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Spatial-Temporal Impacts of Port Development on City Land Use: *Mombasa City*

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Abstract

This study examines the spatial-temporal impacts of port development on land use in Mombasa, Kenya, with a focus on the Port Reitz area. Using Landsat 9 imagery (2010–2022), Land-Use and Land-Cover (LULC) analysis, and Pearson correlation tests, the research assessed how port expansion influenced vegetation cover, open spaces, and built-up areas. Results reveal strong negative correlations between port development and vegetation (r = –0.9595) and open spaces (r = –0.9981), indicating significant ecological decline and urban land-use transformation. Qualitative findings from key informants confirmed that uncoordinated port growth has displaced livelihoods and degraded natural environments. The study concludes that port development, while economically beneficial, compromises urban sustainability when detached from spatial planning. It recommends integrated port–city master planning, public participation, and green corridor initiatives to balance development with ecological preservation in line with SDG 11 on Sustainable Cities and Communities.

Keywords: Port development, land use, sustainable development, land cover, GIS, Mombasa, Kenya

INTRODUCTION

Mombasa, Kenya's oldest and busiest port city, owes much of its historical and spatial development to the growth and transformation of its port infrastructure. The port and the city function as a mutually reinforcing system whose operations have shaped urban form, economic function, and environmental outcomes over time.

Globally, ports are recognised as drivers of urbanisation and regional development, but they also generate profound spatial and ecological impacts on host cities. In Mombasa, rapid port expansion—especially around the Kilindini Harbour—has spurred industrial growth and infrastructural development while simultaneously transforming land-use patterns and diminishing natural landscapes. These dynamics raise important questions about the balance between port-driven economic progress and sustainable urban development.

This study examines the spatial-temporal impacts of port development on land use in Mombasa, with a focus on the Port Reitz area. It investigates how port expansion between 2010 and 2022 has influenced vegetation cover, open spaces, and built-up areas, using Landsat 9 imagery, key informant interviews, and land-use analysis. The research contributes to the understanding of port–city interactions in the Global South and aligns with Sustainable Development Goal (SDG) 11 on sustainable cities and communities by proposing strategies for integrated, sustainable port–city planning.

THEORY

Ports have been considered origins of many cities and springboards of urban development in most parts of the globe (OECD, 2013). Strong and historical linkages of the port and the city have resulted in the port shaping the city's urban form and structure (Akhavan, 2017). Drawing on inferences from the "Anyport" model developed by Bird in 1963, which was based on central place theory, it was noted that ports and cities have recursive positive and negative effects on development (Veenboer, 2014).

In this case, the study sought to contextualise

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AFRICA HABITAT REVIEW 20(3) 2025

Mombasa's duality on port city development, which it considered was based on the following causal flow;

Port Development->Land Use Change->Urban Sustainability Outcomes

When it comes to the Global South, and Africa in particular, there is a lack of a concise body of knowledge regarding port-city development, which this study seeks to build upon. Drawing on established port-city theories, the study will frame port-city development as a system influenced by the growth-pole effects of each entity, with dynamic feedback loops as highlighted above.

In this regard, the study selected to investigate the latter by focusing on the port city of Mombasa, located along Kenya's Indian Ocean coast. It did so by considering by postulating that:

Port Development Affects on the City's Land Use

The city of Mombasa boasts two ports: the Old Port in the Old Town area and the Kilindini Port on the western side of Mombasa Island. The old port of Mombasa facilitated trade from as early as the 13th century (County Government of Mombasa, 2016). The Old Port is located along the Tudor Creek near Mombasa 'Old Town' on the eastern side of the Island before it relocated to the western side of the Island in Kilindini. The operations of the 'new' Kilindini port facilitated the urban expansion of the city of Mombasa and the Western facade of the Island. This introduced new urban form and landscapes within the western part of the Mombasa Island, heralded by the development of road networks, new settlements, industries, and urban infrastructure, which facilitated port operations (Government of Kenya, 1971). Against the backdrop of such development, city authorities have utilised land use tools to guide development within their territories.

Notably, land use pertains to framing or organising activities in a region denoted by similar spatial extents based on the socioeconomic or functional aspects of land (UN Statistics, 2019). At the same time, land is described as the biophysical cover on its surface, also referred to as land cover. Cities manage land use either through pre-defined uses or a more flexible approach, consisting of the specific activity being undertaken on a particular piece of land (The Organisation for Economic Co-operation and Development , 2017). In Kenya, city authorities plan and manage their areas through the formulation of land use plans (Government of Kenya, 2019). Land uses directly affect the city's economic and environmental performance. Proper planning and management of land uses are critical for sustainable development. One way to track land-use change is through Land Use and Land Cover (LULC) analysis, which has been employed in this study.

To better understand the progression of land use within the city of Mombasa, this study observed that the former Municipal Council of Mombasa prepared the Draft Physical Development Plan, which ran from 1971 to 2000. The plan outlined, among other things, how port expansion, port-related uses, and other land uses around the city would coexist harmoniously (Government of Kenya, 1971). At the time, the East African Harbour Corporation [a body within the East African Community then] undertook port development as provided for in the city development plan.

With the collapse of the East African Community in 1977, the Government of Kenya created the Kenya Ports Authority (KPA), whose mandate included port planning and development (Government of Kenya, 1979). KPA has undertaken a series of port master plans, which were mainly 'sea-facing' and had little to no consideration of their impacts within the city of Mombasa (Kenya Ports Authority, 2019). These changes led to negative externalities on the urban landscape of Mombasa, whose imprint has altered the urban form and structure of Mombasa, especially in areas adjacent to the port (Moretti, 2019).

Conceptual Framework

Conceptual Basis

The study is anchored on the Anyport Model (Bird, 1963) and the Central Place Theory, which together explain the reciprocal relationship between port growth and urban development. The framework integrates these theories with systems theory (Leighninger, 1978), positing that a port and its host city function as a dynamic system characterised by positive and negative feedback loops.

Conceptual Linkages

i. **Port Development (Independent Variable)**
Refers to physical expansion, technological advancement, and infrastructural improvement of port facilities. This includes terminal expansion, reclamation works, and improved logistics corridors.

ii. **Land Use Change (Mediating Variable)**
Denotes the transformation of land uses in port-adjacent areas, including the conversion of residential, recreational, and ecological spaces into industrial and logistical uses.

iii. **Urban Sustainability Outcomes (Dependent Variable)**

. Represent the overall effects of port-induced land-use changes on ecological balance, social inclusion, and spatial equity — measured through indicators such as open space, vegetation cover, and livability indices consistent with SDG 11.

iv. **Moderating Factors**

- *Policy and Governance Frameworks*: Effectiveness of urban planning instruments, port master plans, and coordination between the Kenya Ports Authority (KPA) and Mombasa County.
- *Public Participation:* Inclusion of communities affected by port expansion in decision-making.
- *Technological Innovations:* Maritime efficiency and land-use optimisation technologies influencing spatial patterns.

Conceptual Model

The conceptual model illustrates the interactions among port development, land-use change, and urban sustainability outcomes, forming a cyclical, cause-and-effect relationship moderated by governance and technology. Port development acts as the main driver of spatial transformation in Mombasa City, influencing land conversion and settlement restructuring. As the port expands, adjacent residential, recreational, and ecological zones are converted into industrial and transport-oriented spaces. This transformation reshapes the city's spatial balance, increasing pressure on land and creating sustainability challenges related to the environment, accessibility, and livability.

The feedback loop highlights the importance of governance and planning in achieving sustainable outcomes. Effective coordination between the Kenya Ports Authority (KPA), Mombasa County, and local communities can reduce the negative impacts of expansion through integrated planning and participatory decision-making. The model therefore captures both the causal chain—from port growth to urban transformation—and the feedback mechanism that promotes balance between port-driven economic growth and sustainable urban development.

Model Explanation

i. **Causal Chain:**
The model illustrates a causal sequence — Port Development → Land Use Change → Urban Sustainability Outcomes — highlighting how uncoordinated port growth drives land-use conversion and urban transformation.

ii. **Feedback Mechanism:**
The lower loop represents a feedback process where governance frameworks, planning interventions, and participatory mechanisms can mitigate adverse effects, restoring ecological balance and social equity.

iii. **Dynamic Interdependence:**
Port development and urban land use are co-evolving systems — each influencing the other through recursive effects. Expansion of port facilities (independent variable) directly induces spatial restructuring (mediator), which, in turn, shapes sustainable urban development outcomes (dependent variable).

iv. **Empirical Anchoring:**
The study found strong negative correlations between port expansion and vegetation/open space coverage ($r = -0.9595$ and -0.9981, respectively), supporting the conceptual pathway that uncoordinated port growth undermines urban sustainability.

Figure 1 illustrates the mutual relationship between port development and city development, emphasising how growth in one sector directly stimulates progress in the other.

To bring out this phenomenon, the study adopted a descriptive approach, as highlighted in the materials and methods section.

RESEARCH METHODS

Description of Study Site

Mombasa is a port city that acts as a growth pole, attracting complementary enterprises and industries. In this context, the port of

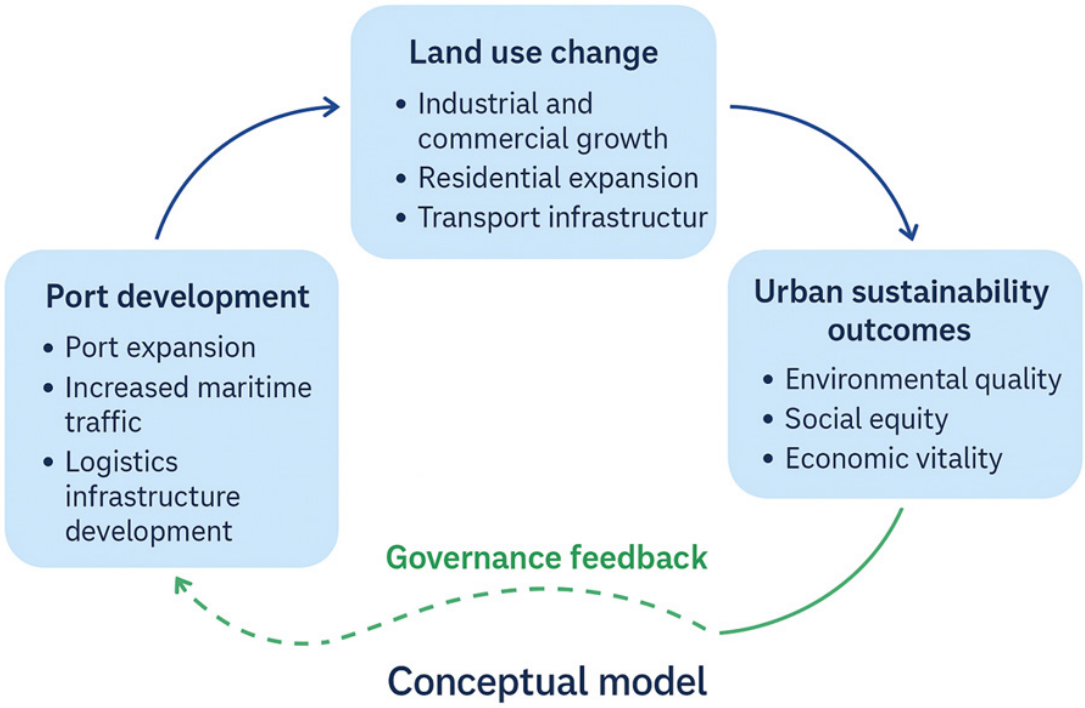

FIGURE 1
Recursive port and city development
Source: Author Analysis, 2025

Mombasa has, over the years, extended from the Island of Mvita downwards to the Mainland West area of Mombasa; typical of port growth trajectories (Moretti, 2019). For this study, the observed geographical scope of the Mombasa Mainland West port-city area exhibited a dynamic relationship between port-city land use, as shown in **Figure 2**.

Data Collection
The study employed a mix of research methods, namely desktop studies, perusal of archival records, key informant interviews, and computer processing methods, to inform the study findings (Kothari, 2019).

Ethical Considerations
The study was granted a research permit from the National Commission for Science, Technology and Innovation (NACOSTI), Kenya and operated within the stipulated guidelines.

Desktop Review and Key Informant Interviews (KII)
The study reviewed available literature on port and city development in Mombasa, including the 1970 draft Mombasa Development Plan, the Integrated Strategic Urban Development Plan (ISUDP) for Mombasa, and the Mombasa Port Master Plans. These documents enabled the study to establish a baseline on the developmental trend for the port and city of Mombasa over time. Additional contextual information was sourced from four (4) key informants who provided temporal knowledge of port-city development in Mombasa. The key informants were drawn from professionals in the urban planning field, the National and County Fisheries Departments, Kenya Ports Authority officers, and members of the local fishermen group, the Beach Management Unit (BMU). The number of interviewees was selected from the sectors the study found critical to make valid inferences. The interview focused mainly on the historical development of the port of Mombasa and the changes the city experienced as a result. Information gathered assisted the study in narrowing in on the western façade of Mombasa County, more specifically, the Port Reitz neighbourhood of Mombasa, delineated by Port Reitz Road to the North and the port area to the South. Specifically, this area abuts the Moi International Airport to the West, the Chaani settlement to the East, Port Reitz Road to the North, and the Kenya Ports Authority Container Terminal Two (CT2) to the South.

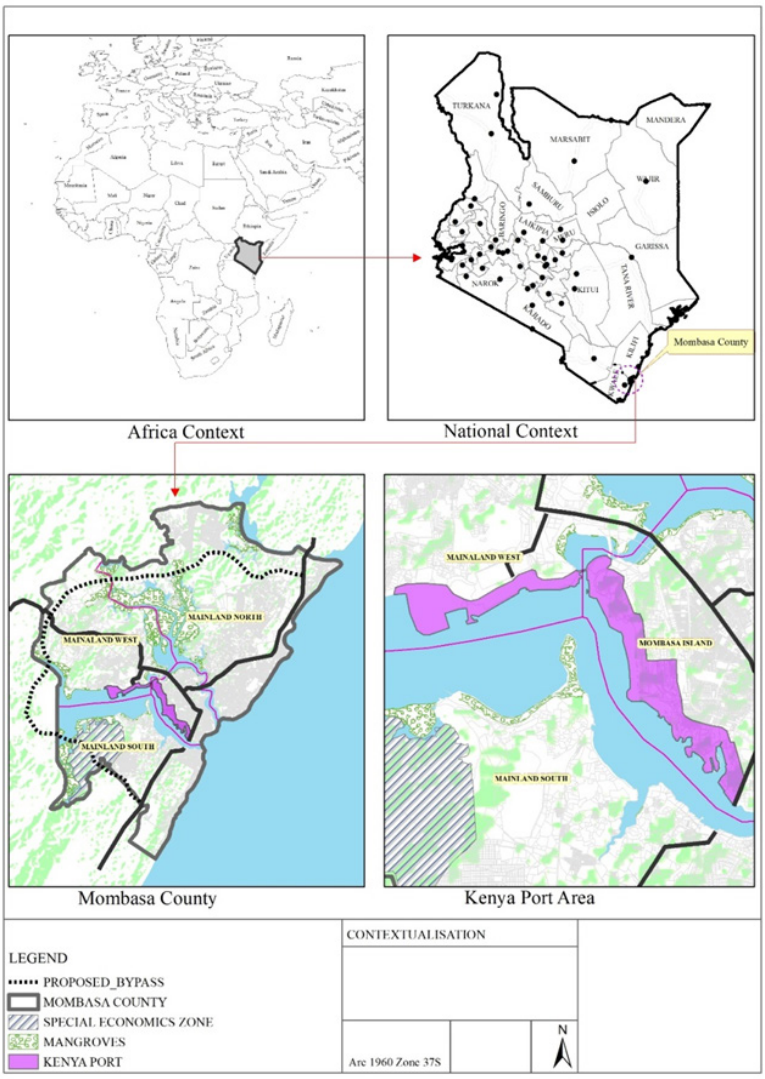

FIGURE 2
Locational context of Mombasa Port City
Source: Author Analysis, 2025

Land Use Land Cover

Since the study narrowed the study area, it was possible to scope sustainable urban development trends using maps generated from Landsat 9 satellite imagery. Importantly, the study applied these maps to the utility of dynamic change in land use-land cover (LULC) using the ArcGIS platform. This incorporated ranking built-up space as a land use and treated the physical attributes of the land as land cover (Illyas, Khan, Sakaouth, & Yasir, 2022). By utilising LULC change, the study investigated the transformation of the Port Reitz area in relation to the development of the port of Mombasa. To do so, the study generated multispectral and multitemporal maps covering the years 2010 to 2022 to support LULC analysis. Subsequently, the generated images were processed using unsupervised image classification, with at least 8 grid codes selected over maximum likelihood classifications, producing rasterised data. This method followed the tenets of pattern recognition (PR), particularly data clustering, which allowed the data to be partitioned into observable features considered to form part of the land use in Port Reitz (Liu, Sun, & Wang, 2006). Subsequently, the raster datasets were reclassified to vector format, yielding polygon features for the grid values, which were utilised to calculate the different areas. The study noted that the vegetation value, in particular, yielded 4 grid values of varying spectral bands, which were merged into 1, bringing the total grid values to 5: vegetation, built-up areas, roads, open space, and ocean, with the ocean area remaining constant across the temporal analysis. The

abstract presentation of areas was then extracted using the intersect and symmetrical difference tools in ArcMap to produce a final output showing temporal variations in land use. Subsequently, the findings from the image analysis of land use change, particularly open spaces and vegetation (green cover), were tested for correlation with the area covered by port development over time using Pearson's correlation coefficient. By doing so, the study enabled the scoping of key targets of SDG 11 on green and open spaces as hallmarks of sustainable urban development. Simple regression was then employed to make inferences about the cause-and-effect relationship between port development and the city's land-use development. The resulting data were captured and presented in the form of maps, interview recordings, photographs, graphs and charts (**Figure 3**).

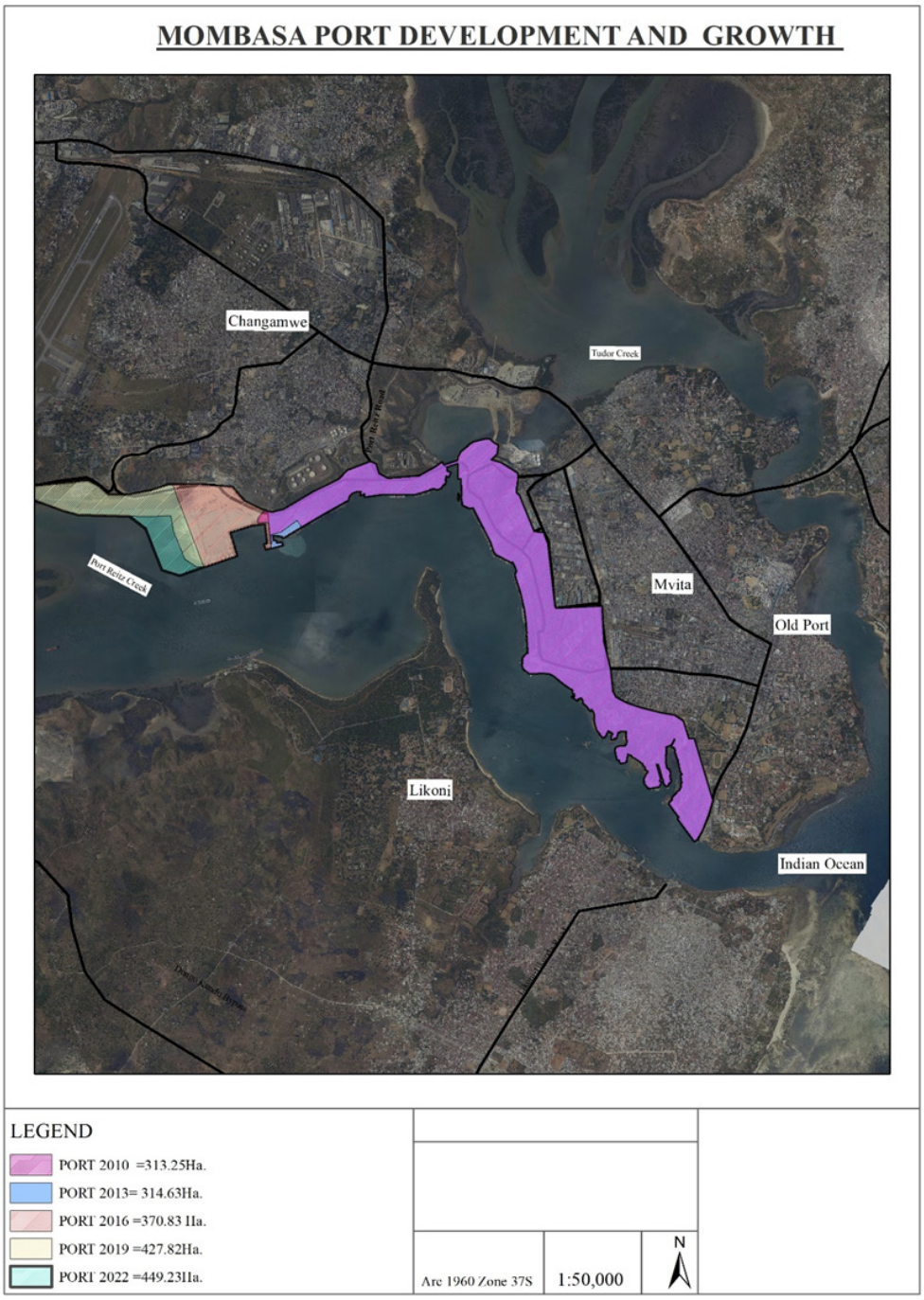

FIGURE 3
Port operation areas in Mombasa
Source: Author Analysis, 2025

RESULTS

The study noted that port development was an inherent part of Mombasa's city development. Based on global evidentiary parameters, port development in Mombasa was noted to be primarily driven by Changes in Maritime Technology, Port Management Policies and Linkage with the Hinterland. These are discussed in the sections below.

Changes in Maritime Technology

Globally, the maritime industry changed significantly after the development of containerization in the 1960s. Ports sought to build competitiveness and efficiency by quickly adapting to changes in maritime technology, including the use of shipping containers, the accommodation of larger shipping vessels, increased cargo throughput, and associated handling infrastructure (Veenboer, 2014; Omoju, Selvaduray, & Yunus, 2022). Port expansion required large swathes of land, making them land-intensive (Ducruet, Juhasz, Nagy, & Steinwender, 2020). It is estimated that a shipping vessel with a capacity of 5000 Twenty Foot Equivalent Unit (TEU) requires about 12 hectares of unloading and storage space (Omoju, Selvaduray, & Yunus, 2022).

Port development and associated technological advancements are land-intensive and often lead to the city experiencing negative externalities (Liu X. , 2020). These include benthic disturbance caused by dredging of the port channel, loss of fishing sites due to sea reclamation, as well as an increase in traffic congestion (Garcia-Menendez, Merk, & Saz-Salazar, 2013).

Furthermore, ports have evolved from storage and processing centres for cargo meant for either import or export to logistical poles (Baydar, Sural, & Celik, 2017). Countries have thus developed port corridors to facilitate efficient evacuation of cargo from their ports into the hinterlands by establishing sustainable logistical corridors. In this regard, port authorities have embraced innovations in the maritime value chain by setting up logistical centres along port corridors where cargo can undergo value addition and distribution, relieving ports of the need to provide cargo storage. The latter is a critical performance indicator for port performance and has been key in driving competitiveness in global ports.

Port Management Policies

Apart from changes in maritime technology, port management policies also affect port development. Ports normally operate as either service ports or as landlord ports, which influences port development. Landlords lease their land to private entities to develop and operate port terminals. Service ports are run by port authorities that are either nationally or municipally owned and developed and operated (Kenya Ports Authority, 2019). In the case of Mombasa, the port is run as a service port managed and operated by the state-run corporation, KPA. KPA has had 'de facto' rights to develop the port, and does so without input from the Mombasa City authorities. The KPA is developing a 30-year port master plan based on 5-year port strategic plans and 3-year port business plans. Consequently, port development has shifted Pareto efficiency away from the city's sustainable development (Liu X., 2020), negatively impacting the city of Mombasa. At the same time, KPA lacked sufficient funds to build new container terminals to keep pace with the influx of shipping containers. This necessitated the licensing of Container Freight Stations (CFSs) and Empty Container Terminals (ECTs) to offer storage and customs services for excess cargo.

Linkage with the Hinterlands

Once ports have invested in their technology and have a well-defined operational policy, they also work to establish corridors into the hinterlands. Ports strive to provide seamless linkages to their hinterlands to offer efficient evacuation of cargo (Moretti, 2019). Corridor development is crucial for the successful evacuation of cargo from ports; so much so that Kenya, through the port of Mombasa, is part of the Northern Corridor, which seeks to link the port of Mombasa to Uganda, Rwanda, Burundi, South Sudan and Eastern Democratic Republic of Congo (DRC) (Northen Corridor Transit and Transport Cordination Authority, 2021). The government has, over the years, invested in these aspects through the development of the Standard Gauge Railway (SGR) and road links to the port, which involved sea reclamation and extensive earthworks. These have significantly transformed the city's landscape and urban form, including the Port Reitz area (Kenya Ports Authority, 2019).

AFRICA HABITAT REVIEW 20(3) 2025

Figure 4 depicts the spatial layout and infrastructure of the Port of Mombasa, Kenya's principal maritime gateway and one of the busiest ports in East Africa.

Table 1 presents the expansion of the port area over time, showing a steady increase in total spatial coverage from 2010 to 2022.

Operations at the port of Mombasa attracted CFSs, ECTs and port-related enterprises within the Port Reitz area. In particular, Port Reitz, being the area bound by Port Reitz Road and the Port of Mombasa, had six (6) CFSs and ECTs with corresponding 90 truck and logistical yards as observed from county land records, satellite imagery and government reports (Competition Authority of Kenya, 2019). With regards to the latter, application of the location quotient (LQ) established that the Port Reitz area in Mombasa was the area greatly affected by the porosity of the port into the city, as compared to other areas such as Mombasa Island, whereby 80% of CFSs, ECTs

FIGURE 4
Port Extents in Mombasa
Source: Author Analysis, 2025

TABLE1
Expansion of the port's spatial coverage between 2010 and 2022

Year	Port Area (x)
2010	54.275
2013	54.275
2016	110.578
2019	167.507
2022	188.935

Source: Author's analysis (2025)

and logistical yards in Mombasa were located in the Port Reitz area. The foregoing was derived from the fact that, out of the 16 CFSs registered in Mombasa, 5 were located on undesignated land-use areas in the city. Additionally, four (4) of the five (5) CFS were located within the Port Reitz area. Thus, Port Reitz had a high score of 80 for CFSs and ECTs located in undesignated areas, compared with all other areas of Mombasa ((4/5) x 100).

Figure 5 illustrates the classification of land uses accommodating port enterprises within the Port Reitz area.

Stemming from the fact that ports act as growth poles for port-related industries, records from the County Government of Mombasa's valuation roll indicated that 47% of the land parcels being used for port-related enterprises were operating in areas that were designated as residential land use, as captured in Chart 1. These areas were primarily attractive to port enterprise given their close proximity to the port of Mombasa. Interviews with key informants enabled the study to reinforce the finding that port development resulted in port porosity, with port-related activities extending into city spaces intended for other uses, leading to spatial fragmentation. One case in particular involved the conversion of a fish landing site and a public beach (recreational) into a reclaimed port terminal, resulting in the loss of livelihoods. Continuous Port expansion was also linked to the loss of livelihoods through the closure of fish landing sites, such as the Kwa Skembu site, and the loss of recreational grounds, as the area also served as a public beach. The fishermen interviewed pointed out that they had not been allocated an alternative site. Fishermen interviewed reported a decline in their daily catch from 20 kg in 2010 to 2 kg in 2022, which they attributed to the reclamation and dredging of the sea by the Kenya Ports Authority. **Table 2** highlights significant changes in the annual catch of BMUs at Port Reitz, indicating a decline during the period when the port underwent extensive development. Kwa Skembu fish landing site was, however, taken up by the development of new container berths at the port of Mombasa through sea reclamation, leaving Kitanga Juu as the main BMU along Port Reitz Creek as of 2017. The decline in their daily catch can be corroborated from studies that found that sea reclamation was directly linked to an increase in turbidity and a reduction of dissolved oxygen

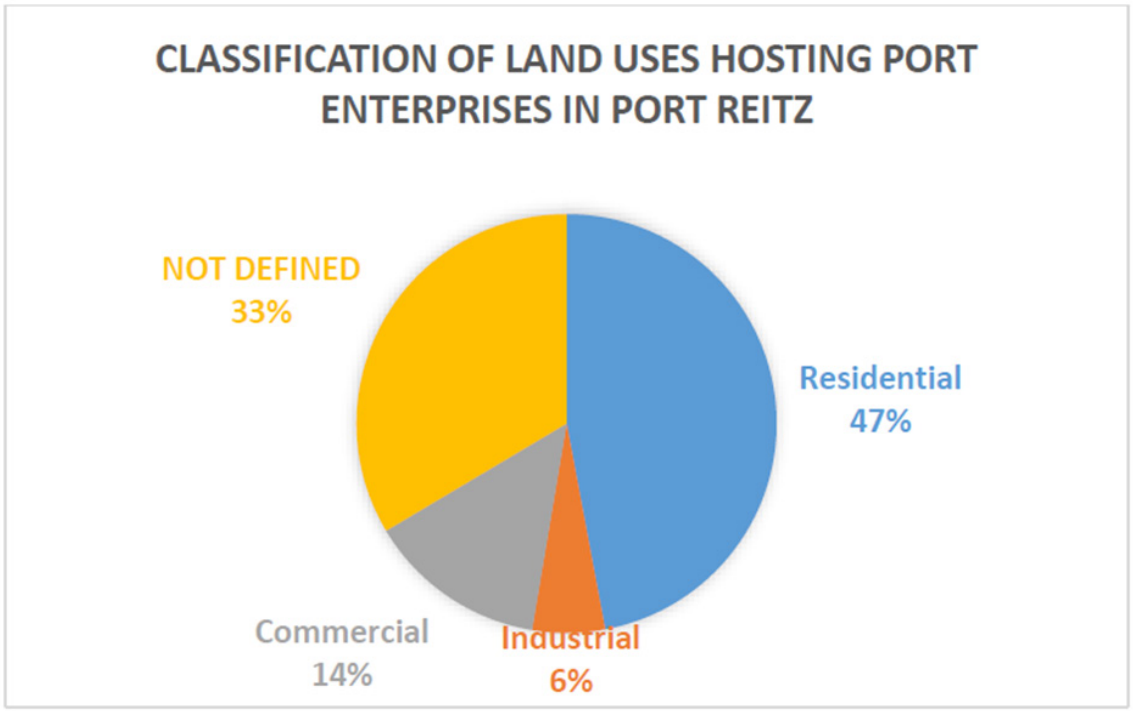

FIGURE 5
Land uses of areas domiciling port enterprises in port reitz
Source: Author Analysis, 2025

AFRICA HABITAT REVIEW 20(3) 2025

in the sea, which led to a significant reduction in the ocean's biotic resources (United Nations Environment Program, 2021). (Garcia-Menendez, Merk, & Saz-Salazar, 2013).

Tables 2(a) and **2(b)** present the trend in agricultural production decline across two study locations—Kitanga Juu and Port Reitz/Kwa Skembu—over selected years.

From the foregoing, port development was noted to exacerbate the porosity of port-related land uses into residential areas, leading to urban decay in the Port Reitz area. The area was initially a high-value medium-to-low-density residential area, but its close proximity to the port of Mombasa and availability of large tracts of land attracted port-related enterprises. This led to a change in land use in the Port Reitz area from predominantly residential to industrial. Many of these conversions were unprocedural, as land valuation data obtained from the County Government of Mombasa indicated that close to 47% of the industrial yards were captured as residential plots in the County valuation roll as of 2023. Consequently, the Port Reitz area experienced a change in its urban form, diminishing its aesthetic appeal and urban vibrancy, leading to an increase in built-up areas and a reduction in open and green spaces.

The temporal analysis of satellite imagery in Port Reitz is presented in **Table 3**.

Table 3 illustrates the progressive transformation of land-use patterns within Mombasa, focusing specifically on the Port Reitz area between 2010 and 2022.

On this basis, the study sought to conduct correlation tests on two variables whose relationship was considered linear and causal. What was apparent from the study was that green and open spaces in Port Reitz had reduced by almost half [26.5% and 33.6% respectively in 2010, to 14.2% in 2010 and 19.8% in 2022]. This was attributed to an increase in port-related enterprises, which almost doubled the percentage of built-up spaces in Port Reitz (27.4% in 2010 to 42.5% in 2022). On the other hand, from the image analysis, it was noted that the connecting road and railway networks to the port were categorised under transportation in the study, and this also witnessed a significant increase from 12.5% in 2010 to 23.5% in 2022, indicating

TABLE 2(a)
Trend in Agricultural Output and Percentage Decline in Kitanga Juu (2017–2019)

Kitanga Juu		
Year	KGs	Percentage Decline
2017	38898	0.00%
2018	35430	8.92%
2019	27821	21.48%

Source: Author's analysis (2025)

TABLE 2(b)
Trend in Agricultural Output and Percentage Decline in Kitanga Juu (2017–2019

Port Reitz/ Kwa Skembu		
Year	KGs	Percentage Decline
2013	341,276	0.00%
2014	105,222	69.17%
2015	67,525	35.83%
2016	39,775	41.10%

Source: Author's analysis (2025)

TABLE3

Temporal Changes in Land-Use Coverage within the Port Reitz Area of Mombasa (2010 – 2022)

Year	2010		2013		2016		2019		2022	
Attributes	**Area (Ha)**	**% coverage**	**Area (Ha)**	**% coverage**	**Area (Ha)**	**% coverage**	**Area (Ha)**	**% coverage**	**Area (Ha)**	**% coverage**
Vegetation Cover	135.53	26.51%	125.25	24.50%	115.53	22.60%	96.11	18.80%	72.80	14.24%
Open spaces	171.63	33.57%	168.70	33.00%	144.16	28.20%	109.91	21.50%	101.22	19.80%
Built-up Areas	140.01	27.39%	144.16	28.20%	168.34	32.93%	207.91	40.67%	217.26	42.50%
Transportations	64.04	12.53%	73.10	14.30%	83.17	16.27%	97.28	19.03%	119.93	23.46%
Total	**511.21**	100.00 %	**511.21**	**100.00 %**	**511.21**	**100.00 %**	**511.21**	**100.00 %**	**511.21**	**100.00 %**

Source: Author's analysis (2025)

the transformational nature of port development on the urban landscape of Mombasa. Historically, the growth of the city of Mombasa has heavily depended on the development of the port, beginning with the shift of the port from Old Town to Kilindini, which led to the development of the western side of Mombasa Island. In this case, port extent under port development was considered the independent variable (x), with changes in the study area's open space and vegetation cover as the dependent variable (y), which were scoped to represent changes in the urban landscape. It is important to note that the study considered the coverage of green spaces and the interspersion of open spaces in Port Reitz as key indicators of sustainable urban development in relation to SDG 11 and the AIVP-International Association of Cities and Ports 10 goals for sustainable port cities (International Association for Cities and Ports, 2021). Based on the foregoing, the study noted that port development was a key driver of urban development and thus highlighted calculating how port development, as symbolised by port size, influenced changes in the urban landscape through changes in green and open space coverage by the temporal scoping of port development against green and open spaces in Port Reitz.

Port Development against Vegetation and Open Space Variables

Tables 4(a) and **4(b)** illustrate the spatial relationship between the expansion of the port area and the corresponding decline in open space and vegetation cover within the Port Reitz area between 2010 and 2022.

Additionally, the sum of the change in areas from the different years was computed using the formula:

$$r = \sum ((X - M_y)(Y - M_x)) / \sqrt{((SS_x)(SS_y))}$$

TABLE 4(a)

Relationship between Port Area Expansion and Reduction in Open Space Area (2010–2022)

Year	Port Area (x)	Open Space Area (y)
2010	54.275	171.63
2013	54.275	168.70
2016	110.578	144.16
2019	167.507	109.91
2022	188.935	101.22

Source: Author's analysis (2025)

TABLE 4(b)
Relationship between Port Area Expansion and Reduction in Vegetation Cover Area (2010–2022)

Year	Port Area in Ha (x)	Vegetation Cover Area in Ha(y)
2010	54.275	135.53
2013	54.275	125.25
2016	110.578	115.53
2019	167.507	96.11
2022	188.935	72.80

Source: Author's analysis (2025)

Where:
X: X Values
Y: Y Values
M_X: Mean of X Values
M_Y: Mean of Y Values
$X - M_X$ & $Y - M_Y$: Deviation scores
$(X - M_X)^2$ & $(Y - M_Y)^2$: Deviation Squared
$(X - M_X)(Y - M_Y)$: Product of Deviation Scores

Hence, with regard to Open Spaces against Port Development, the study computed that, from image classification and calculations at https://www.socscistatistics.com.;

$\sum = 575.57$
Mean = 115.114
$\sum(X - M_X)^2 = SS_X = 15617.91$
Y Values
$\sum = 695.62$
Mean = 139.124
$\sum(Y - M_y)^2 = SS_y = 4246.912$

X and Y Combined

N = 5
$\sum(X - M_X)(Y - M_y) = -8128.57$

R Calculation

$r = \sum ((X - M_y)(Y - M_X)) / \sqrt{((SS_X)(SS_y))}$

r = -8128.57 / √ ((15617.91) (4246.912)) = -.9981 with the a significant p value of < .05

The results thus indicated that port development and open space in Port Reitz had a strong negative correlation (r =- .998, p < .05).

The performance of Port Development Against Green Spaces (Vegetation Cover) was computed as follows

Values
$\sum$ = 575.57
Mean = 115.114
$\sum(X - M_X)^2 = SS_X = 15617.91$
Y Values
$\sum$ = 545.22
Mean = 109.044
$\sum(Y - M_y)^2 = SS_y = 2487.127$
X and Y Combined
N = 5
$\sum(X - M_X)(Y - M_y) = -5979.978$
R Calculation
$r = \sum((X - M_y)(Y - M_X)) / \sqrt{((SS_X)(SS_y))}$

r = -5979.978 / √((15617.91)(2487.127)) = -.9595 with the a significant p-value of < .05

The results thus inferred that port development and a strong negative correlation with vegetation cover in Port Reitz r =- .9595), p<.05. This clearly demonstrates how port development has a negative impact on a city's land use, especially when carried out in an uncoordinated framework from the city's development planning frameworks.

Study Limitations

In one instance, the study was unable to acquire high-resolution satellite imagery due to limited funds. However, the use of Landsat 9 imagery was considered sufficient and robust to support valid inferences for the study. At the same time, the study had to rely on global data, as the field of port-city development had not been extensively researched in the Global South.

The results collectively demonstrate that the expansion of the Port of Mombasa has been a major catalyst in shaping the city's spatial and socio-economic landscape, particularly within the Port Reitz area. The findings highlight strong negative correlations between port development and the coverage of open and vegetated spaces, indicating that the port's spatial growth has occurred largely at the expense of urban ecological balance and public land uses. These transformations underscore the extent to which uncoordinated port expansion, driven by technological, policy, and infrastructural imperatives, has influenced patterns of land conversion, environmental degradation, and livelihood displacement. The following discussion interprets these results in the broader context of port–city dynamics, spatial governance, and sustainable urban development in Mombasa and comparable port cities within the Global South, where rapid infrastructural expansion often outpaces integrated urban planning and ecological safeguards.

DISCUSSION

In light of the preceding, it was clear that ports and cities function as a system whose operations lead to recursive negative or positive externalities (Liu X. , 2020). A key element of coordinating the activities of the port-city system is through a collaborative planning framework (Hoyle, 1989). For the port city of Mombasa, the only development plan to offer such a framework was the Draft Physical Development Plan of 1971. In the year 2016 the city prepared the Mombasa Integrated Strategic Urban Development Plan (ISUDP) which had limited proposals with regard to port development owing to the siloed planning approach between the port and the city (County Governemt of Mombasa, 2016). Furthermore, the port of Mombasa also prepares independent port business, strategic, and master plans, with the current port master plan in operation from 2018 to 2047 (Kenya Ports Authority, 2019).

Port development often acts as a growth pole to attending port-related functions (Moretti, 2019). In particular, from the image classification and analysis, the study noted that the p-value was less than 0.05, indicating that the observed findings were not due to chance. Furthermore, the percentage of land under transportation land use in Port Reitz had risen from 12.53% in 2010 to 23. 46% in 2022, signifying an increase of 87.23%. Notably, this was attributed to the development of the port of Mombasa and enhanced linkages to the hinterland through the Northern Corridor Project and the Mombasa Port Area Development Project (MPAD).

It is not lost on the study that ports strive to specialise as cargo gateways, juxtaposed with corresponding corridor development into the hinterlands within an inelastic port-city region. An influx of port-related enterprises, as earlier noted, greatly altered the city's urban form by converting residential areas into port-related uses, especially around areas close to the port, such as Port Reitz. It is on this account that the area witnessed a considerable decrease in vegetation cover from 135.53 Ha in 2010 to 72.80 Ha in 2022, a reduction of about 12%. Interestingly, open spaces within Port Reitz also decreased by about 13%, from 171.63 Ha in 2010 to 101.22 Ha in 2022. These changes in Port Reitz's landscape occurred outside established planning frameworks, as noted earlier, resulting in fragmented land-use patterns in the area.

Fragmented land use patterns have been linked to unsustainable urban development by affecting the livability of a particular area (UN Habitat, 2016). In this regard, the study proposed the following three measures for the city of Mombasa to foster sustainable port and city development. By one, integrating both port and city development planning; two, enhancing public engagement and participation in port-city development decision-making; and three, applying green approaches to sustainable port logistics corridors.

Sustainable port-city development is characterised by balancing the intersection of city development, port development, livelihoods, logistical corridor enhancement, and green infrastructure development. An integrated port-city development framework should enhance these enshrined elements. For this study, the critical elements that the city of Mombasa should focus on include the following:

Integrated Port and City Development Planning
The port of Mombasa had been preparing port master plans that were not linked to the city structure plans. The study established that, globally, best-performing ports, such as the port

AFRICA HABITAT REVIEW 20(3) 2025

of Shanghai, as ranked by Lloyd's List (2022), had integrated their port expansion plans into the city's structure plan (Wang & Ducruet, 2012). The Shanghai Master Plan (2017-2035) contained a structure plan that identified port influence in the city, making it necessary to plan city areas to contain the varied nature of port-related enterprises. For example, areas within the city considered intermediate in the port-city region were designated for high-tech industries, which offered quality jobs to city residents. This was unlike the uncoordinated approach to port-city development witnessed in Mombasa. The study thus proposes the application of an integrated port and city development approach, especially in intermediate areas of the port city region, complemented by a strong service sector within the city's main urban core. Industrial and logistical zones which support the port should be located along the fringes of the city with strong transportation linkages [corridors] to the port area (Shanghai Municipal People's Government, 2018). The port of Mombasa should also endeavour to holistically plan its corridor using a logistics corridor framework, as was the case in the development of the Durban-Gauteng Corridor in South Africa under Operation Phakisa (TRANSNET, 2019). There is therefore a need for the port and city authorities to collaborate and formulate integrated port and city master plans that stipulate clear land-use and zoning guidelines for port-related land uses (Akhavan, 2017).

The integrated port-city plan should, in particular, urgently seek to relocate heavy and port-related industries from areas such as Port Reitz to the proposed Mombasa Industrial Park (MIP) through land use planning tools such as zoning. Borrowing from the United Kingdom's (UK's) freight village concept, the MIP can be an area designated to undertake activities relating to transport, logistics and distribution of goods from the port of Mombasa (Baydar, Sural, & Celik, 2017). The MIP has been proposed by the County Government of Mombasa to be located on the fringes of Mombasa Mainland West, and approximately 12 km from the main port container terminals (Mombasa Investment Corporation, 2023). The proposed MIP site is owned by the County Government of Mombasa and measures approximately 569 acres, offering adequate space to operate port-related industries and enterprises (**Figure 6**). The MIP would also benefit from the agglomeration of other industries and would be a great area to explore the creation of a port cluster within the port city of Mombasa. By incorporating the MIP into the sustainable port logistics corridor development, the city of Mombasa will be able to address the challenge of fragmented land-use patterns, which are driven by uncoordinated port-city expansion. The plan should also be regularly updated, preferably every 5 to 10 years after formulation.

Enhanced Public Engagement

Public participation involving communities affected by port expansion projects is critical to

FIGURE 6
Proposed Mombasa Industrial Park
Source: County Government of Mombasa

safeguard livelihoods and promote social inclusion in port development. Successful port or city projects are based on frequent consultation between port and city actors within the port-city system (Debrie & Raimbault, 2016). This would allow port or city authorities to prepare elaborate resettlement action plans (RAPs) that provide alternative livelihoods to affected communities. In the case of Mombasa, local fishermen in Port Reitz complained that they were neither resettled nor provided with alternative livelihoods, including fishing gear and training to venture into deep-sea fishing, as a result of the port authority's development of port facilities on their fishing areas. A good example of how port and city engagement has been able to fuel successful port-city operations lies in the Shanghai 2035 plan, which has been hailed as a good example of how to actively engage citizens in a port-city planning process (Shanghai Municipal People's Government, 2018). The port and city authority of Mombasa would therefore need to establish a an integrated port and city planning committee which would comprise of port officials, city officials, community representatives, fisheries officials, national government administration, transport and logistics firms, commerce and industry representatives, road authorities, Kenya Railways with option to co-opt other members as necessary so as to coordinate future port development projects. Through this integrated planning committee, port and city development plans would be formulated through a systems approach to mitigate the negative externalities in the port-city territories (Notteboom & Rodgrigue, 2005).

Application of Green Approaches to Sustainable Port Logistical Corridors

Finally, areas adjacent to the port that experienced rapid land-use change as a result of port expansion should be rezoned by the city authority into a port zone, with designated areas for open and green spaces to form a greenbelt and promote sustainable urban development within Mombasa. Drawing on best practices, the city of Shanghai deliberately integrated green belts along the logistical corridors leading to the port since port development was established to reduce open and green spaces within the city. The green corridors would leverage Nature-Based Solutions (NBS) to offset climate-related risks associated with port development. This would thus be a critical element to be incorporated into future port development projects. It is worth noting that the Northern Corridor Transit and Transport Coordination Authority, which oversees the implementation of the Northern Corridor Project to include Mombasa Port Area, advocates for the adoption of the green corridor concept in their strategic plan (Northern Corridor Transit and Transport Coordination Authority, 2017).

CONCLUSION

Port development is a vital driver of economic growth and urban transformation, yet its impacts extend far beyond trade and logistics. This study found that while the Port of Mombasa has stimulated industrialisation, improved connectivity, and positioned Kenya as a regional maritime hub, it has also triggered extensive land-use conversion, loss of vegetation, and a reduction in open spaces—particularly in the Port Reitz area. The findings underscore that uncoordinated port expansion disrupts ecological balance, erodes urban aesthetics, and compromises social stability. Sustainable port growth, therefore, depends on integrated planning frameworks that align economic objectives with environmental stewardship and social inclusion.

Moving forward, it is essential for the Kenya Ports Authority and Mombasa County to pursue a coordinated development model that embeds sustainability at every stage of port expansion. Collaborative planning, stakeholder participation, and the adoption of nature-based solutions are crucial to mitigating adverse impacts and promoting resilience. By embracing green port strategies, enforcing planning regulations, and linking port development to city master plans, Mombasa can serve as a model for balanced and inclusive port–city coexistence in the Global South—one in which economic progress complements rather than compromises environmental and urban sustainability.

RECOMMENDATIONS

To enhance sustainable port–city coexistence in Mombasa and address the environmental, spatial, and social challenges arising from port expansion, the study recommends the following:

Integrated Port–City Planning: Develop a joint Port–City Master Plan between the Kenya Ports

AFRICA HABITAT REVIEW 20(3) 2025

Authority (KPA) and the County Government of Mombasa to align port expansion with urban land-use planning. Establish a coordination committee to harmonise implementation, review plans periodically, and manage development within the port–city interface.

Green and Climate-Resilient Development: Adopt nature-based solutions (NBS), such as green belts, buffer zones, and mangrove restoration, to mitigate environmental degradation. Promote clean energy use in port operations and integrate climate-**r**esilient infrastructure to reduce carbon emissions and coastal risks.

Public Participation and Livelihood Safeguards: Institutionalise community consultations before major projects and prepare Resettlement Action Plans (RAPs) for affected populations. Provide compensation, skills training, and alternative livelihood opportunities to displaced fisherfolk and informal workers.

Policy, Legal, and Governance Reforms: Amend the Physical and Land Use Planning Act (2019) and Kenya Ports Authority Act (1979) to facilitate joint port–city planning. Strengthen zoning enforcement to curb industrial encroachment in residential areas and ensure environmental accountability in development approvals.

Research, Monitoring, and Global Collaboration: Establish a Port–City Observatory to monitor land-use change, socio-economic trends, and environmental impacts using GIS tools. Promote research partnerships with universities and collaborate with global port cities—such as Shanghai, Durban, and Rotterdam—through the AIVP network for best practices in sustainable port–city governance.

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