [4].

Over the past decade, digital technologies and artificial intelligence (AI) have become central to this strategy. The Smart Nation initiative (2014, renewed as Smart Nation 2.0 in October 2024) and the National AI Strategy (2019, updated as NAIS 2.0 in December 2023) have made logistics and port operations a priority field for AI applications such as predictive maintenance, automated terminal equipment and the optimisation of truck and vessel movements [5–7]. Singapore's experience with centralised but market-oriented governance, innovation-led investment and workforce development may hold lessons for other economies, although headwinds such as the COVID-19 disruptions of global supply chains and the effects of climate change on maritime routes also expose its limits [8].

The Singapore model is distinctive in development economics. Theoretically, it can be read through endogenous growth theory, in which deliberate investment in knowledge and technology generates lasting productivity growth [9], and through the new economic geography, in which increasing returns and transport costs allow early advantages in location and infrastructure to become self-reinforcing [10]. In maritime logistics, AI shifts the basis of competitiveness from basic factors of production, such as land and labour, towards knowledge and technology. Reviews of Industry 4.0 technologies in logistics report efficiency and environmental gains from data-driven optimisation, although their size depends strongly on the context [11, 12].

Singapore's position on the Strait of Malacca, the shortest sea route between the Indian Ocean and the Pacific and the second-largest oil-trade chokepoint after the Strait of Hormuz [13], is an advantage that the country did not create. What it did create was the ability to capture traffic passing through the strait by offering faster, cheaper and more reliable port and logistics services than its competitors [14, 15].

The purpose of this paper is threefold: (1) to analyse why Singapore prioritised the logistics industry and how this priority evolved; (2) to examine the role of state intervention, the promotion of FDI and the use of advanced technologies, in particular AI, in the transformation of the industry; and (3) to assess which elements of the model can be transferred to developing economies, especially members of the Association of Southeast Asian Nations (ASEAN). Section 2 describes the approach and sources; Section 3 reviews the historical context; Section 4 the evolution of policy and governance; Section 5 key indicators; Section 6 the role of AI; Section 7 challenges and lessons; Section 8 policy recommendations; and Section 9 concludes. Figure 1 summarises the argument of the paper.

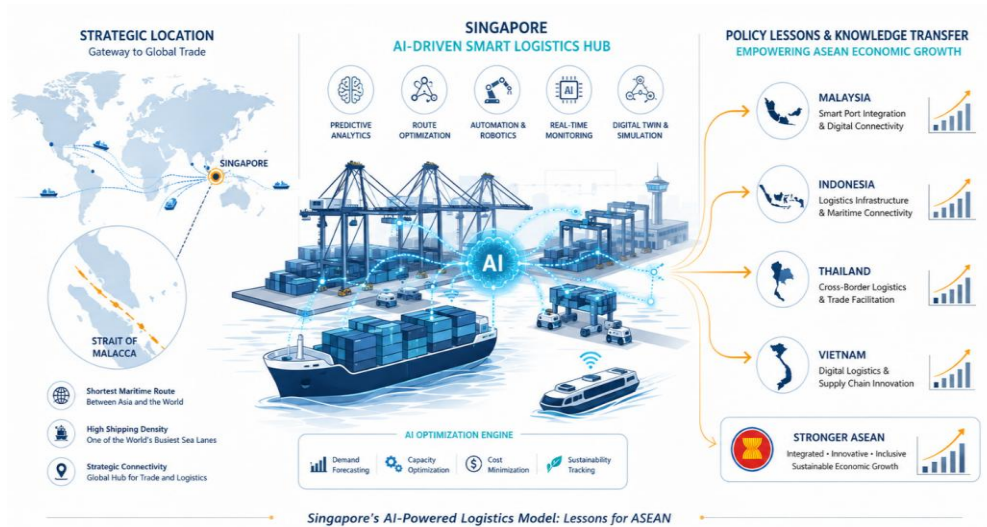


Fig. 1. Graphical abstract: Singapore's AI-driven logistics hub, from its strategic location and AI applications in port operations to policy lessons and knowledge transfer for ASEAN member states.

2. APPROACH AND SOURCES

The study is a qualitative policy case study based on document analysis. It covers the period from the establishment of the Economic Development Board (EDB) in 1961 to 2025. Three groups of sources were used: (1) official Singapore sources, namely the Department of Statistics (SingStat), the Ministry of Trade and Industry (MTI), the Maritime and Port Authority (MPA), the EDB, the National Research Foundation (NRF), Smart Nation Singapore and the Ministry of Digital Development and Information (MDDI), and PSA International; (2) reports and databases of international organisations, namely the World Bank, the International Monetary Fund (IMF), the Organisation for Economic Co-operation and Development (OECD), the United Nations and the ASEAN Secretariat; and (3) peer-reviewed studies of Singapore's growth, port management and AI ecosystem. Quantitative indicators were taken from the primary statistical source wherever possible, and figures reported by operators (for example, the effects of individual AI tools) are presented as reported by the organisation concerned. Information was triangulated across sources; where sources disagreed, the official statistic was used and the disagreement noted. Because the study relies on secondary data and covers a single country, it identifies plausible mechanisms and lessons but does not estimate causal effects.

3. HISTORICAL CONTEXT AND MOTIVATIONS

Singapore faced severe structural problems after its separation from Malaysia in 1965: unemployment of around 10%, no natural resources and the loss of its economic hinterland [16]. The government under Prime Minister Lee Kuan Yew responded with an export-oriented industrial strategy that drew on Singapore's position at the southern entrance of the Strait of Malacca. The EDB, created in 1961 before independence, became the main instrument of this strategy: it offered incentives to multinational corporations, developed industrial estates and sought to reduce dependence on neighbouring economies by making Singapore a regional centre for manufacturing, trade and logistics [16, 17].

In the 1960s and 1970s the emphasis was on physical infrastructure. The Port of Singapore Authority (PSA) was formed on 1 April 1964 to take over the functions of the Singapore Harbour Board [18], and Jurong Port began operations in 1965 to serve the Jurong industrial estate [19]. In June 1972 Singapore opened Southeast Asia's first container berth at Tanjong Pagar [18], positioning the port for the container revolution in shipping. Competition with Hong Kong and other regional ports encouraged early investment in information technology at the port [20]. In 1989

the Trade Development Board launched TradeNet, one of the first national electronic single windows for trade documentation; typical approval times fell from two to four days to minutes [21].

From the 1990s, services such as contract logistics, smart warehousing and supply-chain management were added to transport and port services, and air and sea freight were increasingly integrated. These developments were driven by economic diversification, regional competition and the goal of making Singapore a global logistics hub. Table 1 lists the main milestones.

Table 1. Key milestones in the development of Singapore’s logistics sector.

No.	Year	Milestone
1	1961	Establishment of the Economic Development Board (EDB)
2	1964	Formation of the Port of Singapore Authority (PSA)
3	1965	Start of operations at Jurong Port
4	1972	First container berth in Southeast Asia at Tanjong Pagar
5	1989	Launch of TradeNet, a national electronic single window for trade
6	1997	Corporatisation of PSA (PSA Corporation)
7	2014	Launch of the Smart Nation initiative
8	2016	Launch of the Logistics Industry Transformation Map
9	2019	National AI Strategy (updated as NAIS 2.0 in 2023)
10	2021–2022	Start of operations and official opening of the automated Tuas Port
11	2024	Launch of Smart Nation 2.0

4. EVOLUTION OF POLICY AND GOVERNANCE FRAMEWORKS

Singapore’s logistics industry rests on a developmental-state model in which the government plans strategically and participates directly in the economy while relying on market mechanisms and openness to global capital. The EDB was the central agency of industrial policy: it offered tax incentives and ready-built infrastructure to attract FDI and encouraged multinational corporations to locate regional headquarters and logistics hubs in Singapore. Today more than 7,000 multinational corporations operate in Singapore [17].

PSA was responsible for port management and infrastructure development from 1964. Heavy investment in terminal capacity and information technology, including early computerised terminal operations, made Singapore one of the largest transshipment hubs in the world [20]. In 1996 the regulatory functions of the port were transferred to the newly formed Maritime and Port Authority of Singapore (MPA), and on 1 October 1997 PSA was corporatised as PSA Corporation [18]. The separation of the regulator from the operator and the commercial orientation of PSA increased its flexibility in responding to shocks such as the Asian financial crisis of 1997–1998 and allowed it to expand into terminal operations abroad.

Public research and innovation funding has been organised in five-year national plans coordinated by the National Research Foundation since 2006. The most recent completed plan, RIE2025 (2021–2025), committed about SGD 25 billion, or about 1% of GDP, to research, innovation and enterprise across several domains, including manufacturing, trade and connectivity [22]. The Smart Nation initiative (2014) and Smart Nation 2.0 (2024) oriented the economy, including logistics, towards automation, the Internet of Things and AI [5, 6]. The Logistics Industry Transformation Map, launched in 2016 and refreshed for 2025 by Enterprise Singapore, set out measures to raise productivity and digitalise small and medium-sized enterprises (SMEs), including support for integrated supply-chain systems [23]. Table 2 summarises the main governance frameworks.

Table 2. Key governance frameworks and strategic initiatives in the development of Singapore’s logistics sector.

No.	Policy / initiative	Year	Purpose	Main outcome
1	Economic Development Board (EDB)	1961	Attracting FDI through industrial incentives and infrastructure	More than 7,000 multinational corporations in Singapore [17]
2	Port of Singapore Authority (PSA)	1964	Port management and infrastructure development	41.12 million TEU handled by Singapore’s ports in 2024 [3]
3	TradeNet	1989	Electronic single window for trade documentation	Approval times reduced from days to minutes [21]

4	MPA and corporatisation of PSA	1996–1997	Separation of port regulation from terminal operation	Commercial flexibility and international expansion of PSA [18]
5	National R&D plans (RIE2025)	2006–2025	Funding of research, innovation and enterprise	About SGD 25 billion (about 1% of GDP) in 2021–2025 [22]
6	Smart Nation / Smart Nation 2.0	2014 / 2024	Digital transformation and AI integration	Transition of logistics towards Industry 4.0 [5, 6]
7	Logistics Industry Transformation Map	2016 (refreshed for 2025)	Roadmap for productivity, digitalisation and skills	Support programmes for SMEs and integrated supply chains [23]

5. KEY GROWTH INDICATORS

Singapore’s nominal GDP rose from about USD 1 billion in 1965 to USD 501 billion in 2023 and USD 547 billion in 2024 [1]. Real growth averaged about 9% per year in the first quarter-century after independence, with manufacturing, trade-related services and FDI as the main drivers [16]. In 2024 nominal GDP reached SGD 731.4 billion, and transportation and storage contributed 9.1% of nominal value added [2]; the wider logistics ecosystem, which also includes wholesale trade and business services related to supply chains, is larger than this share suggests.

Container throughput is the most visible indicator of the sector. From the first container berth in 1972, throughput rose to a record 39.0 million TEU in 2023 and 41.12 million TEU in 2024 [3]. Singapore also ranked first in the World Bank’s Logistics Performance Index in 2023, which measures the efficiency of customs, the quality of infrastructure, the ease of arranging shipments, logistics competence, tracking and timeliness [4]. These indicators show that the sector has sustained its competitiveness, but they do not by themselves show how much of the recent performance is due to AI; the operator-reported effects of individual AI tools are presented in Section 6. Table 3 summarises the indicators.

Table 3. Key economic and logistics indicators of Singapore.

No.	Indicator	Value	Year	Source
1	Nominal GDP (USD billion)	about 1	1965	World Bank [1]
2	Nominal GDP (USD billion)	501 / 547	2023 / 2024	World Bank [1]
3	Nominal GDP (SGD billion)	731.4	2024	SingStat [2]
4	Transportation and storage, share of nominal value added (%)	9.1	2024	SingStat [2]
5	Container throughput (million TEU)	39.0 / 41.12	2023 / 2024	MPA [3]
6	Logistics Performance Index, rank	1	2023	World Bank [4]

6. THE ROLE OF AI IN ADVANCING LOGISTICS

AI applications in Singapore’s logistics industry have developed since the early 2010s, and the National AI Strategy of 2019 gave them additional momentum. Among the first national AI projects of that strategy was intelligent freight planning, alongside projects in municipal services, chronic disease management, education and border clearance [7, 24]. The updated NAIS 2.0 (2023) aims to triple the number of AI practitioners to 15,000, and the government has committed more than SGD 1 billion over five years to AI compute, talent and industry development [7]. The strategy emphasises the use of AI to make supply chains more efficient, less costly and more sustainable.

At the operational level, PSA uses AI in several parts of the port system. At Tuas Port, which began operations in 2021, was officially opened in 2022 and is designed to handle up to 65 million TEU when completed in the 2040s, AI supports predictive maintenance, traffic management and the navigation of automated guided vehicles [25]. According to PSA, its OptETruck platform, which matches truck trips with container moves, has reduced empty truck trips by more than 50% and saves about 10 million kg of CO₂ per year, and OptEVoyage supports just-in-time vessel arrivals that reduce fuel consumption and emissions [26]. PSA also reports that robotic process automation saved the equivalent of about 49 person-years of work in 2023 [27].

Public–private partnerships have been integral to this change. The OptEModal platform, launched by PSA and Cargo Community Network in 2025, integrates sea and air freight by providing real-time tracking and estimated arrival times across both modes [28]. These developments are part of the Logistics Industry Transformation Map, which aims to raise productivity and create higher-skilled jobs in the sector [23].

Overall, AI has become an important instrument of Singapore’s strategy to maintain the productivity, sustainability and competitiveness of its logistics industry. Because most reported effects come from the operators themselves and refer to individual tools, the system-wide effect of AI on costs and productivity has not yet been measured independently. Table 4 lists the main AI initiatives.

Table 4. Key AI initiatives in Singapore’s logistics sector (effects as reported by the organisations concerned).

No.	Initiative	Year	Description	Reported effect
1	National AI Strategy 2.0	2023	National roadmap with logistics among the priority fields	Target of 15,000 AI practitioners; more than SGD 1 billion over five years [7]
2	OptETruck (PSA)	before 2023	AI-based matching of truck trips with container moves	More than 50% fewer empty truck trips; about 10 million kg CO ₂ saved per year [26]
3	OptEVoyage (PSA)	before 2023	Just-in-time vessel arrival planning	Lower fuel consumption and emissions [26]
4	Tuas Port automation	2021–2022	AI for predictive maintenance and automated terminal operations	Designed capacity of 65 million TEU in the 2040s [25]
5	OptEModal (PSA and Cargo Community Network)	2025	AI-enabled sea–air multimodal platform	Real-time tracking and coordination across modes [28]
6	Robotic process automation (PSA)	2023	Automation of administrative processes	About 49 person-years of work saved in 2023 [27]

7. CHALLENGES AND LESSONS LEARNED

Despite its achievements, Singapore’s logistics industry faces persistent challenges. The most fundamental is land: the country covers only about 735 km², which limits the space available for ports and warehouses and raises costs. This constraint has encouraged land reclamation, multi-storey warehousing and smart systems that use space more intensively. A second challenge is the shortage of skilled workers, especially in technology and AI, which is aggravated by population ageing and international competition for talent [15].

Global disruptions also affect the sector. The COVID-19 pandemic caused port delays and sharp increases in freight rates around the world. In 2024, diversions of container ships away from the Red Sea led to bunching of vessel arrivals and temporary congestion in Singapore, despite its record throughput [3]. Geopolitical tensions along key shipping lanes and the effects of climate change, such as sea-level rise and more frequent extreme weather, add further risk. Legal and regulatory questions, for example on data sharing and the liability of automated systems, can slow the adoption of new technologies [29].

Several lessons nevertheless emerge from Singapore’s experience. First, integrated long-term state planning, combined with early investment in infrastructure and technology, created capabilities that later attracted private investment. Second, public–private partnerships helped overcome structural constraints by combining public coordination with private innovation. Third, sustained investment in education and training, including sector-specific programmes, eased talent shortages and supported the transition to a knowledge-based economy. Fourth, the separation of regulation from operation, as in the creation of the MPA and the corporatisation of PSA, combined public oversight with commercial discipline. Finally, continuous innovation under constraints allowed Singapore to turn its limitations into advantages. Table 5 summarises the challenges and lessons.

Table 5. Challenges of Singapore’s logistics sector and the corresponding lessons.

No.	Category	Challenge	Impact	Lesson
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1	Geography	Limited land (about 735 km ²)	Constraints on port and warehouse expansion; higher costs	Land reclamation, vertical development and intensive use of space
2	Labour market	Shortage of skilled workers in digital and AI fields	Slower digital transformation	Continuous upskilling and training programmes
3	Global disruptions	COVID-19 pandemic (2020–2022)	Port delays and higher logistics costs	Resilient and flexible supply chains
4	Capacity pressure	Congestion in 2024 linked to Red Sea diversions	Operational delays and higher costs	Capacity expansion and automation
5	Geopolitical risk	Trade conflicts and disruptions of shipping lanes	Uncertainty in global logistics flows	Diversification of routes and risk management
6	Climate change	Sea-level rise and extreme weather	Greater operational vulnerability	Climate adaptation and decarbonisation strategies
7	Regulation	Legal and regulatory barriers to AI adoption	Slower adoption of emerging technologies	Adaptive governance and regulatory sandboxes
8	Governance	Strong reliance on centralised planning	Risk of rigidity in fast-changing environments	Balance between state planning and market flexibility

8. POLICY RECOMMENDATIONS FOR DEVELOPING ECONOMIES

Singapore's experience suggests that developing economies, especially those in ASEAN, can turn locational and structural constraints into competitive advantages through deliberate and consistent policy. The recommendations below are derived from the analysis above and from regional policy assessments [30, 31]. They must be adapted to the size, institutions and fiscal capacity of each country; Singapore's results depended on decades of consistent policy and cannot be expected to follow quickly from individual measures.

Investment in digital infrastructure and AI. Governments should earmark a stable multi-year budget for digital port and logistics infrastructure, such as single windows, port community systems and AI-based planning tools for predictive maintenance and automation. As a benchmark, RIE2025 committed about 1% of Singapore's GDP to research and innovation across all domains [22]; a smaller, logistics-focused share is a realistic starting point for most developing economies. Innovation hubs established jointly with the private sector, following Singapore's public–private partnership approach, can accelerate adoption [32].

Regional cooperation within ASEAN. Countries can adopt common digital standards and interoperable single windows, develop integrated transport corridors and agree on rules for sharing logistics data, in line with the ASEAN Connectivity Strategic Plan 2026–2035 [31]. Regional integration lowers trade costs and spreads geopolitical risks across several routes.

Support for SMEs. As in Singapore's Logistics Industry Transformation Map [23], targeted grants or tax incentives for investment in logistics technology, combined with training programmes, can help SMEs digitalise. Incentives should be time-limited and tied to measurable adoption, and their effect on productivity should be evaluated.

Environmental sustainability. Ports and logistics operators should adopt green standards, such as electrification of terminal equipment, shore power and AI-based optimisation of truck and vessel movements, with targets aligned with national and International Maritime Organization decarbonisation commitments. Singapore's operator-reported savings from OptETruck [26] show that efficiency and emission reductions can be pursued together.

Future-oriented workforce development. Countries should create centres of logistics excellence and training programmes for AI and data specialists in partnership with universities and industry, with targets scaled to the size of their logistics sector. Singapore's goal of 15,000 AI practitioners [7] illustrates the scale of ambition of a small, high-income economy rather than a benchmark for every country.

Table 6 summarises the recommendations together with indicators that can be used to monitor their implementation.

Table 6. Policy recommendations for developing economies and indicators for monitoring.

No.	Recommendation	Main measures	Indicative scale	Indicator to monitor
1	Digital infrastructure and AI	Single windows, port community systems, AI-based planning tools	Stable multi-year budget, scaled to GDP	Port dwell time; document processing time
2	ASEAN regional cooperation	Common digital standards, interoperable single windows, transport corridors	Joint regional funding	Intra-ASEAN trade costs and transit times
3	Support for SMEs	Time-limited grants or tax incentives and training	Tied to measurable technology adoption	Share of logistics SMEs using digital tools
4	Environmental sustainability	Green port standards, electrification, AI-based optimisation	Green infrastructure investment	CO ₂ emissions per TEU handled
5	Workforce development	Centres of excellence, AI and data training	Scaled to the size of the sector	Number of trained specialists; vacancy rates

9. CONCLUSION

The development of Singapore's logistics sector from independence in 1965 to 2025 is one of the clearest examples of how geographic and resource constraints can be turned into economic advantages through consistent policy. Its success rests on a developmental-state model that combined strategic planning, FDI, investment in infrastructure and people, and the early adoption of digital technologies, culminating in today's use of AI in port operations. Initiatives such as the Smart Nation programme and the National AI Strategy are moving logistics towards Industry 4.0, while disruptions and climate change remain persistent risks.

For developing economies, especially in ASEAN, the main lessons are the value of long-term planning, public-private partnerships, investment in skills and regulatory frameworks that separate oversight from operation. The recommendations of this paper, including investment in digital infrastructure and AI, regional cooperation, support for SMEs, environmental sustainability and workforce development, should be adapted to each country's context and evaluated with clear indicators. The analysis is based on secondary sources and on effects reported by operators; future research should measure the system-wide effect of AI on logistics costs and productivity and test how far the Singapore model can be transferred to larger and less centralised economies.

Author contributions

A. Esparham: conceptualization, analysis of sources, writing – original draft; A. Nazarnezhad: data curation, preparation of tables and figures, writing – review and editing.

Conflict of interest

The authors declare no conflict of interest.

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Data availability

All data used in this study are publicly available from the sources cited.

Use of AI tools

An AI-based tool was used to improve the language of the manuscript; the authors reviewed the text and take full responsibility for it.

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