Feasibility Study of Using Autonomous Vehicle Parking Systems and Their Impact On the Management and Operation of the Car Terminal Yard at Laem Chabang Port

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***Abstract*— This study evaluates the feasibility of implementing Automated Valet Parking (AVP) technology at Laem Chabang Port, Thailand's primary automotive export hub. The study addresses key operational challenges, including port congestion, labor shortages, operational inefficiencies, and safety concerns. The findings indicate that AVP technology demonstrates high technical feasibility and strong potential to improve vehicle yard operations through automation and intelligent parking management systems. From an economic perspective, the project demonstrates strong investment potential, with a positive Net Present Value (NPV) of approximately 15.8 million THB, an Internal Rate of Return (IRR) of 11.17%, and a payback period of 6.42 years. These benefits are primarily driven by improved space utilization, reduced labor dependency, increased operational efficiency, and lower operational costs. From a management perspective, the implementation of AVP technology can significantly reduce human error, improve operational safety, and support more efficient vehicle handling processes within the port environment. However, successful implementation requires strategic process re-engineering, workforce reskilling and development, stakeholder acceptance, and effective integration with existing port management systems.**

Overall, the adoption of AVP technology has the potential to enhance the competitiveness of Laem Chabang Port while supporting Thailand's Smart Port and Green Port development policies through improved operational sustainability, safety, and environmental performance.

Keywords*— *Automated Valet Parking (AVP), RoRo terminal, vehicle yard management, Laem Chabang Port, feasibility study, financial analysis

I. INTRODUCTION

Thailand continues to play a crucial role as ASEAN's automotive manufacturing and export hub, consistently exporting millions of vehicles annually, despite pressure from household debt, credit policies, and competition from electric vehicles[1,2]. This makes the development of logistics and port systems essential for maintaining competitiveness. Laem Chabang Port, a key infrastructure under the Eastern Economic Corridor (EEC), plays a vital role in automotive exports but faces bottlenecks, particularly in vehicle parking areas with limitations in space, labor, safety, and the complexity of management and efficiency control [3].

Automated Valet Parking (AVP) technology, a SAE Level 4 automated driving system, can help improve space utilization, reduce labor, decrease vehicle search and retrieval time, and support the Green Port concept. Evidence suggests it can increase parking capacity and reduce redundant valet parking [4].

In the Thai context, autonomous vehicle legislation is still under development. However, its use in "enclosed areas," such as port parking lots, is highly feasible both legally and practically, and aligns with the Phase 3 automated port development guidelines [5]. Nevertheless, there are still research gaps regarding the use of AVP in Ro-Ro ports, which have unique characteristics such as vessel density, open areas, and safety requirements. Therefore, a feasibility study of AVP at Laem Chabang Port is crucial, both academically and in terms of policy, to enhance the efficiency, safety, and long-term sustainability of Thailand's automotive logistics system.

II. OBJECTIVES OF THE STUDY

1. Assess AVP system feasibility in the terminal yard.
2. Analyze AVP's impact on yard management and operations.
3. Propose AVP technology application guidelines for the port.

III. RESEARCH METHODOLOGY

This study is a feasibility study using a mixed-methods research approach to evaluate the suitability of applying Automated Valet Parking (AVP) technology in the vehicle parking area of Laem Chabang Port. It covers technical, economic, and management dimensions, as detailed below:

A. Research Design

This research employs a descriptive and analytical research approach combined with a case study, focusing primarily on the Auto Terminal Yard of Laem Chabang Port to analyze the potential and impacts of implementing AVP technology.

B. Data sources and data collection

Primary Data Collection

Primary data were collected through in-depth interviews, field observations, and focus group discussions involving stakeholders directly related to port and yard operations. A total of 15 key informants participated in the study, consisting of 5 port management personnel from Laem Chabang Port, 4 parking yard operation supervisors, 3 logistics and supply chain specialists, and 3 automation and intelligent transportation technology experts. Participants were selected using purposive sampling based on the following criteria: (1) having at least 5 years of experience in port, logistics, parking yard, or automation-related operations, (2) direct involvement in vehicle yard management or logistics systems, and (3) knowledge or experience related to automation technologies, smart parking systems, or port operations. Field observations were conducted to study actual operations in the parking areas, such as vehicle storage procedures, internal valet movement, and vehicle preparation for loading and unloading from ships, providing a more concrete understanding of the operational context. In addition, one focus group discussion involving 8 stakeholders was conducted to gather opinions regarding operational challenges, technology acceptance, implementation barriers, and the expected impacts of AVP technology on operational efficiency and safety.

Secondary Data Collection

Secondary data was collected from reports and documents of relevant agencies, such as the Port Authority of Thailand (PAT), as well as research and academic articles on logistics, ports, and AVP technology. This data served as a theoretical baseline and was used for comparison with the research results. Furthermore, technical data on related systems, such as Terminal Operating System (TOS), Yard Management System (YMS), and RTLS/UWB positioning systems, were studied, along with cost and operational data of the yard (if accessible) for economic analysis and investment feasibility assessment.

C. Data Analysis

Qualitative data obtained from interviews and focus group discussions were analyzed using thematic content analysis. The collected data were categorized into key themes, including operational efficiency, parking space utilization, labor reduction, human error reduction, safety improvement, and sustainability potential.

The qualitative findings were subsequently integrated with technical and economic feasibility analyses to support the study conclusions regarding the suitability and practicality of implementing AVP technology at Laem Chabang Port.

Secondary data and technical documents were analyzed using descriptive and comparative analysis methods to evaluate operational feasibility, investment potential, and expected management impacts.

IV. RESULTS

The researchers analyzed the potential and feasibility of applying an Automated Valet Parking (AVP) system in the parking areas of Laem Chabang Port, covering industry aspects, market and competition, cost structure, management, investment, as well as risk factors and project success, to assess the suitability of implementing automation in the context of a modern port. The study results are presented in various dimensions, including an analysis of automotive and logistics industry trends, comparisons with leading international ports, a financial cost-benefit analysis, and an assessment of the impact on efficiency, safety, and sustainability of the AVP system. This reflects the potential for upgrading Laem Chabang Port to a Smart Port in the future.

A. Industry Analysis and Agv Feasibility

Thailand is a major ASEAN automotive hub. Exports faced a slight decline in 2024 due to economic factors and EV competition. The industry is rapidly transitioning to Zero Emission Vehicles (ZEV) supported by government policies, necessitating port logistics adaptation. [6] Laem Chabang Port, a key auto export gateway, uses specialized Ro-Ro terminals. These face significant space limits and operational bottlenecks due to manual, labor-intensive processes, leading to delays and accidents. Transitioning to a "Smart Port" via automation is critical. This study focuses on Automated Guided Vehicles (AGVs), like the "Stan" robot. Stan lifts 2.6-ton vehicles using LiDAR and RTK GPS/SLAM. AGVs replace manual driving with automated valet parking, enabling high-density "stack" parking, 24/7 operation, reduced labor, and improved safety [7]

Figure 1: AGV Technology, area of hand over [8]

Estimates for Terminal A5 show an AGV fleet of 12 robots is needed to move 1,000 cars in 3 days. Each robot averages 4.28 cars/hour. The initial capital expenditure is estimated at $1,050,000 (34.65 million THB) for the 12 robots.

B. Market and Competitor Analysis

Thailand is a key ASEAN automotive/logistics hub (LPI 3rd ASEAN, 34th globally). Road transport dominates (80%) due to inadequate infrastructure. The logistics market is projected to grow (6.22% CAGR) from $53.38B (2025) to $72.19B (2030). Growth is driven by auto, electronics, food, China+1 policies, and e-commerce (15% CAGR). Despite high logistics costs (13.4-13.8% of GDP), significant infrastructure investment is ongoing. Laem Chabang Port's Ro-Ro transshipment shows robust growth (+40.8% actual; 8-12% forecast), offsetting stagnant exports. High capacity utilization necessitates automation to prevent bottlenecks. [9,10].

Table1: Strategic summary and growth rate

Category	2024-2025 Growth (Actual)	Long-Term CAGR Forecast (Est.)	Status
Export	-1.7%	-1.5% to 0.0%	Stagnant/ Decline
Import	+14.1%	+2.0% to +4.0%	Stable/ Moderate Growth
Transshipment (T/S)	+40.8%	+8.0% to +12.0%	High Growth / Key Driver
TOTAL UNITS	+6.0%	+2.5% to +4.5%	Slow & Steady Recovery

Thailand's port and automotive transportation industry, particularly Laem Chabang Port, is undergoing a transition to automation. This is supported by government policies such as Smart Port, EEC (Eastern Economic Corridor), and ZEV (Zero-Electric Vehicle) targets, driving the development of technologies like AVP (Automated Vehicle Automation) while considering safety and cybersecurity standards.

Economically, the automotive industry remains a key driver of the country's economy. The growth of electric vehicles and investment in the EEC has led to continuously increasing port usage. While AVP has high initial costs, it offers long-term benefits through reduced labor costs and improved operational efficiency.

Socially, AVP technology plays a crucial role in enhancing safety, reducing accidents, and improving the image of modern ports. However, its success depends on workforce acceptance, requiring reskilling and clear communication.

Technologically, AVP has proven internationally, with key technologies such as GNSS-RTK, LiDAR, 5G, AYMS, and TOS enabling accurate real-time apron management.

In terms of demand, the volume of vehicles passing through Laem Chabang Port is continuously increasing and is expected to grow significantly in the future. This has led to the inadequacy of existing systems and congestion, making automated systems like AVP essential for increasing capacity, handling increased workloads, and reducing labor costs. And reduce carbon emissions [11].

On the supply side, current operational systems rely heavily on human labor, limiting efficiency and workload capacity. While the adoption of automation is still in its early stages, bottlenecks such as human error, labor costs, and system integration need to be addressed.

Finally, in terms of competitiveness, world-class ports such as PSA Singapore and Yokohama have already adopted fully automated systems. While Thai operators are beginning to adapt to semi-automated systems, they still lag behind overall. Therefore, implementing AVP (Automated Port Value) is a key strategy to enhance competitiveness and develop towards international “Smart Port” standards in the future. [12]

C. Cost Structure and Labor

a) Cost Structure and Labor

AVP systems significantly cut variable labor costs (60-80% reduction) compared to manual operations. While requiring substantial initial CapEx (robots, sensors, infrastructure), AVP lowers long-term OpEx due to reduced wear and consistent performance. AVP's use of electricity offers stable, lower variable costs and reduces emissions, supporting "Green Port" initiatives.

b) Work Structure (Operations)

AVP implementation necessitates organizational restructuring. Manual operations are labor-intensive (OpEx ~3.8M THB/month). AVP shifts cost structure, reducing direct labor but requiring specialized technical staff investment.

c) Time and Productivity

Manual systems suffer inconsistent throughput and long cycle times due to human factors and delays. Automated AVP systems enable 24/7 operation, eliminate delays, optimize vehicle movement, and ensure consistent throughput, improved scheduling, and efficient yard utilization. Maximum benefits require seamless system integration.

d) Management: Safety and Worker Acceptance

AGVs enhance safety through advanced sensors and autonomous operation, significantly reducing human error and accidents. Successful AVP adoption demands comprehensive workforce reskilling and continuous stakeholder engagement for smooth transition and sustainability benefits.

e) SWOT Analysis of Key Competitors

Global automated ports demonstrate significant strengths: proven, stable automation (AGVs, remote cranes) boosting safety, efficiency, and throughput. Their leading image attracts business. Weaknesses include high initial investment, reliance on skilled technical personnel, and potential inflexibility for diverse cargo. Opportunities arise from growing Smart Port and Green Port demand in ASEAN, and specialized solutions for vehicle yards. Threats include rapid technological change (AI, IoT, 5G), new low-cost tech players, and evolving safety regulations for autonomous vehicles.

f) Benchmarking Against International Ports

Benchmarking international ports like Yokohama (semi-automated, EVs, IoT) and PSA Singapore (fully automated, AGVs, 5G) reveals key standards. These leaders prioritize automation, sustainability, and reduced labor, achieving high throughput and safety. Thai ports, largely manual, lag in automation. This gap highlights the necessity for Laem Chabang to adopt similar advanced systems to meet modern port standards and Smart/Green Port objectives.

g) Summary of Market and Competitor Analysis

The analysis indicates high potential for AVP at Laem Chabang Port. Market trends show continuously increasing vehicle traffic, driven by Thailand's automotive industry growth and EEC policies. Current manual operations create bottlenecks, making automation a structural necessity. Competitor analysis clearly shows leading ports utilize advanced digital infrastructure (AGVs, central control, 5G) for superior efficiency and lower costs. Thai ports must embrace AVP to remain competitive and meet evolving global standards.

h) National Competitive Advantage (Porter's Diamond Model)

Thailand's automotive industry status (2026 onwards) reveals a complex competitive landscape.

(1) Factor Conditions: Strengths include robust transport infrastructure (Laem Chabang Port), a skilled workforce, and substantial EV investments. However, managing parking bottlenecks, chip supply chain flexibility, and EV infrastructure gaps remain challenges.

(2) Demand Conditions: Domestic market slowdown (26% vehicle sales reduction in 2024) is driven by high household debt. Demand shifts towards xEVs (54.7% of passenger cars are HEV/PHEV/BEV), but BEV growth faces price wars. Commercial vehicle demand is affected by economic slowdowns and natural disasters.

(3) Related and Supporting Industries: Strong automotive parts and logistics industries (linked to Laem Chabang) are advantages. However, reliance on imported semiconductors creates supply chain vulnerability.

(4) Firm Strategy, Structure, and Rivalry: Intense competition, especially from Chinese EV manufacturers, drives innovation but forces restructuring for some players. Foreign EV investments boost market competition.

(5) Government Role: Proactive government support (EV 3.0/3.5, BOI incentives, Smart Port development) is a significant advantage, though international trade policies (Trump Tariffs, trade diversion, RVC rules, NVES) pose external challenges to exports.

(6) Chance Events: Unpredictable factors like chip supply issues, natural disasters (El Niño, floods), and geopolitical conflicts (Middle East) significantly impact industry stability.

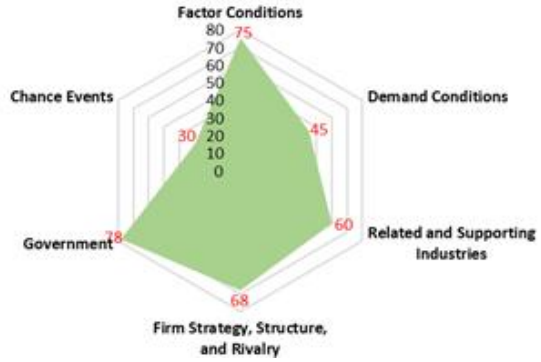

Figure 2: Porter's Diamond Model Assessment: Thai Automotive Industry (2026 and Future)

In summary, Thailand's automotive sector must adapt to complex dynamics. Key strengths are government/private investment in EVs and strong logistics. Weaknesses include supply chain fragility and domestic demand issues. Future competitiveness relies on elevating production factors, responding to evolving market demands, strengthening supporting industries, implementing agile firm strategies, and sustained proactive government support.

D. Cost Structure and Labor Finance, Investment, and Returns

This chapter financially assesses implementing Automated Valet Parking (AVP) systems at Laem Chabang Port's vehicle yard. It analyzes Capital Expenditure (CapEx), operational costs (OpEx), projected revenues, and economic benefits using key financial metrics (NPV, IRR, Payback Period) and Sensitivity Analysis to determine viability and risks.

a) Estimated Capital Expenditure (CapEx)

AVP implementation requires a significant initial investment, estimated using the Stanley Robotics model:

- Construction & Infrastructure: Covers surface, electrical, charging, communications, control room, and safety systems. Total: 16,632,000 THB.
- Automated Equipment: Includes 12 AVP robots, sensors, navigation, and fleet management software. Total: 83,160,000 THB.
- Training & Maintenance: Funds personnel training and initial maintenance setup. Total: 4,158,000 THB.

Total Initial Capital Expenditure (CapEx): 103,950,000 THB

b) Estimated Revenue and Economic Benefits

The AVP system generates revenue and economic benefits through:

- Increased Space Utilization & Throughput: Automated, high-density parking handles more vehicles (estimated 10% capacity increase), boosting service revenue.
- Reduced Penalties: Minimizes delays, cutting "Over Storage Charge" penalties.
- Labor & Efficiency Savings: Significant reduction in manual drivers (60-80%), less congestion, and fewer human errors lead to substantial cost savings.
- Environmental Benefits: Electric AGVs cut CO2, PM2.5, and noise, aligning with "Green Port" initiatives.

Total Annual Economic Benefit (Base Case): 16,186,040 THB (Comprising increased revenue, labor savings, reduced downtime/damage, and environmental/ image benefits.)

c) Financial Metrics (Cost-Benefit Analysis)

Assuming a 10-year project life and an 8% discount rate, the AVP project shows strong financial viability:

- Net Present Value (NPV): +15,826,000 THB (Positive NPV indicates value creation).
- Internal Rate of Return (IRR): ≈ 11.17% (Exceeds the 8% discount rate, confirming profitability).
- Payback Period: 6.42 years (Reasonable recovery time for a large infrastructure project).

d) Sensitivity Analysis

The project's robustness was assessed under varying conditions:

- Revenue/Benefit Sensitivity: A 10% revenue/benefit decrease still yields a positive NPV (+10.90 million THB). Even a 30% reduction keeps NPV positive (+2.00 million THB), showing strong market resilience.

- CapEx Sensitivity: A 10% CapEx increase maintains a positive NPV (+5.43 million THB). However, a 20% CapEx increase results in a negative NPV (-4.97 million THB), emphasizing CapEx management.
- Worst-Case Scenario: Even with a 20% revenue decrease and a 10% CapEx increase, NPV remains positive (+1.20 million THB) (IRR 8.6%, 8.83-year payback). This demonstrates project robustness.

E. Risks and Success Factors

a) Risk Identification

Key risks: robot malfunctions, sensor errors, and communication failures. Financial risks include budget overruns and revenue shortfalls. Management risks involve change resistance, skill gaps, and unclear roles. Environmental and safety risks include human-robot interactions and regulatory compliance.

b) Risk Mitigation

Proactive strategies are crucial. Use proven technologies, pilot projects, and robust SLAs. RaaS models can manage CapEx. Continuous training, clear communication, and defined roles for the automation team are vital. Safety requires strict zoning and emergency protocols.

c) Critical Success Factors (CSFs)

Successful AVP relies on strong government and private support. It needs appropriate technology and comprehensive workforce reskilling. Seamless integration with port systems is essential. Proactive stakeholder engagement fosters acceptance.

V. CONCLUSIONS AND RECOMMENDATIONS

a) Feasibility Summary

AVP implementation at Laem Chabang Port is highly feasible. Technical aspects are supported by proven technologies, requiring infrastructure upgrades. Market potential is strong due to automotive demand and regional competition. Financially, the project is viable with positive NPV, 11.17% IRR, and a 6.42-year payback. Managerially, it demands organizational transformation with strong governance.

b) Policy and Implementation Recommendations

Phased implementation, starting with pilot projects, is recommended. Significant investment in infrastructure (yards, power, networks) and human resource development (reskilling) is needed. Strategic planning should align short-term improvements with long-term automation goals, supporting Smart and Green Port objectives.

c) Future Research

Future studies should explore detailed simulation and Digital Twin modeling for AGV deployment. Life-cycle cost analysis and comparative investment models (ownership, RaaS, PPP) are vital. Research on socio-economic impacts (employment, acceptance) and advanced cybersecurity for autonomous port systems is crucial.

REFERENCES

[1] Thai Auto Institute. (2024). Thai Automotive Industry Facts & Figures 2024. Thailand Automotive Institute. https://data.thaiauto.or.th/images/PDF/Facts_Figures_2024V1.pdf
[2] DP World. (2025). DP WORLD DEPLOYS ELECTRIC INTERNAL TRANSFER VEHICLES IN THAILAND. https://www.dpworld.com/en/news/dp-world-deploys-electric-internal-transfer-vehicles-in-thailand?utm_source=chatgpt.com
[3] Port Economics. (2023). Port Economics, Management and Policy. https://doi.org/10.4324/9780429318184
[4] SAE International. (2021). Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles (SAE Standard J3016_202104). SAE International. https://www.sae.org/standards/content/j3016_202104/
[5] PRD Thailand. (2024). News & announcements. Public Relations Department (PRD). https://thailand.prd.go.th
[6] Ministry of Industry and the Energy Policy and Planning Office. (2023). Five-Year Action Plan (2023–2027), Revised Fiscal Year 2023. Office of the Permanent Secretary, Ministry of Industry.
[7] Saowaluk Uayporn and Rachada Kongkhuntien. (2019). Port Authority of Thailand signs MOU with DEPA to develop Laem Chabang Port as a pilot Smart Port. InfoQuest. Retrieved from https://www.infoquest.co.th/news/2019 8cb3e04c865367396f80fd65abea270c
[8] Standard Bots. (2025). The most advanced robots in 2025. https://standardbots.com/blog/most-advanced-robot?
[9] The Nation Thailand. (2025). Foreign investment in Thailand hits five-year high at THB324bn in 2025. The Nation Thailand. https://www.nationthailand.com/business/investment/40065410
[10] OECD. (2020). Tackling coronavirus (COVID 19): Contributing to a global effort, http://www.oecd.org/coronavirus/en/.
[11] EEC. (2023). Thailand collaborates with UNIDO to found EEC industrial hub 4.0 in the region. https://www.eeco.or.th/en/press_release/thailand-collaborates-with-unido-to-found-eec-industrial-hub-4-0-in-the-region/?utm_
[12] Port Authority of Thailand (PAT). (2023). Thailand's smart/digital port strategy. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). https://www.unescap.org/sites/default/d8files/event-documents/6_PAT%20Digital%20Strategy.pdf