Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 01:2026
DOI: 10.5281/zenodo.18345174

ENHANCING PORT COMPETITIVENESS AND MARITIME TRANSPORT IN THAILAND: A CASE OF DEVELOPING A DISTRIBUTION CENTER IN BANGKOK PORT WITH TRAFFIC IMPACT ASSESSMENT

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Abstract

Bangkok Port, located within metropolitan areas face increasing challenges related to traffic congestion, land-use inefficiency, and environmental externalities. Bangkok Port (Khlong Toei Port), Thailand's primary international river port, exemplifies these challenges, due to its inner-city location and heavy reliance on truck-based freight transport. This study assesses traffic impact from development of a multi-storey distribution center (DC) within Bangkok Port. It evaluates its impacts through a comprehensive Traffic Impact Assessment (TIA) framework integrated with smart port and port decarbonization strategies. The objective of the paper is to analyze, assess and forecast the current level of urban traffic congestion at specific intersections in Bangkok Port, using urban planning perspective. The traffic congestion measures and strategies have been recommended. A mixed-method research approach is adopted, by combining traffic volume surveys, origin–destination analysis, passenger car unit (PCU) conversion, level-of-service (LOS) evaluation, and long-term traffic forecasting over a 30-year horizon. Scenario analysis compares baseline conditions with a redevelopment scenario featuring vertical land-use consolidation, truck appointment systems, and external buffer yards. Results indicate that the proposed DC development can significantly reduce internal truck circulation and queuing, maintaining acceptable LOS levels (C or better) on critical road segments. Importantly, congestion reduction yields measurable environmental co-benefits. It reduces truck idling of 10–30 minutes per trip correspond to annual savings of approximately 620–1,860 tCO_2 and 3–9 kg of PM2.5 from freight vehicle operations. The findings demonstrate that integrating traffic management with vertical port redevelopment, not only improves logistics efficiency, but also delivers tangible decarbonization and local air-quality benefits. Further, the redevelopment reduces logistics costs per GDP. The study also provides policy-relevant insights for sustainable redevelopment of inner-city ports in rapidly urbanizing regions.

Keywords: Bangkok Port, Distribution Center, Traffic Impact Assessment, Urban Congestion, Smart Port, Decarbonization.

1. INTRODUCTION

Ports are critical nodes in global and regional supply chains, yet ports located within dense urban areas increasingly struggle to balance logistics efficiency with urban livability and environmental sustainability. Bangkok Port, officially known as Tha Ruea Krung Thep and commonly referred to as Khlong Toei Port, is a strategic river port situated along the Chao Phraya River in the heart of Bangkok. Established in 1947 and operated by the Port Authority of Thailand (PAT), the port continues to function as a major logistics gateway

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for the Bangkok Metropolitan Region (BMR), handling approximately 1.2–1.5 million TEUs annually.

Despite its economic importance, Bangkok Port generates substantial negative externalities, such as pollutants and traffic congestion. Freight transport associated with port operations relies overwhelmingly on road transport, contributing to chronic traffic congestion, elevated increasingly logistics costs, and air pollution in surrounding communities. Moreover, traditional horizontal port development has resulted in inefficient land use, limiting opportunities for urban regeneration and green space provision.

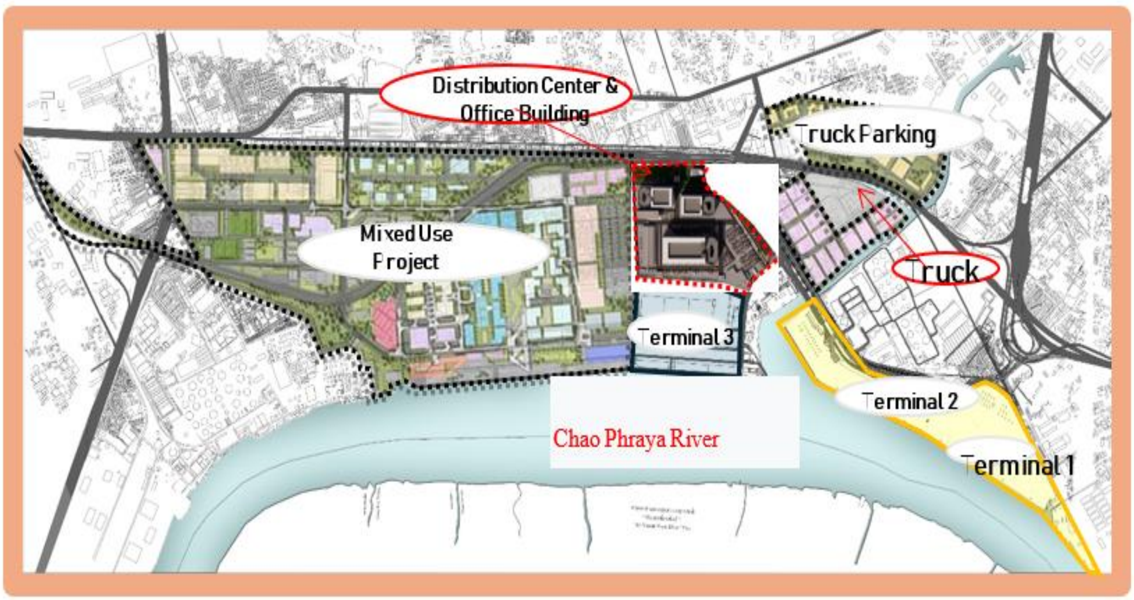

Figure 1: Physical layout plan of Bangkok Port, and the area of Central Distribution Center Project

In response, PAT has proposed transforming Bangkok Port into a "Smart and Green Port," with a central strategy being the development of a multi-storey distribution center (DC) that vertically consolidates cargo handling, container freight station (CFS) activities, and administrative functions.

Figure 1, it represents Physical layout plan of Bangkok Port, and the area of Central Distribution Center (CDC) Project in 138 Rai (220,800 m²). While such redevelopment promises operational and environmental benefits, it also necessitates careful assessment of traffic impacts on both internal port circulation and surrounding urban road networks.

This paper addresses the following research question: How can the development of a central distribution center (CDC) in Bangkok Port, supported by traffic impact assessment and smart–green port strategies, mitigate urban traffic congestion and advance port decarbonization? To answer the question, the study conducts the literature by integrating traffic impact assessment with port land-use restructuring and sustainability objectives, and conducting traffic count and survey.

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2. LITERATURE REVIEW

To focus on traffic impact assessment with new port project development, the paper reviews research related with traffic congestion as is a major urban transportation problem, traffic congestion and port-city Interfaces, traffic impact assessment in freight-dominated developments, and smart ports with sustainable port development. The aim of the literature is to examine definition of traffic congestion, and how to measure and assess traffic congestion in new project development.

2.1 Traffic congestion as is a major urban transportation problem

The primary objective of the paper is to propose a framework for developing a measure of transport congestion and relief in ports (Md, Aftabuzzaman. 2007). It provides a definition of traffic congestion and reviews the desirable attribute of an appropriate traffic congestion measure and sets criteria for assessing a congestion measure (Litman, T. 2004). Table 1 presents a summary of definition of congestion from the research literature. These definitions can be broadly categorized into three groups: Demand capacity related; delay-travel time related; and cost related (Md, Aftabuzzaman. 2007).

Table 1: Summary of definition of congestion from the research literature

Classification	Definition	Author
Demand capacity related	Traffic congestion occurs when travel demand exceeds the existing road system capacity	Rosenbloom, 1978
	Congestion is a condition in which the number of vehicles attempting to use a roadway at any time exceeds the ability of the roadway to carry the load at generally acceptable service levels	Rothenberg, 1985
	Congestion is a condition that arises because more people wish to travel at a given time than the transportation system can accommodate: a simple case of demand exceeding supply.	The Institute of Civil Engineers, 1989 cited in Miller and Li, 1994
	When vehicular volume on a transportation facility (street or highway) exceeds the capacity of that facility, the result is a state of congestion.	Vuchi and Kikuchi, 1994
	Congestion is the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches its capacity.	ECMT, 1999
	Congestion may be defined as state of traffic flow on a transportation facility characterized by high densities and low speeds, relative to some chosen reference state (with low densities and high speeds).	Bovy and Salomon, 2002
Delay- travel time related	Congestion is an imbalance between traffic flow and capacity that causes increased travel time, cost and modification of behavior.	Pisaraski, 1990 cited in Miller and Li, 1994
	Traffic congestion is travel time or delay in excess of that normally incurred under light or free-flow travel conditions.	Lomax et al., 1997
	Traffic congestion is a condition of traffic delay (when the flow of traffic is slowed below reasonable speeds) because the number of vehicles trying to use the road exceeds the traffic network capacity to handle them.	Weisbrod, Vary, and Treyz, 2001

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	Congestion is the presence of delays along a physical pathway due to presence of other users.	Kockelman, 2004
	Congestion can define as the situation when traffic is moving at speeds below the designed capacity of a roadway.	Downs, 2004
	In the transportation realm, congestion usually relates to an excess of vehicles on a portion of roadway at a particular time resulting in speeds that are slower-sometimes much slower-than normal or “free flow” speeds.	Cambridge Systematics and TTI, 2005
Cost related	Traffic congestion refers to the incremental costs resulting from interference among road users.	VTPI, 2005

Source: Adapted from Md, Aftabuzzaman. (2007). Measuring traffic congestion-A critical review. The 30th Australasian Transport Research Forum, Melbourne, 25 - 27 September 2007.

Criteria of an appropriate congestion measures by a range of features have been suggested for a measure of congestion (Md, Aftabuzzaman. 2007). Turner (1992) examined indicators of congestion and suggested that measures to quantify the level of congestion should: 1 deliver comparable results for various systems with similar congestion level; 2 accurately reflect the quality of service for any type of system; and 3 be simple, well-defined and easily understood and interpreted among various users and audiences. Levinson and Lomax (1996) discussed desired attributes of a congestion index and suggested that a congestion index should: be easy to communicate; measure congestion at a range of analysis level; measure congestion in relation to a standard; provide a continuous range of values; be based on travel time data because travel time based measures can be used for multimodal analysis and for analyses that include different facility types; and adequately describe various magnitudes of congested traffic conditions. Boarnet et al (1998) identified three issues that must be addressed in measuring congestion. It should: reflect the full range of highway performance; be based on widely available data; and allow comparison across metropolitan areas. Lomax et al (1997) indicate that an ideal congestion measure would have: clarity and simplicity; descriptive and predictive ability; statistical analysis capability; general applicability.

The congestion measure in the subsequent sections will be assessed using the following criteria: demonstrates clarity and simplicity; describes the magnitude of congestion; allows comparison across metropolitan areas; provides a continuous range of values; includes travel time; and relates to public transport congestion relief. Measures of traffic congestion can be categorized into four groups: basic measures; ratio measures; level of service; and indices (Lomax, T.J. 1990; Litman, T. 2004).

2.2 Traffic Congestion and Port-City Interfaces

Traffic congestion occurs when traffic demand exceeds available roadway capacity, resulting in increased travel time, delays, and environmental impacts (B.S. Hoyle, César Ducruet, and T.A. Daamen. 1989). In port cities, congestion is exacerbated by the high proportion of heavy vehicles, whose size and operating characteristics disproportionately affect road capacity and traffic flow. Previous studies highlight that port-related congestion

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differs from commuter congestion due to its dependence on vessel schedules, gate operations, and terminal productivity.

2.3 Traffic Impact Assessment in Freight-Dominated Developments

Traffic Impact Assessment (TIA) is a standard planning tool used to evaluate the transportation impacts of new developments. In port-related projects, TIA focuses on truck volumes, vehicle composition, gate performance, and interactions between port traffic and urban networks. Common analytical tools include traffic counts, turning movement analysis, origin–destination surveys, passenger car unit (PCU) conversion, and level-of-service (LOS) evaluation based on Highway Capacity Manual principles (Lomax, T.J. 1990; Litman, T. 2004).

2.4 Smart Ports and Green Ports

Smart ports employ innovative and digital technologies such as intelligent transportation systems (ITS), port community systems (PCS), RFID, and data analytics to optimize operations and information flows. (Mohamed. Elhussieny. 2025). Green ports emphasize reducing environmental impacts through energy efficiency, modal shift, electrification, and sustainable land-use planning. Integrating smart and green port concepts is increasingly recognized as a pathway toward port decarbonization and long-term competitiveness.

The study identifies research gaps of the literature. Mohamed. Elhussieny. (2025) examine smart port technologies and green port initiatives, limited research integrates traffic impact assessment with vertical port land-use restructuring as a congestion mitigation and decarbonization strategy. This study addresses this gap by empirically evaluating the traffic and sustainability implications of a vertical DC development in an inner-city port. When reviewing the study area (T, Theppitak, 2024; Md, Aftabuzzaman. 2007; Lomax, T.J. 1990; Litman, T. 2004), Bangkok Port (BKP) occupies approximately 2,353 rai (about 3.76 million m²), with around 898 rai (about 1.44 million m²), located within the customs-controlled operational area. Historically, port facilities such as warehouses, container yards, and support services have been developed horizontally. Recent feasibility studies indicate that through vertical development, core port activities can be consolidated into approximately 138 rai—around 15% of the land currently used for traditional operations—freeing remaining land for mixed-use and green development. Although Bangkok Port handles a smaller share of national container throughput compared with Laem Chabang Port, as major deep-sea port, its location within Bangkok means that port-related truck traffic has a disproportionate impact on urban congestion and air quality in the Khlong Toei district.

3. RESEARCH METHODOLOGY

Properly measuring traffic congestion is crucial in order to accurately assess the level of congestion and the level of service provided (Lomax, T.J. 1990; Litman, T. 2004). To achieve the objectives, the research is designed by adopting an inductive, mixed-method research design combining qualitative analysis (policy review and literature synthesis), with quantitative traffic analysis and forecasting. The hypothesis is the measurement of

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the level of traffic congestion at mid-block (MB) and turning movement counts (TMC). It can indicate the efficiency of urban mobility and level of service (LOS). The level of traffic congestion at selected intersections in port is measured and calculated using various parameters such as traffic volumes, traffic flows, delay ratio, total segment delay, congested time, travel time, and delay time rates.

For data collection, primary data were collected through: - Mid-block (MB) traffic volume surveys at six locations within the Bangkok port; - Turning movement counts (TMC) at six key intersections within and around the port. Furthermore, a survey was conducted in conjunction with a questionnaire and in-depth interviews to obtain comprehensive perspectives. The origin–destination surveys on major access roads, including Art Narong, Sunthon Kosa, Kluay Nam Thai, and Kasem Rat roads. There are several intersections in the area that experience complicated traffic congestion due to high mobility. Observation was made and a videography technique, which was used to collect data on pedestrians and vehicles. This was done to enhance the physical analysis and measure the level of traffic congestion at the chosen intersections.

The questionnaire and measurements data were initially inputted into the SPSS version 14.0, Aside from analyzing interviews and questionnaire, the research involved interpreting video recorded data, GIS, photographs, and secondary written documents. This measured data is essential for policy makers and urban planners to implement appropriate mitigation methods. The research gap necessitates additional investigation and research. Secondary data was gathered through historical container throughput statistics, land-use plans, and operational data provided by the Port Authority of Thailand (PAT). Traffic analysis methods, vehicle volumes were converted into passenger car units (PCU), using standard equivalency factors. Roadway performance was evaluated using volume-to-capacity (v/c) ratios and LOS classifications. Traffic demand was forecast over a 30-year period under baseline and redevelopment scenarios.

4. FINDING RESULTS AND DISCUSSION

4.1 Existing traffic and trailer survey conditions

Research consistently finds that freight vehicles dominate port-related road networks, necessitating specialized analysis distinct from urban traffic.

- Dominance of Trucks: Port collection and distribution roads exhibit a high proportion of trucks, and container vehicles (semi-trailer trains, full-trailer trains), compared to general urban roads. This traffic composition has a disproportionately larger impact on traffic efficiency and road capacity, due to the vehicles' size, long body length, and poorer acceleration/deceleration performance.
- Peak Time Variation: Unlike commuter traffic, port road traffic does not have a fixed peak time, but is closely related to the arrival and departure of ship schedules. Traffic flow is generally heavier before and after vessel loading and unloading operations.

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- Overloading/Overdimension (ODOL) Impact: For major logistical corridors (like those serving deep-sea ports), violations such as overdimension and overloading in heavy vehicles are a significant finding. These violations, often aimed at reducing logistics costs, exacerbate congestion, reduce overall traffic speed and efficiency, and cause accelerated damage to road infrastructure.

Data Reliability Challenge: A major operational challenge in volume studies is the high uncertainty and proportion of missing values in sensor data. Researchers often employ imputation methods, such as k-Nearest Neighbors (kNN), to enhance the reliability of the observed traffic volume data before analysis.

Table 2: Container volumes throughput in Bangkok Port during 2019-2023

Year	Inbound Container			Outbound Container			Container Throughput (T.E.U.)		
	LCL/FCL T.E.U.	Empty T.E.U.	Total T.E.U.	LCL/FCL T.E.U.	Empty T.E.U.	Total T.E.U.	LCL/FCL T.E.U.	Empty T.E.U.	Total T.E.U.
2019	868,910	11,229	880,139	536,331	34,661	570,992	1,405,241	45,890	1,451,131
2020	847,547	16,929	864,476	552,328	18,261	570,589	1,399,875	35,190	1,435,065
2021	874,191	20,022	894,213	529,438	14,039	543,477	1,403,629	34,061	1,437,690
2022	796,015	28,628	824,643	439,673	12,717	452,390	1,235,688	41,345	1,277,033
2023	759,004	16,948	775,952	459,342	23,980	483,322	1,218,346	40,928	1,259,274
Total	4,145,667	93,756	4,239,423	2,517,112	103,658	2,620,770	**6,662,779**	197,414	**6,860,193**
Aver. Per Year	**829,133**	**18,751**	**847,885**	**503,422**	**20,732**	**524,154**	**1,332,556**	**39,483**	**1,372,039**

Source: Adapted data from Port Authority of Thailand, 2026

Table 2 shows container volumes through in Bangkok Port during 2019-2023. The figure shows that average container throughput in last five years is at 1,372,039 T.E.U. by a proportion of inbound and outbound containers are at 62 and 38 percent respectively. While numbers of container growth is significantly fluctuate, according to economic recession, geopolitics conflict, and COVID-19 pandemics.

Table 3: Traffic volume in Bangkok Port in 2025 and demand forecasting during 2025-2055

Year	Trucks (Unit)	Full Cargo		No Cargo		Empty Container (TEU)	LCL Container (TEU)	FCL Container (TEU)	Total (TEU)
		Truck (Unit)	Trailer (Unit)	Truck (Unit)	Trailer (Unit)				
2025	406,188	109,655	245,659	270,277	304,956	20,648	77,222	423,550	521,420
2030	495,450	133,752	299,643	329,673	371,971	25,186	94,192	516,626	636,004
2035	637,370	172,066	385,476	424,106	478,521	32,400	121,173	664,613	818,186
2040	637,370	172,066	385,476	424,106	478,521	32,400	121,173	664,613	818,186
2045	637,370	172,066	385,476	424,106	478,521	32,400	121,173	664,613	818,186
2050	637,370	172,066	385,476	424,106	478,521	32,400	121,173	664,613	818,186
2055	637,370	172,066	385,476	424,106	478,521	32,400	121,173	664,613	818,186

Source: Adapted data from Port Authority of Thailand, 2026

The result shows that information of truck and trailer movements dominates port-related traffic. Current LOS values on internal port roads and adjacent urban arterials generally range from B to C, indicating moderate traffic flow, but increasing vulnerability during peak port activity periods. When conducting traffic forecasting, it reveals that if without

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intervention, growing container volumes would degrade level of service (LOS) on several critical road segments to level D or worse within the next two decades.

4.2 Purposes of travelling around Bangkok Port

Table 4: Purposes of travelling around Bangkok Port

No	Purpose of Traveling	Vehicle Survey (PCU)	Percent
1	Home Based Work (HBW)	314,172	37.61
2	Home Based School (HBS)	157,295	18.83
3	Home Based Other (HBO)	315,342	37.75
4	Non-Home Based (NHB)	48,533	5.81
	Total	**835,344**	**100.00**

Table 4 results purposes of travelling around Bangkok Port. The study counted vehicles driving though 6 MB and 6 TMC survey, it shows that there are 835,344 personal car unit (PCU). Their purpose of traveling is mostly business and personal affairs or at 37.75 percent. Secondly, their purposes are home-based work and home-based school at 37.61 and 18.83 percent respectively. Traffic impact assessment shows that redeveloping CDC project cannot inevitable an adverse effect to traffic congestion around Bangkok Port.

4.3 Traffic volume in MC and TMC (intersections) for roads within Bangkok Port

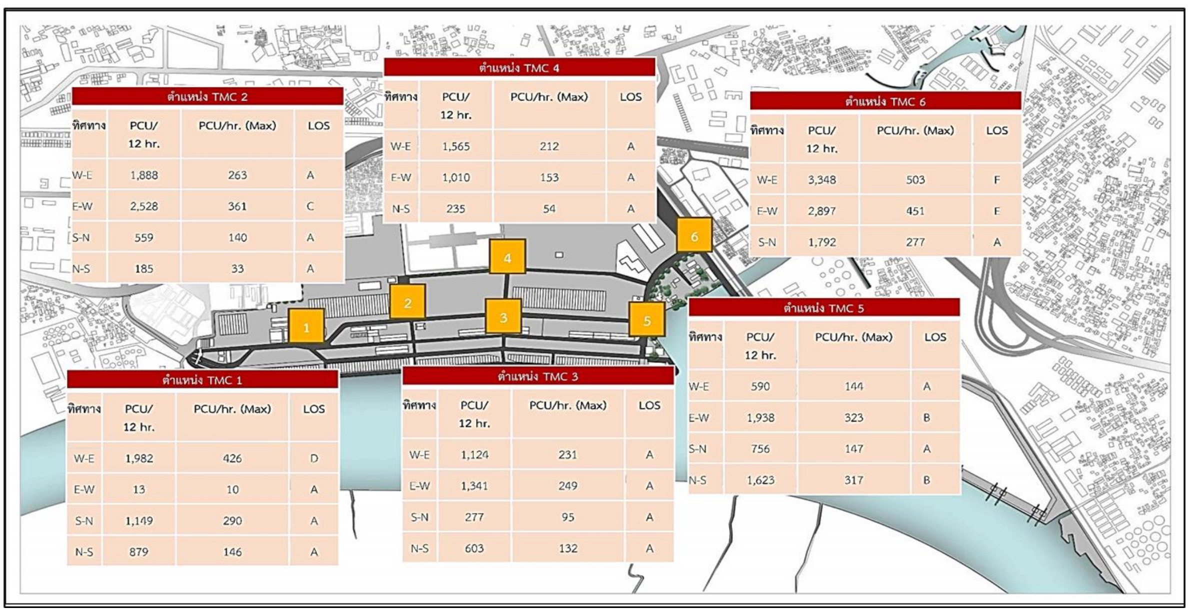

Figure 2: Traffic volume in intersections within Bangkok Port (Surveyed on September 2024)

Figure 2 represents Traffic volume in MC and TMC (intersections) for roads within Bangkok Port. Bangkok Port plans to redevelop central distribution center and its port facilities. The proposed vertical DC redevelopment alters traffic patterns by centralizing cargo handling, reducing internal circulation distances, and restricting port access to trucks with confirmed service appointments. External buffer yards accommodate waiting

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trucks outside the urban core. Under this scenario, impact of CDC redevelopment, LOS levels of C or better can be maintained throughout the forecast horizon. While, estimating CO_2 and PM2.5 Benefits from Congestion Reduction (Queue/Idling Mitigation).

Figure 3: Traffic volume in MC and TMC (intersections) outside Bangkok Port (Surveyed on September 2024)

The CDC redevelopment is paired with traffic-management measures (e.g., external buffer yard, truck appointment/booking, truck queue, and gate process optimization) to reduce stop–go traffic and extended idling inside and near Bangkok Port. Because queuing and idling are strong contributors to energy waste and local air pollution. This study quantifies environmental co-benefits in terms of CO_2 and PM2.5 avoided from reduced idling time per freight trip. This estimation focuses on tailpipe emissions during idle/queue conditions (gate queue and internal circulation delays). Running emissions from speed improvement on surrounding arterials can be added in future work, using link-based speed–flow emission functions.

The result shows freight vehicle movements, as annual freight vehicle movements are taken from the port traffic forecast used in the TIA. For example, the forecast for year 2568 indicates approximately 521,420 freight vehicle movements (baseline demand used for impact assessment).

In terms of decarbonization, it reveals emission factors for idling (CO_2 and PM2.5). For idling/queue conditions, this study applies emission rates consistent with extended-idle emission evidence used in mobile-source modelling. The US EPA "extended idle emission rates" provide CO_2 = 7,151 g/hr. (7.151 kg/hr.); for heavy-duty trucks and PM2.5 = 0.034 g/hr. for a representative modern diesel group (2010–2012; values are reported alongside other model-year groups). To align CO_2 results with fuel-based accounting commonly used in carbon reporting, Thailand-based carbon label references provide an

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indicative diesel combustion factor of 2.770 kgCO_2e per liter**.** (Using this, the EPA CO_2 idle rate implies an idle fuel use of ~2.58 L/hr., which is reasonable for heavy-duty idling).

Calculation approach

Let:

- N = annual freight vehicle trips (trips/year)
- Δt\Delta tΔt = average idling time reduction per trip (minutes/trip)
- EFCO2EF_{CO2}EFCO2 = idling CO_2 emission rate (kg/hr.)
- EFPM2.5EF_{PM2.5}EFPM2.5 = idling PM2.5 emission rate (g/hr.)

Then:

H saved = N×Δt60H_{saved} = N \times \frac{\Delta t}{60}H saved=N×60Δt CO2 saved = H saved×EFCO2CO2_{saved} = H_{saved} \times EF_{CO2}CO2saved=Hsaved ×EFCO2 PM2.5saved=Hsaved×EFPM2.5PM2.5_{saved} = H_{saved} \times EF_{PM2.5}PM2.5saved=Hsaved×EFPM2.5

Where CO2 saved CO2_{saved} CO2 saved is in kg/year (convert to t/year by ÷1000) and PM2.5 saved PM2.5_{saved} PM2.5 saved is in g/year (convert to kg/year by ÷1000).

The scenario results illustrative ranges. Because the TIA mitigation package targets queue control (buffer + booking + gate operations), three conservative scenario reductions are assessed: 10-, 15-, and 30-minutes average idling reduction per freight trip.

Using N=521,420N = 521{,}420N=521,420 trips/year (2568 forecast)

EFCO2=7.151EF_{CO2}=7.151EFCO2=7.151 kg/hr., and
EFPM2.5=0.034EF_{PM2.5}=0.034EFPM2.5=0.034 g/hr.

The result shows that CO_2 benefit is material (hundreds to ~1,900 tCO_2/year in the illustrative range), because idling consumes fuel continuously. PM2.5 tailpipe benefits appear numerically smaller under modern-truck assumptions because diesel particulate control technologies reduce exhaust PM substantially; however, these reductions remain important for near-port exposure, and could be higher for older/failing DPF fleets.

Table 5: Scenario for avg. CO_2 and PM2.5 saved idle reduction

Scenario (avg. idle reduction)	Idle hours saved (hr/yr)	CO_2 saved (t/yr)	PM2.5 saved (kg/yr)
10 min/trip	86,903	621	3.0
15 min/trip	130,355	932	4.4
30 min/trip	260,710	1,864	8.9

The congestion mitigation measures associated with the CDC redevelopment—namely truck appointment systems, external buffer yards, and centralized gate operations—substantially reduce truck idling and stop–go conditions. Based on forecast freight vehicle movements and conservative idling emission factors (as Figure 3), the analysis indicates

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that average idling reductions of 10–30 minutes per trip yield annual reductions of approximately 620–1,860 tCO_2 and 3–9 kg of PM2.5. These benefits are particularly significant in the context of Bangkok Port's dense urban surroundings, where exposure to local air pollutants directly affects nearby communities.

The findings demonstrate that vertical port redevelopment and traffic management measures are mutually reinforcing. Consolidating port activities into a centralized DC decreases internal conflicts and travel distances, while smart traffic management systems smooth truck arrivals and departures. Reduced congestion translates into lower fuel consumption and emissions, supporting port decarbonization objectives. Furthermore, improved land-use efficiency enables urban regeneration and green space development.

5. RESEARCH IMPLICATIONS

Policy recommendations include: (1) adopting vertical land-use strategies in inner-city ports; (2) implementing truck appointment systems and digital gate management; (3) developing external buffer yards to protect urban road networks; and (4) aligning port redevelopment with national decarbonization and sustainable urban development policies.

6. CONCLUSION

This study demonstrates that developing a vertical distribution center within Bangkok Port, supported by a comprehensive Traffic Impact Assessment and smart port measures, provides an effective strategy for mitigating urban traffic congestion, while advancing port decarbonization. The results confirm that consolidating port activities and managing truck demand through appointment systems and buffer yards can sustain acceptable traffic performance over a 30-year horizon. Beyond traffic efficiency, the study highlights clear environmental co-benefits. Reduced queuing and idling of freight vehicles translate into annual savings of several hundred to nearly two thousand tonnes of CO_2, alongside meaningful reductions in PM2.5 emissions in port-adjacent urban areas. These outcomes position traffic management not merely as an operational tool, but as a direct climate and air-quality mitigation strategy for inner-city ports.

The Bangkok Port's CDC redevelopment case illustrates how land-use restructuring, intelligent traffic management, and sustainability objectives can be integrated into a single redevelopment framework. The proposed approach is transferable to other metropolitan ports seeking to balance logistics competitiveness with urban livability and climate goals. Future research should extend this framework by incorporating link-based running emission models and evaluating cumulative health impacts of air-quality improvements.

Acknowledgements

The authors acknowledge the top management, Mr. Kriengkrai Chaisiriwongsuk**,** the Director General of the Port Authority of Thailand (PAT) and Lt. Phum Saengkham Director of Bangkok Port, and committees of Port Authority of Thailand, including associated agencies for providing data and technical support.

ISSN (Online):0493-2137
E-Publication: Online Open Access
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DOI: 10.5281/zenodo.18345174

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