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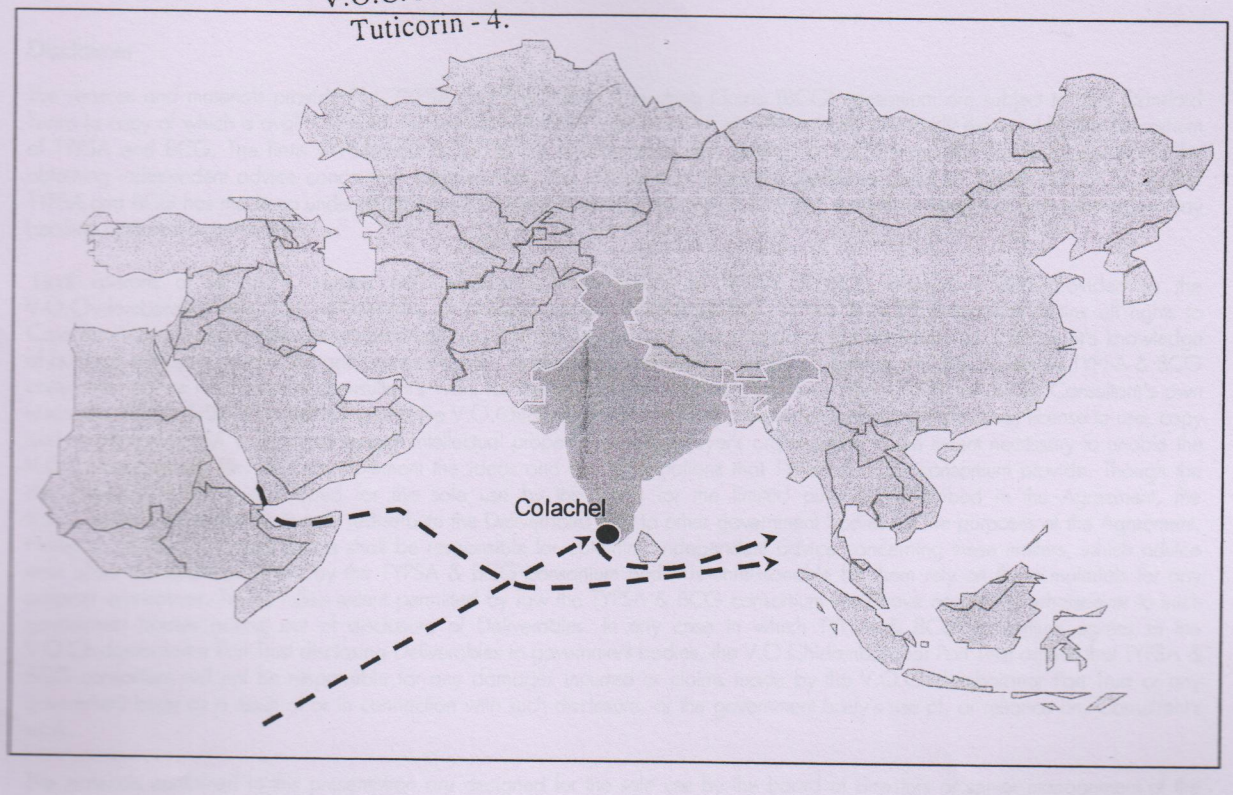

V.O.Chidambaranar Port Trust

Preparation of Rapid Techno-Economic Feasibility Report for Development of Colachel Port in Tamilnadu

TYPSA INGENIEROS CONSULTORES Y ARQUITECTOS

BCG

Final Report (Revised) Dated 14.08.2015

Volume 1 of 2: Report

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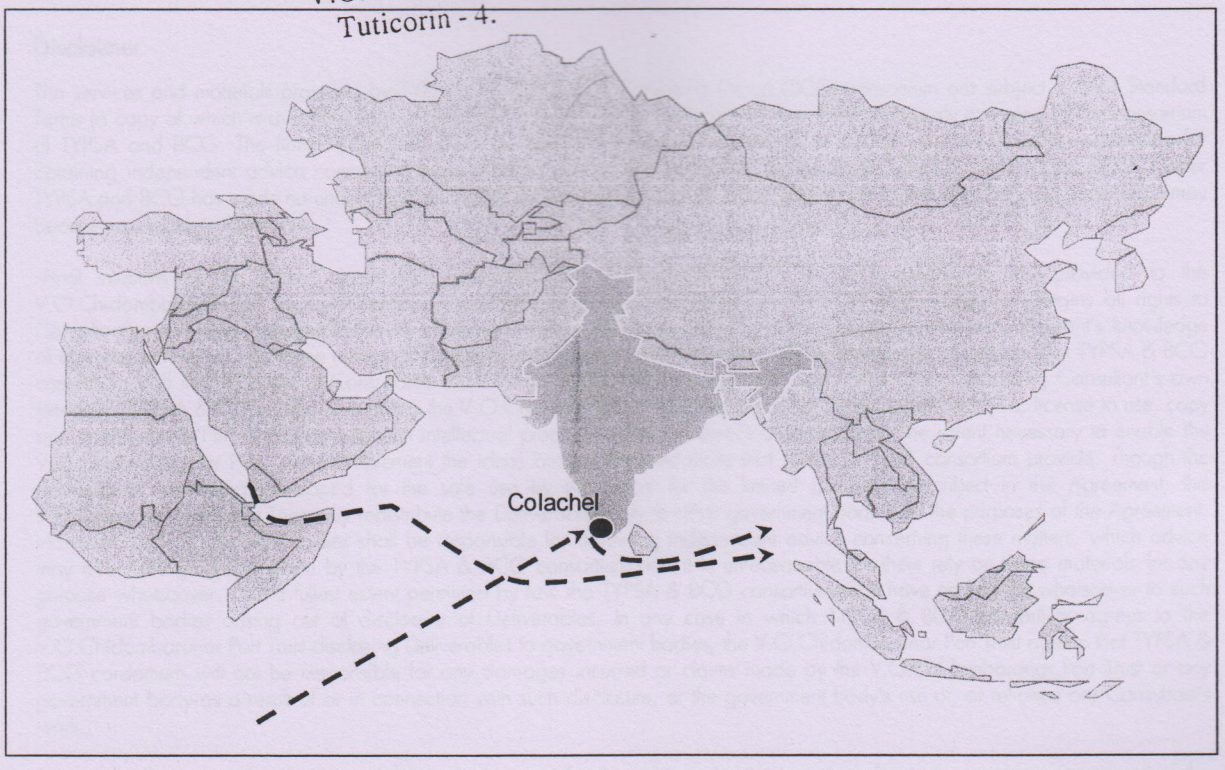

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Glossary

A-RMG	Automated Rail Mounted Gantry crane
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CFS	Climate Forecast System
CFSR	Climate Forecast System Reanalysis
CHA	Custom House Agent
CRZ	Coastal Regulation Zone
CSD	Cutter Suction Dredger
CSR	Corporate Social Responsibility
DCF	Discounted Cash Flow
DPR	Detailed Project Report
EDI	Electronic Data Interchange
EGM	Export General Manifests
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Analysis
ESMP	Environmental and Social Management Plan
EXIM	Export & Import
GDP	Gross Domestic Product
GoI	Government of India
GOT	Global Ocean Tides
GT	Great Diurnal Range
HAT	Highest Astronomical Tide.
HHWS	Highest High Water Spring
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities.
IEE	Initial Environmental Examination
IGM	Import General Manifests
IPA	Indian Ports Association
IRE	Indian Rare Earths Ltd.
IRR	Internal Rate of Return

JNPT	Jawaharlal Nehru Port Trust
LAT	Lowest Astronomical Tide
LLWS	Lowest Low Water Spring
MAT	Minimum Alternate Tax
MDA	Maximum Dissimilarity Algorithm
MHHW	Mean Higher High water
MHLW	Mean Higher Low Water
MLHW	Mean Lower High Water
MLLW	Mean Lower Low Water
MoEF	Ministry of Environment and Forest
MSL	Mean Sea Level
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
O&M	Operation and Maintenance
PIANC	Permanent Association of Navigation Congresses
POL	Petroleum, oil and lubricants
PPE	Personal Protective Equipment
PPP	Public Private Partnership
RBF	Radial Basis Function
R&D	Research & Development
RMG	Rail-Mounted Gantry crane
RMS	Royal Mail Ship
RS	Reach Stacker
RSC	Roll-over Safety Coefficient
SAGT	South Asia Gateway Terminals
SC	Shuttle Carrier
SEZ	Special Economic Zone
SHG	Self Help Groups
SSC	Sliding Safety Coefficient
STS	Ship-to-shore gantry crane

SWAN	Simulating Waves Nearshore
TAMP	Tariff Authority for Major Ports
TAT	Turn Around Times
TEFR	Techno-Economic Feasibility Report
TEU	Twenty-foot Equivalent Unit (shipping container)
TNMB	Tamil Nadu Maritime Board
TOS	Terminal Operating System
TPA	Tonnes per annum
TS	Trans-shipment
TSHD	Trailing Suction Hopper Dredger
UKC	Under Keel Clearance
VAT	Value Added Tax
VGF	Viability Gap Funding
VISA	Visa International Service Association
VOCPT	V.O. Chidambaranar Port Trust
VTMS	Vessel Traffic Management System
WW3	Wave Watch 3
YoY	Year over Year

1. BACKGROUND

1.1. GENERAL

Container traffic in India has seen tremendous growth in the last decade. The traffic has grown by more than 10% CAGR. The traffic is expected to continue growing at this rate as the global economy recovers and India's GDP growth rate accelerates back to 7 – 8% YoY growth. The demand for container traffic can further accelerate if the plans for debottlenecking of logistic infrastructure are implemented in time and the 'Make in India' push drives greater exports and manufacturing outsourcing to India.

In order to support this accelerated cargo growth and also, to enable 'Make in India' initiatives, it will be important to plan additional capacities and drive greater port productivity.. As of now, there are only a few ports in India that have sufficient draft and match global cargo handling efficiencies.. This has resulted in a large percentage (~25%) of containers that originate from India to be trans-shipped in foreign ports such as Colombo, Singapore, Klang etc. This is leading to an economic loss for the country and an economic dependence on foreign ports. Hence, the Ministry of Shipping (Government of India) through VOC Port Trust has asked the consultant to identify a suitable site and assess feasibility of developing a new container trans-shipment port on the Southern coast of India near Colachel.

Colachel is located on the south-west coast of India. It is a strategic location given its proximity to the international East-West shipping route. This route accounts for a major share of the total global container traffic flows and the mainline vessels use this route for transporting cargo between US, Europe and Asia. A significant share of India's current container cargo also moves through this route. The following figure shows proximity of Colachel to the east-west mainline shipping route.

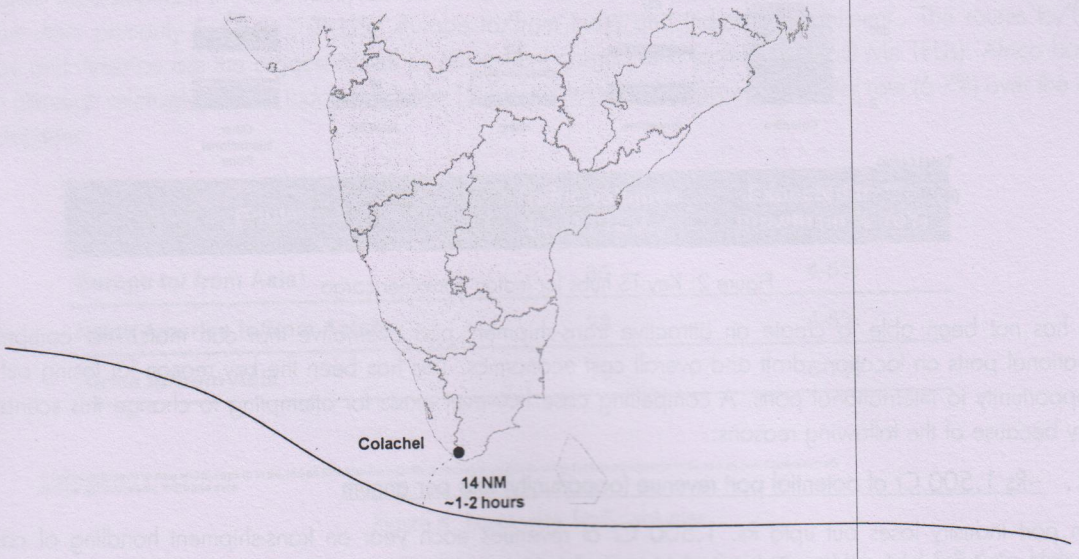


Figure 1: Proximity of Colachel to main shipping line

Additionally, Colachel has a natural deep draft which makes it viable for servicing large sized vessels, which is an important factor in attracting shipping lines. Global vessel sizes have significantly increased in the last decade and most main liner vessels have capacities of 10,000 TEUs and above, with the largest vessel reaching a capacity of 18,000 TEUs. .

This document is a Final Report that summarises the findings of the Techno-Economic Feasibility study and provides recommendations for development of the port.

1.2. INDIA'S TRANS-SHIPMENT TRAFFIC: AN UNADDRESSED OPPORTUNITY

Indian ports handled ~10.9 M TEUs of container cargo in 2014. Nearly 75% of this cargo was gateway (7.5 Mn TEUs), while ~25% was trans-shipped (TS) en-route to destination (2.8 Mn TEUs). Currently, all of India's trans-shipped cargo gets handled in ports outside of India. Colombo, Singapore and Klang handle more than 80% of this cargo, while Colombo alone handles around 1.2 Mn TEUs. Figure 1 below gives a detail port wise breakup of India's transhipment traffic.

Volume of Indian cargo trans-shipped at different TS hubs

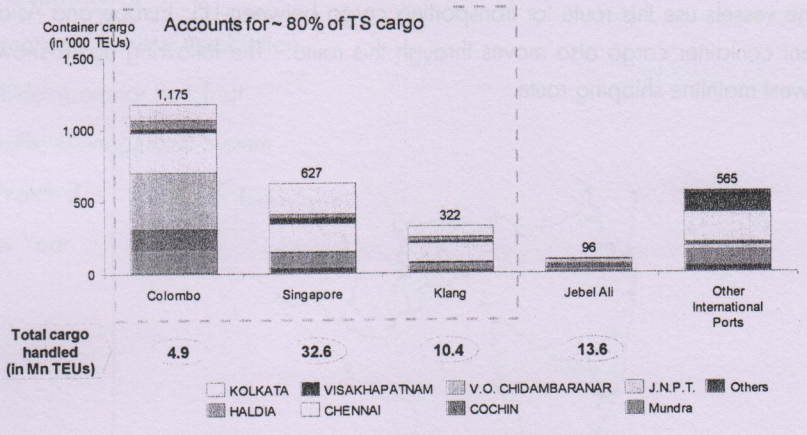


Figure 2: Key TS hubs for Indian container cargo

India has not been able to create an attractive trans-shipment port alternative that can match the competing international ports on location, draft and overall cost economics. This has been the key reason for losing out on this opportunity to international ports. A compelling case however exists for attempting to change this scenario, mainly because of the following reasons:

1. <u>~Rs 1,500 Cr of potential port revenue (opportunity) loss per annum</u>

Indian port industry loses out upto Rs. 1,500 Cr of revenues each year on trans-shipment handling of cargo originating / destined for India. This translates into an estimated total loss of Rs. 3,000-4,500 Cr to economy (assuming an economic multiplier of 2 – 3x for ports). The loss is even higher if opportunity to handle cargo emerging from other countries in the region is considered.

2. <u>Inefficient logistics for a large segment of India's EXIM industry situated in South India</u>

Trans-shipment of cargo results in logistic cost inefficiencies for Indian industry (especially from South India) given the extra port handling charges incurred at the trans-shipment hubs. The cost of this additional port handling is to the tune of USD 80-100 per TEU, which would be saved if the container is imported/ exported as direct gateway cargo instead of being trans-shipped. The figure below illustrates this cost inefficiency using an example of cargo movement for a typical exporter from Madurai, T.N. using trans-shipment in Colombo and shipping to Antwerp in Europe.

	TS route through Colombo	Cost (in USD / TEU)	Gateway route through Colachel	Cost (in USD / TEU)
Inland Transport	Madurai to Tuticorin	70-75	Madurai to Colachel	120-130
Port Charges	[illegible] idling charge	120-130	-	-
	Colombo handling charge	75-80	Colachel handling charge	75-80
Shipping costs	Tuticorin to Colombo	8-10	Colachel to Antwerp	65-70
	Colombo to Antwerp	65-70	-	
Total	Overall logistics cost	~350		~250

Upto 100 USD/ TEU of logistics cost can be saved for Madurai exporters by routing traffic through Indian gateway port

Figure 3: Simulation: Transport cost breakup for exports from Madurai district

A significant share of this cargo can be converted to Gateway by strategically locating a port near the Southern tip of India. This could also potentially help in further growth of trade due to improved cost competitiveness.

3. Opportunity to become a large trans-shipment hub for trade between US, EU, Africa and Asia

Container trans-shipment in Asia mainly occurs on three key routes – 1) US/ Europe to/from Far East, 2) Africa to/from Asia primarily Far East , 3) US/ Europe to/from India and Indian sub-continent.. The routes to/from Europe and America are the biggest routes as per current cargo traffic (combined ~60 Mn TEUs). Africa bound traffic although relatively smaller today (~10 Mn TEUs), it is expected to grow at a faster rate (6-7%) over the next few decades.

Routes	Traffic Volumes (in Mn TEUs)	Expected traffic growth (in % YoY)
Europe to/ from Asia[1]	30	4-5%
North America to/from Asia[2]	28	4-5%
Africa to/from Asia	10	6-7%

1. Includes Europe to Asia and Europe to India, Indian Sub-Continent traffic 2. Includes . Includes US to Asia and Europe to India, Indian Sub-Continent traffi
Source: BCG Analysis, IHS trade data

Figure 4: Route wise Traffic volumes

Currently, Asia has 3 main transhipment port clusters - Middle East Hub, South Asia Hub and S.E.Asia Hub. The following figure describes these clusters and the volume of traffic handled by each.

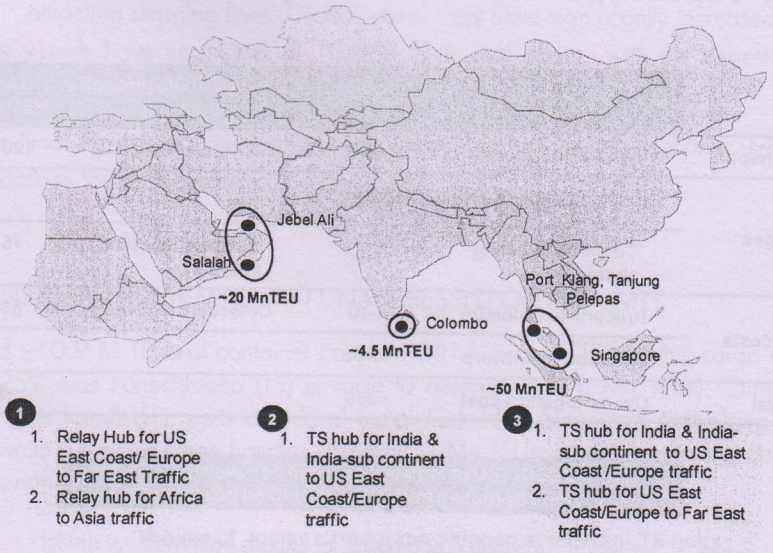


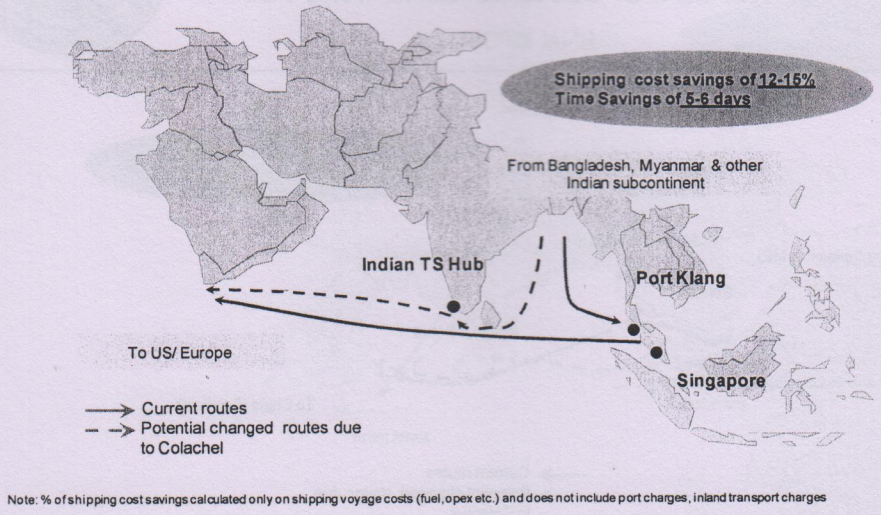
Figure 5: Major TS hub clusters in Asia

While, most of the transhipment trade happens in the South East Asian and Middle East cluster, the South Asian location (including Southern tip of India) is in-fact the most efficient location for transhipment of cargo moving to Africa, EU or East Coast of America.

i. Indian-subcontinent to US/ Europe traffic currently trans-shipped in Singapore cluster

Currently, ~70% of cargo from Bangladesh and Myanmar gets trans-shipped in Singapore. A trans-shipment hub at the Southern tip of India can save voyage time by 5-6 days for cargo bound to Africa, EU or East coast of America, resulting in potential cost savings of 12-15%. Currently, only Colombo port is the alternative in the South Asia zone with a capacity of ~5 Mn TEU. Whereas, the South East Asian cluster already handles more than 50M TEUs. Thus, due to this significant scale difference South East Asia continues to be the main aggregation point. Emergence of new hubs such as Colachel and further growth of Indian container cargo traffic can change this scenario in the near future.

Indian sub-continent to/from Europe/ West Coast US			
Current Route	**Voyage time (in days)**	**Route with Indian TS hub**	**Voyage time (in days)**
Chittagong to Singapore (feeder)	5-6	Chittagong to Colachel (feeder)	4-5
Singapore to Antwerp	25-26	Colachel to Antwerp	20-21
Total voyage time	**30-31**	**Total voyage time**	**25-26**



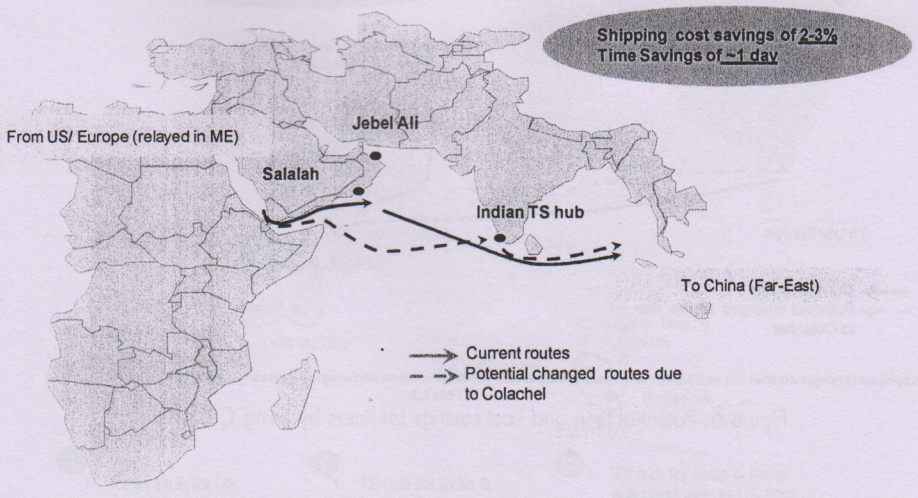
Note: % of shipping cost savings calculated only on shipping voyage costs (fuel, opex etc.) and does not include port charges, inland transport charges

Figure 6: Potential time and cost savings for liners by using Colachel (I)

ii. US/ Europe to Far East traffic currently trans-shipped/ relayed in the Middle Eastern TS hub

US/ Europe to Far East (including China) is the busiest trade route with volumes of ~30 Mn TEUs. Liners have started using the Middle Eastern cluster ports, mainly Salalah and Jebel Ali as relay hubs for this route, with one service bringing cargo from China to Salalah, while another service picks up this cargo and moves to US West Coast. TS port in South India is well placed to attract some of this relay traffic as it will account for ~1 day voyage time saving and 2-3% shipping cost savings.

Europe/ West Coast US to/from Far East			
Current Route	**Voyage time (in days)**	**Route with Indian TS hub**	**Voyage time (in days)**
Antwerp to Salalah	~16	Antwerp to Colachel	~20
Salalah to Shanghai (relay)	~17	Colachel to Shanghai (relay)	~12
Total voyage time	**~33**	**Total voyage time**	**~32**



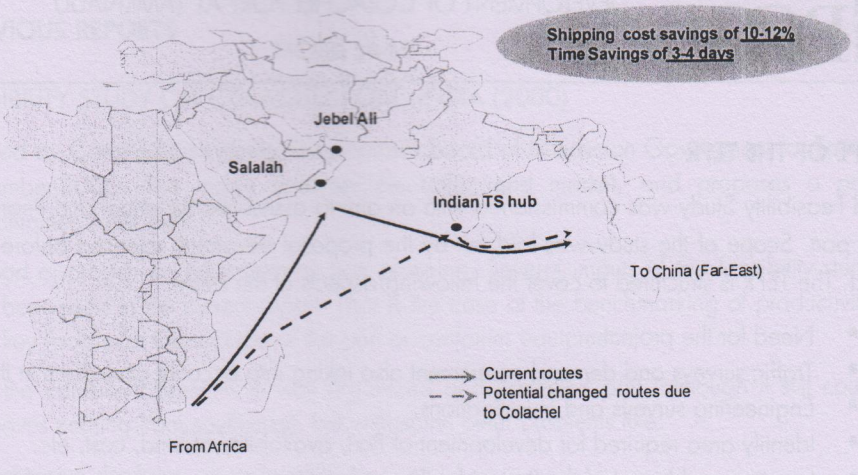
Note: % of shipping cost savings calculated only on shipping voyage costs (fuel, opex etc.) and does not include port charges, inland transport charges

Figure 7: Potential time and cost savings for liners by using Colachel (II)

iii. Africa to Asia (Far East) traffic currently trans-shipped/ relayed in the Middle Eastern TS hub

Africa to Asia trade is expected to grow at a 6-7% rate in the next decade. Currently, most of the traffic gets relayed in Middle Eastern port cluster with the cargo arriving from China and destined to US / EU. A TS hub such as Colachel will once again be an attractive alternative as will result in voyage time saving of3-4 days and potential cost savings of 10-12% for the liners.

Africa to/ from Far East			
Current Route	**Voyage time (in days)**	**Route with Indian TS hub**	**Voyage time (in days)**
Cape Town to Salalah	13-14	Cape Town to Colachel	14-15
Salalah to Shanghai (relay)	17-18	Colachel to Shanghai (relay)	12-13
Total voyage time	**30-31**	**Total voyage time**	**27-28**



Note: % of shipping cost savings calculated only on shipping voyage costs (fuel, opex etc.) and does not include port charges, inland transport charges

Figure 8: Potential time and cost savings for liners by using Colachel (III)

4. Mitigate risk to Indian trade due to dependence on international ports

The current scenario where 25% of the country's EXIM cargo is trans-shipped at international ports is not ideal since this makes Indian industries vulnerable to increase in costs, potential inefficiencies, congestion issues etc. at these international ports. This creates long term risks for competitiveness of India's trade and thus is another important reason for promoting a TS port in India.

2. SCOPE OF THE TEFR

The Rapid Feasibility Study was commissioned with an aim to assess the technical and financial feasibility of the proposed port. Scope of the study was laid out by the proposal document released before bidding process for the project. The TEFR is structured to cover the following aspects of the study:

- Need for the project.
- Traffic surveys and demand assessment also taking into account other Ports in the vicinity.
- Engineering surveys and investigations.
- Identify area required for development of Port, availability of land, cost, etc.
- Location and layout of the Project facility and services.
- Initial Environment Examination (IEE).
- Preliminary designs of project facility and services.
- Structuring of project including different options for developing the project.
- Schedules for modification and / or Utility Relocation Plans
- Preparation of Cost Estimates
- Establishing the Technical feasibility and Financial Viability of the Proposal
- Review and update of previous reports on Colachel Port.
- Feasibility in developing Colachel Port as a satellite port of VOCPT, considering the availability of deep draft.
- Key outputs of the rapid feasibility study – traffic, port location and port layout and the resultant financials for the port.
- Key success factors for the port Details out the planned connectivity to the port both in terms of road and railways.
- Phases the costs based on capacity phasing and construction planning.
- Projects free cash flow from the project over the years; calculates resultant IRR.

3. REVIEW OF PREVIOUS REPORTS

3.1. DETAILED FEASIBILITY STUDY ON COLACHEL PORT, INDIA (2000)

The report was prepared by Construction Industry Development Board of Malaysian Government for Tamil Nadu Government in November-2000. The report analyses the traffic and market, and proposes a port near Manavalakurichi for container traffic only.

This report gives a good approach on the container port planning. Several imputs of this feasibility study, after the due update, have been used in the current report. That is the case of the benchmarking of productivity levels for berths and cranes, key factors for the success of the port or container equipment.

Analyzing the layout, the consultant presents a well organized and protected port (although it still could have some problems with waves coming from south-east), but with some other problems like:

- A difficult and expensive dredging on rocky soil
- A river inside the basin which would generate the need for continued maintenance dredging
- Very long (around 9,000 m) and costly breakwaters
- A very high need of land acquisition both for port and industrial area
- Negative effects on local fishing industry and Indian Rare Earths Ltd as well

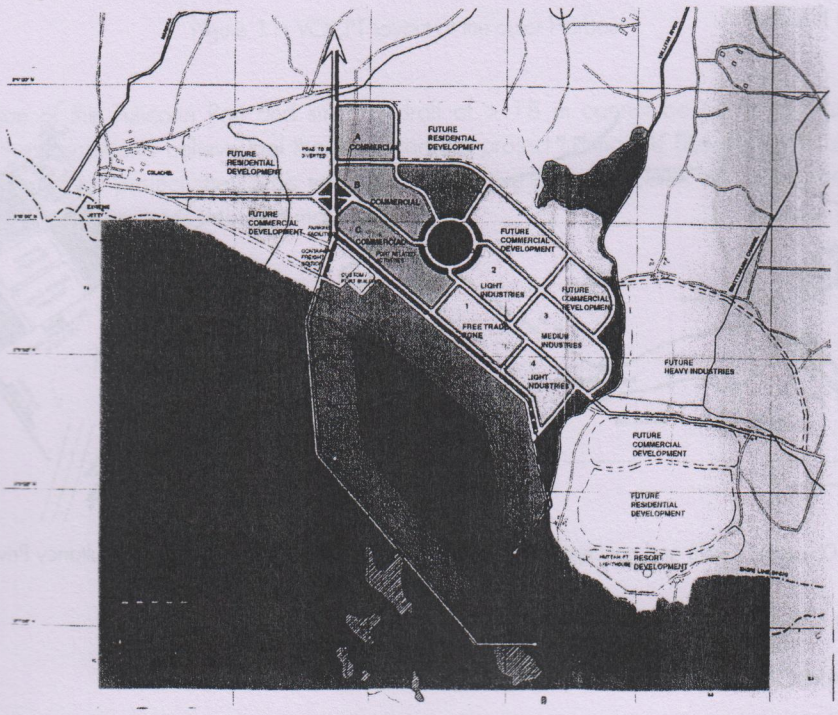


Figure 9: Caption of layout for Colachel port by Construction Industry Development Board of Malaysian Government

Inputs from the traffic and market study are not relevant for this study, since the market has changed over the last 15 years.

3.2. TECHNO ECONOMIC FEASIBILITY STUDY FOR COLACHEL PORT (2010)

This report was made by M/s i-maritime Consultancy Private Ltd. for Tamil Nadu Maritime Board (Ministry for Highways and Ports) in July 2010 and analyses the viability of establishing a multi-purpose commercial port, concluding that the port would only be viable if a captive thermal power plant is set up.

I-maritime proposes a port on the Manavalakurichi shoreline, which, from a technical point of view, has certain issues, for example:

- It is poorly protected from the swell coming from the south.
- The stocking yard of container terminals are onshore while the berths are far from them and seem too small for the expected vessels.
- The solution needs a large and difficult dredging.
- Since the port is located in the middle of a physiographic unit between Colachel and Manavalakurichi, it would have a big adverse impact to the beach dynamics and shape.
- Again, the port needs large amount of land to be acquired for terminals, which is likely to be difficult to achieve in this district.

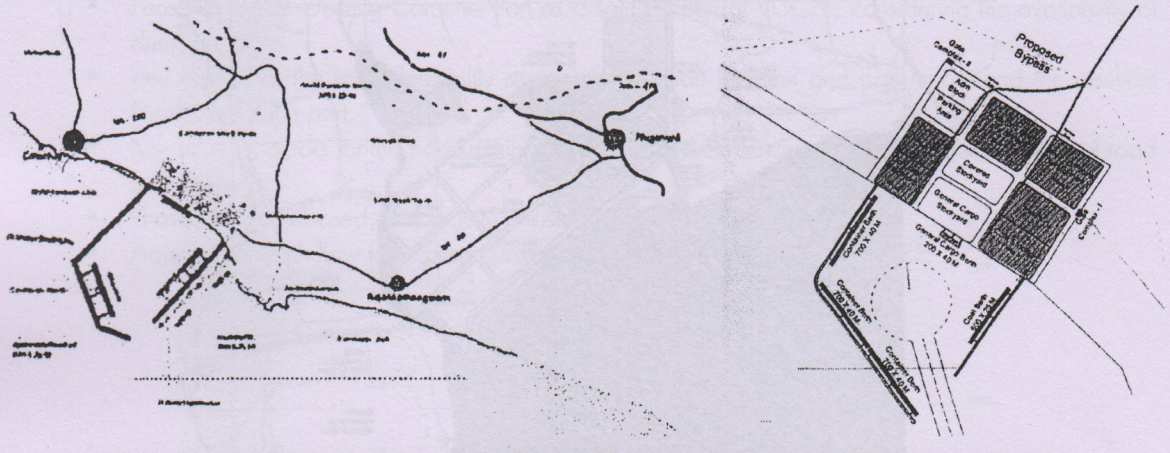


Figure 10: Location (left) and concept layout (right) for Colachel port by i-maritime Consultancy Private Ltd

Inputs have been taken on traffic and financial study from this report.

3.3. OUTER HARBOUR OF VOC PORT

M/s i-maritime Consultancy Private Ltd prepared a Detailed Project Report for the development of Outer Harbour at VOC Port in December, 2013, and a Supplementary Report adding some considerations and comments from VOCPT in October, 2014.

On February, 2015, Indian Ports Association (IPA) submitted a Report to Review and Validate the Detailed Project Report made by i-maritime. This report undertakes a detail review and proposed a new optimized layout (see figure below) and several adjustments on the design.

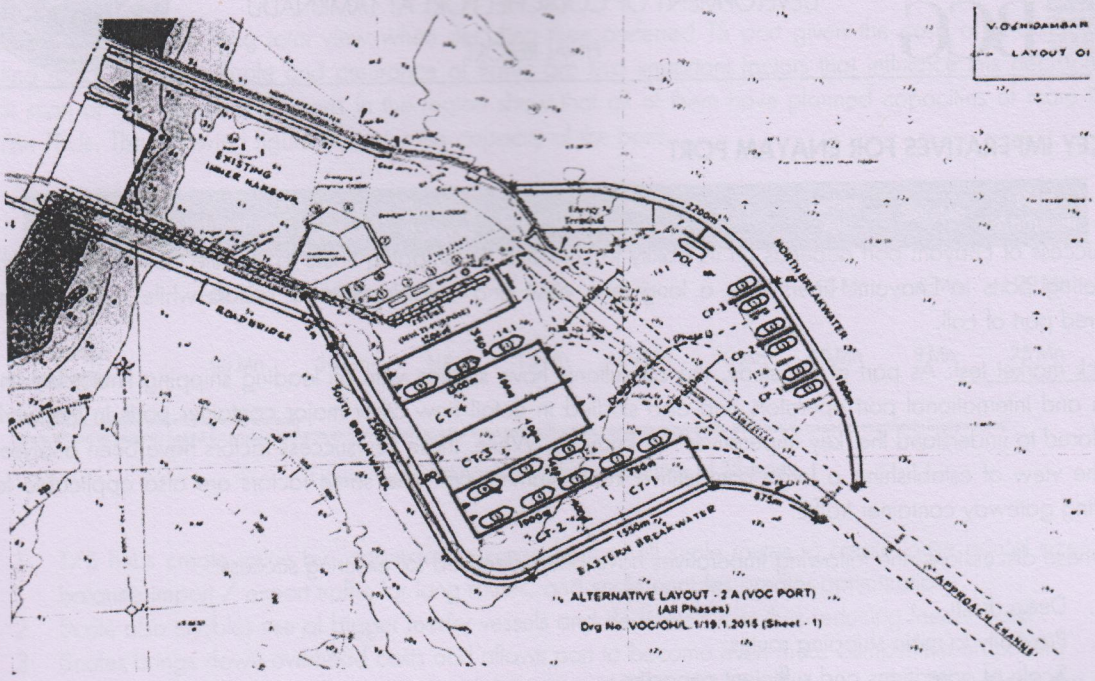


Figure 11: VOCPT Layout of the outer Harbour

Given, the location of the Tuticorin Port and since a draft of > 18 m cannot be achieved through the Outer harbour project, the Consultants believe that the outer harbour project cannot be developed as an alternative to Enayam. The Enayam port project should be taken up irrespective of the decision on Outer harbour project to cater to the regional container trans-shipment market.

4. KEY IMPERATIVES FOR ENAYAM PORT

The success of Enayam port depends on its ability to convince the shipping liners to re-route their traffic from the competing ports to Enayam. Liners take a long term view and consider several factors while deciding their preferred port of call.

Dipstick market test: As part of the study, the consultants have spoken with all leading shipping liners, leading Indian and International port operators and also studied in detail how other major container ports in the world have fared to understand the 'key imperatives' for Enayam. While, these key success factors have been analysed with the view of establishing a large competitive trans-shipment port, the same factors are also applicable for attracting gateway container traffic.

Basis these discussions, the following imperatives have been identified for ensuring success:

1. Deep draft
2. Proximity to main shipping routes
3. Scale of operations and sufficient capacity
4. Support and assurance of gateway traffic
5. Sufficient feeder capacity and cost efficient network
6. Competitive overall logistic economics
7. Efficient customs approval process
8. Hinterland road and rail connectivity
9. Cheap bunkering services

1. Deep Draft

The Suez route accounts for a major share of the total global container traffic flows and the mainline vessels use this route for transporting cargo between US, Europe and Asia. Nearly ~80% of India's current container trans-shipment cargo also moves through this route.

Liners prefer minimum deviation from their routes when selecting a trans-shipment port. As described in the figure below, it is clearly evident that all ports on east and west coasts of India are located at a distance of >1 day of voyage from the shipping route, which makes these locations unattractive for trans-shipment.

2. Proximity of main shipping routes

Global vessel sizes have significantly increased in the last decade and most main liner vessels have capacities of 10,000 TEUs and above, with the largest vessel reaching a capacity of 18,000 TEUs. Hence, availability of adequate draft has become an important factor in attracting shipping lines. The current Indian ports which are <1 day distance from main route have insufficient drafts to attract mainline vessels. Cochin has 14.50 m draft and Tuticorin has only 14.10 m draft. Only one terminal (CICT) has draft of 18 m (with dredging) in Colombo.

3. Scale of operation and port capacity

Shipping liners keep a long term view when deciding their preferred TS port given the costs of re-configuring existing route networks. Scale and assurance of traffic are two important factors that influence this decision. A quick scan of the successful TS ports in the region show that all of them have planned capacities of more than 10 Mn TEUs. The following figure illustrates the capacity of the ports.

In Mn TEUs	Singapore	Port Klang	Tanjung Pelepas	Colombo	Ham-bantota	Galle	Jebel Ali	Salalah	Port Abdullah
Current capacity	~32 Mn	~16 Mn	~9 Mn	~5 Mn	0	0	~15 Mn	~5 Mn	~20 Mn
Planned capacity [1]	50 Mn	30 Mn	NA	13 Mn	20 Mn	10 Mn	19 Mn	8 Mn	25 Mn

1. Planned capacity includes existing capacity
Note: Planned capacity based on announcements and press release from the port authorities; can vary significantly from actual capacity expansion implemented

Figure 12: Existing & planned capacities of TS ports

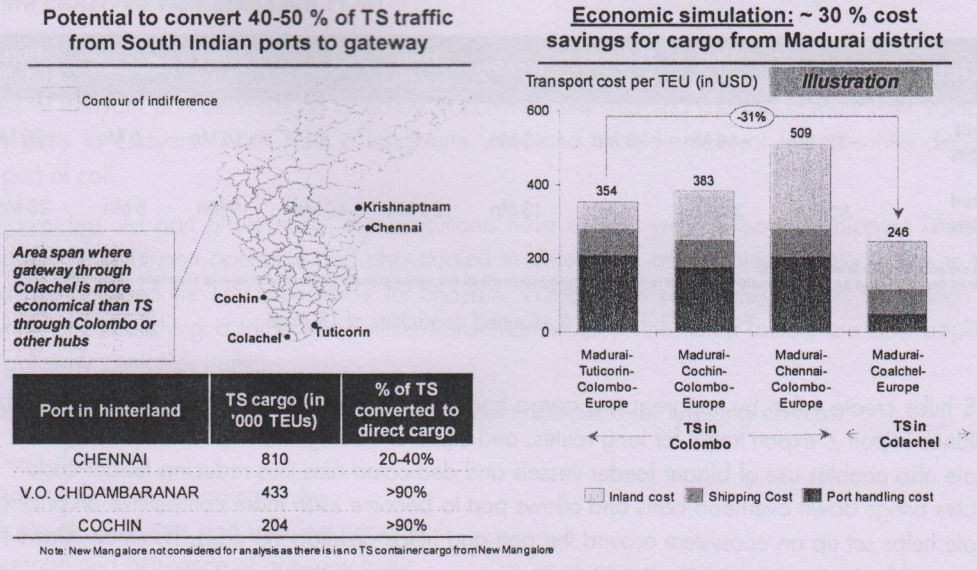
1. T/S hubs create value by aggregating cargo from small scale routes to create large parcel sizes and balance import / export traffic for long routes, and scale enables greater optimization
2. Scale also enables use of bigger feeder vessels and dedicated runs thus reducing feeder costs
3. Scales brings down overhead costs and allows port to become even more competitive on pricing
4. Scale helps set up an ecosystem around the port and helps develop the area. This then allows the port, liners and logistic companies to attract talent.

Colachel has 10 M TEUs capacity (assuming coal berth in converted to container) due to its 4km long shoreline which provides sufficient scale for the port. This capacity can be further expanded to ~18 M TEUs (post phase III of the port) by converting the breakwater into a container handling berth.

4. Assurance and support of Gateway traffic

Presence of significant assured Gateway cargo is often a big factor in liners' decision to move to a new location since it brings down the volume risk. This also becomes a key differentiator as it drives higher scale of operations for the liners and allows them to combine their gateway traffic with trans –shipment traffic without need for a feeder movement.

Colachel has high potential for gateway cargo given its proximity and access to hinterland comprising of T.N. (primary hinterland) and also parts of Kerala, Karnataka and A.P. (secondary hinterland). The hinterland currently generates 2.3 Mn TEUs of container cargo (2014). Out of this, 60% of cargo is currently trans-shipped through foreign ports. A large share of this traffic could be re-directed as gateway through Colachel given better logistic cost economics. Colachel is expected to convert upto 40-50% of the hinterland TS traffic to Gateway. The following figure illustrates the same.



Port in hinterland	TS cargo (in '000 TEUs)	% of TS converted to direct cargo
CHENNAI	810	20-40%
V.O. CHIDAMBARANAR	433	>90%
COCHIN	204	>90%

Note: New Mangalore not considered for analysis as there is is no TS container cargo from New Mangalore

Figure 13: TS traffic converted to gateway traffic through Enayam

Cochin has limited hinterland cargo from Kerala and requires interstate transport for access to T.N. hinterland. Long delays in interstate checkpoints (e.g. delays in Walayar can be as high as 18-24 hours) have made it infeasible for T.N. exporters/ importers to use Cochin for shipping. Colombo, has limited gateway cargo and >70% of its current traffic is TS traffic. A port at Colachel would aggregate the hinterland traffic wherever logistics costs are to its favour.

5. Sufficient feeder capacity and cost efficient network

As per the traffic projections for trans-shipment traffic at Colachel Port, a feeder network with capacity of ~27,300 TEUs for a weekly service would be required in 2025. Currently, the capacity of Indian feeder network for a weekly service is ~5,100 TEUs, which is expected to grow to only ~8,300 TEUs by 2025.

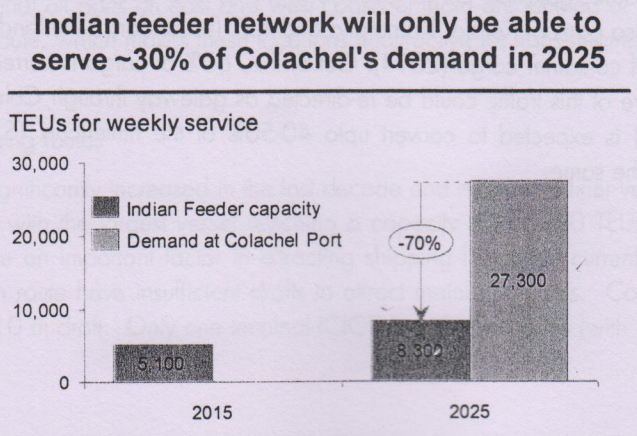


Figure 14: Indian feeder capacity available vs. requirement for Colachel

Clearly, the Indian feeder network will be insufficient to serve the needs of Colachel Port and it will be difficult to expand the capacity of Indian feeder vessels aggressively to meet requirement. This will become an important roadblock in making liners to move traffic to Colachel.

To overcome this constraint, relaxation of Cabotage law will be required to attract international feeder networks to Colachel. The most suitable option is to completely relax Cabotage for container vessel movement in India, potentially around the time when port is ready for operations. As shown in the below graph, Cabotage restriction on container vessel only serves to protect 0.6 Mn of coastal traffic as the trans-shipment traffic is anyways catered by the international feeder network even today. The other option is to relax Cabotage for Colachel specifically.

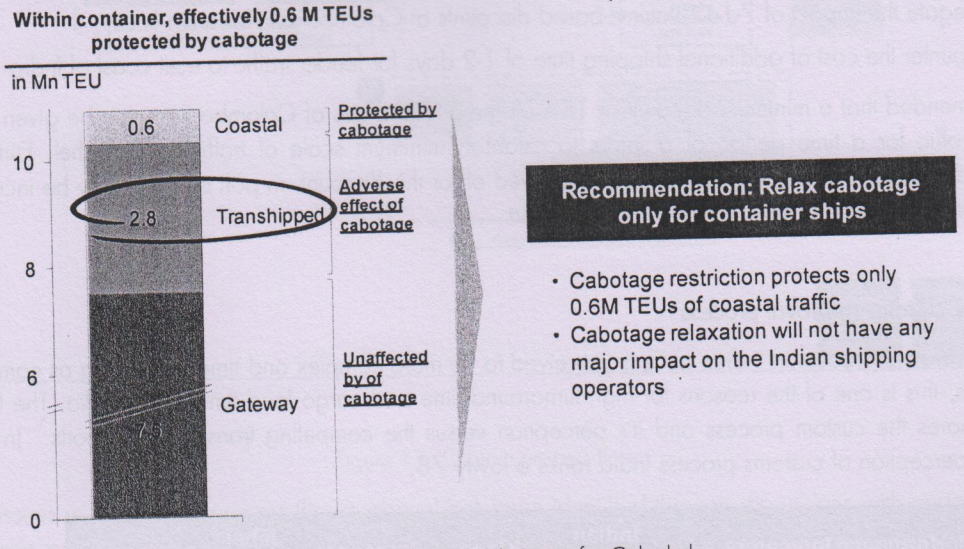


Figure 15: Cabotage relaxation for Colachel

6. Competitive overall logistics economics

The table below compares the port charges at Vallarpadam Terminal, Cochin Port with the competing Trans-shipment ports in the region.

	Vallarpadam (Cochin)	Colombo	Singapore	Klang
Vessel Related Charges - Liner	8	9	6	6
Vessel Related Charges - Feeder	5	2	2	2
Cargo handling charges	149	86	122	84
Service Tax (14%)	21	-	-	-
Total	183	97	130	92

Table 1: Comparison of Port charges for competing trans-shipment ports

The port charges at Cochin Port are ~90% higher versus Colombo Port. In order for Colachel Port to be successful in attracting traffic, it is critical to not just match the port charges with competing ports, especially Colombo Port, but also to have charges below Colombo Port for a few years. It is important to give discount over and above the port charges of Colombo Port for the following reasons:

- To make it economically viable for shipping lines to invest in capital cost of shifting existing operations (building facilities/ infrastructure for employees, office buildings etc.)
- Provide economic incentive for liners to shift and incur the cost of re-configuring their routes
- To negate the impact of 7-14% volume-based discounts at Colombo port for main lines
- To counter the cost of additional shipping time of 1-2 days for feeder traffic to east coast of India

It is recommended that a minimum discount of 15% on the port charges of Colombo Port may be given for trans-shipment traffic for a time period of 5 years to establish minimum scale of traffic in Colachel. Further, it is recommended that either the service tax may be waived off or the discount on port charges may be increased to offset the additional cost of service tax at Colachel Port.

7. Efficient customs approval process

Customs clearance process in Indian ports is perceived to be more complex and time consuming as compared to global ports; this is one of the reasons for high turnaround time and cargo lead times as in India. The following table compares the custom process and it's perception versus the competing trans-shipment ports. In terms of customer's perception of customs process India ranks a lowly 78.

Performance Indicators	Indian ports	Klang	Singapore	Jebel Ali	Colombo
Average number of documents for Import	10	4	3	5	7
Average number of documents for Export	7	4	3	3	7
Average number of signatures required for Import	27	5	3	3	10
Average number of signatures required for Import	22	3	3	3	13
Rank as per perception of customs process	78	14	1	3	72
Clearance Lead Time in days for Import	2	1	1	2	2
Clearance Lead Time in days for Export	2	1	2	2	2

Source: World Bank Study - World Development Indicators 2015

Figure 16: Comparison of customs process benchmarks

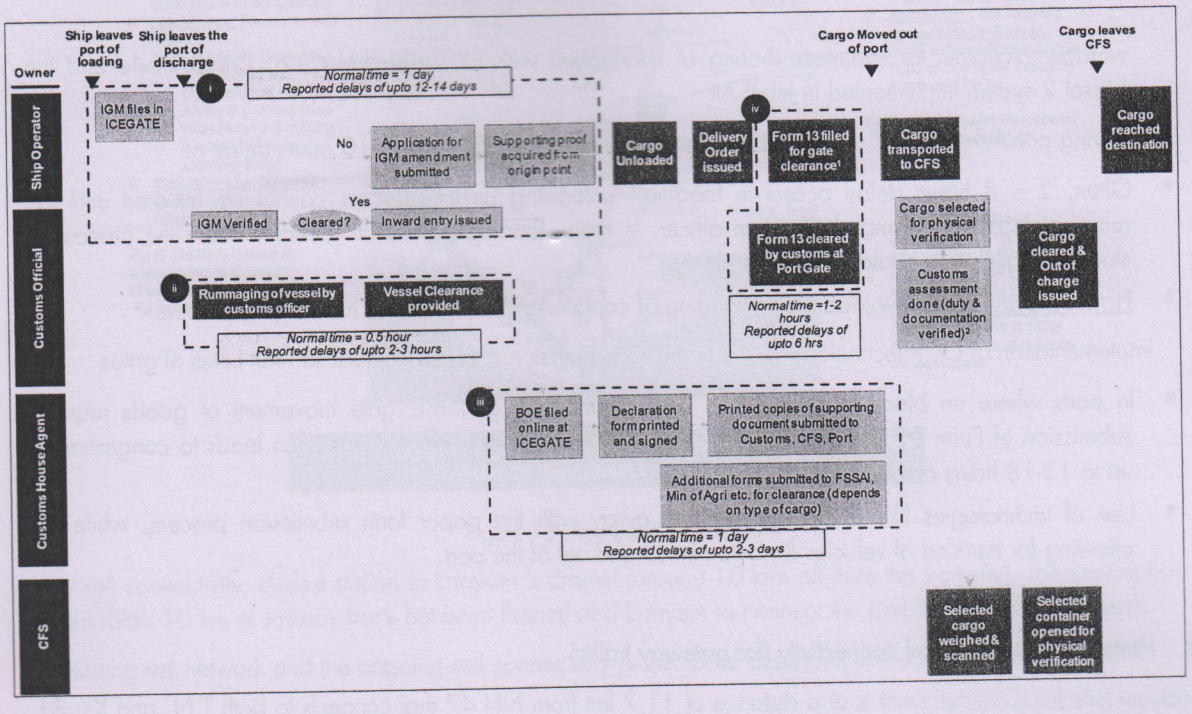


Figure 17: Cuatom process flow

Four key issues in the custom process (figure above) has been identified through discussions with customers, CFS agents, liners and port operators :

i. Complex and time consuming process for rectifying errors in IGM

- Complex form with >80 inputs and often (~10% as reported by users) results in clerical errors.
- Amendment allowed only by ship operator through a written application. The process can take upto 12-14 days and during this time the container lies stuck with port or with CFS.
- Proposed solution: Amendment process can be made simpler by allowing online applications for amendment & authorizing CHAs to make smaller amendments (correction of typographical errors)

ii. Significant documentation burden for BoE and opportunity for digitization

- BoE requires 12-15 accompanying documents and physical copies needs to be submitted to multiple agencies e.g. FSSAI, Ministy of Agriculture etc. (estimated 120 – 150 printouts required)
- Most of these forms ask for same information e.g. both packing list and invoice have data fields on consignee name, address, description of cargo (weight, dimension, quantity) etc.
- Online ICEGATE system currently has limited provisions for attaching supporting documents.
- Proposed solution: Simplify by combining and reducing number of forms/ fields required e.g. Singapore has even combined documents like invoice and packing lists. Also, develop ICEGATE into a single

window platforms for seamless sharing of information with all stakeholders e.g. Dubai Trade and the Mirsal 2 system implemented in Jebel Ali

iii. Allowing parallel loading/ unloading while vessel rummaging can save 2 – 3 hours delay

- Often, 2 – 3 hours delay occurs in loading/ unloading as the process cannot be initiated until the rummaging and clearance by custom officer. In many leading ports such Customs allow the process to start in parallel, thus avoiding the time delay.
- Proposed solution: Allow loading/ unloading of containers in parallel with rummaging process

iv. Implementation of OCR technology versus Form 13 submission process will reduce wait times at gates

- In ports where en block movement has been identified e.g. JNPT, gate movement of goods requires submission of Form 13 by CFS agent and approval by customs officer. This often leads to congestion of up to 12-18 hours at the gates.
- Use of technologies like OCR can help do away with the paper form submission process, while still allowing for tracking of vehicles & containers in and out of the port.

8. Hinterland road and rail connectivity (for gateway traffic)

Enayam (site for Colachel port) is at a distance of 11.7 km from NH 47 that connects to both T.N. and Kerala. NH 47 further connects to NH 7 which is the main arterial route and along which most of the hinterland industries are located. Developing a road connection with NH 47 has been identified as the fastest and cost efficient way of connecting the port with the hinterland.

The map below shows the existing highways and the status of their upgradation projects. NH 7 is an important corridor, which would connect the port to the hinterland industries and the Nanguneri SEZ. In order to establish connectivity with NH 7, it is vital to complete the development of the greenfield 4-lane NH-47 and the last mile connectivity to the NH-47, with the support of NHAI and State Government.

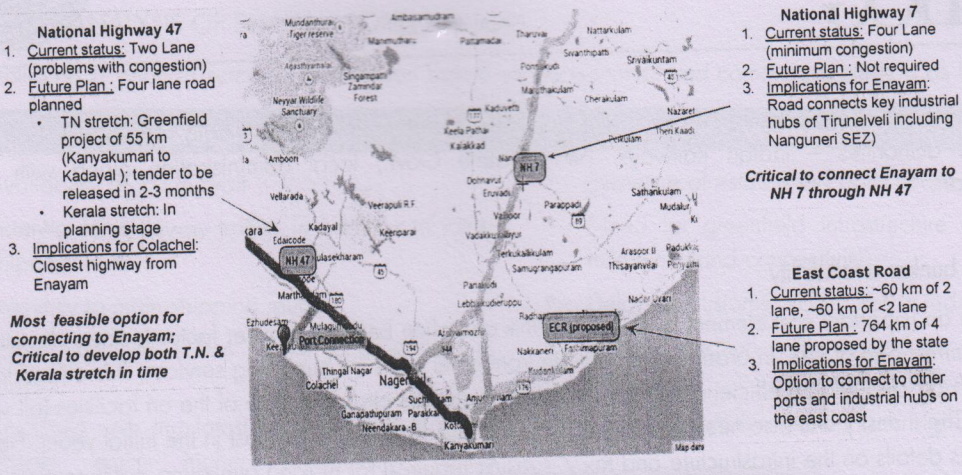


Figure 18. Road connectivity

As for rail connectivity, closest station to Enayam is Eraniel (around 10 kms off from the port site). The best option is to establish 10 km of railway track between Eraniel and Enayam to connect the port to the railway network.

The existing rail network and the ongoing rail connectivity projects are described in the map below.

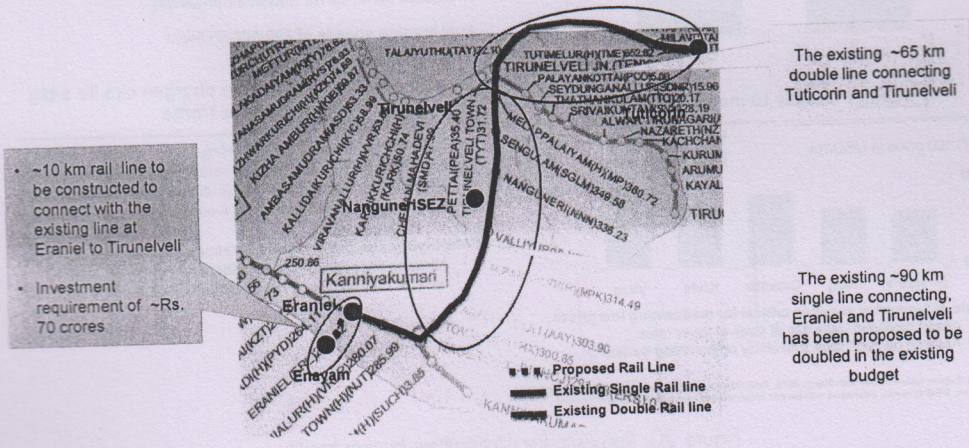


Figure 19. Rail connectivity

Connectivity to Enayam port is contingent on the following projects being completed in time before Colachel becomes operational.

1. Four laning of NH 47 – both in T.N. and in Kerala
2. Road connectivity between Enayam and NH 47 (~11.7 km road stretch)
3. Doubling of railway line between Eraniel and Tirunelveli
4. Rail connectivity between Enayam (location of Colachel port) and Eraniel (~10 km railway stretch)

Connectivity needs to be established before the port gets operationalized. This would require collaboration with all relevant authorities – Indian Railways, NHAI, State Govt., local administration along with the port administration.

9. Cheap bunker availability

Bunkering is an important cost element for liners and this can often become another factor in liners decisions to choose preferred port of call. In order to differentiate from other ports on bunkering services, it is critical to achieve high process related efficiencies (high fuel loading speeds etc.) and state of the art facilities (all weather bunkering). The industry will also need support in terms tax and duty breaks at least in the initial years. Figure below shares details on the infrastructure and tax / subsidy required for making bunkering a differentiator for the port.

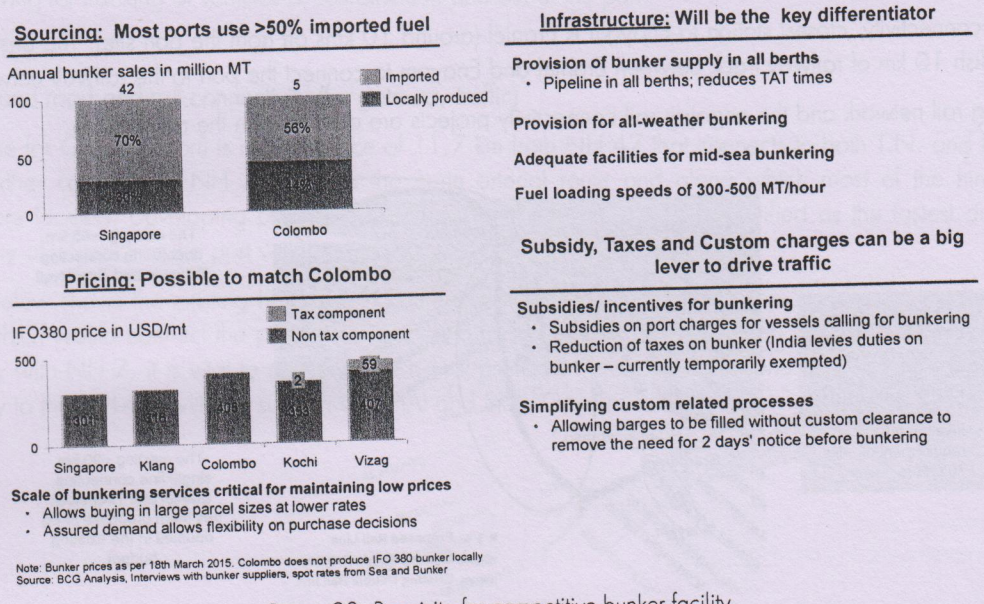


Figure 20: Requisite for competitive bunker facility

4.1. SWOT ANALYSIS OF ENAYAM PORT

An overall SWOT analysis summary for this port based on the technical and commercial study is as follows:

Strengths	Weaknesses
▪ Availability of 20 m draft ▪ Potential for gateway traffic, in addition to trans-shipment traffic ▪ Proximity to main shipping routes ▪ Large capacity (10M TEUs) and ability to expand ▪ Designed with the latest technological that will enable much higher productivity versus competing ports	▪ Existence of established ports nearby ▪ Need for greenfield infrastructure such as last mile hinterland connectivity ▪ Delays in customs procedures in India ▪ Higher taxation with respect to international ports ▪ Insufficient feeder network and higher costs
Opportunities	**Threats**
▪ Potential of in gateway traffic acceleration because of 'Make in India' campaign ▪ Growth of Africa-Asia and intra-Asia trade ▪ Development of the Indian feeder Transport System through this port	▪ Price war with Colombo Port ▪ Emergence of new ports in the region, like Hambantota ▪ Inability to attract liner as anchor investors

5. OPTIONS FOR LOCATING THE PORT

5.1. BACKGROUND

Four port locations –Kanyakumari, Manavalakurichi-Muttom, Colachel and Enayam- have been identified and analyzed from a technical, economical and environmental standpoint in order to propose the best option for locating the port.

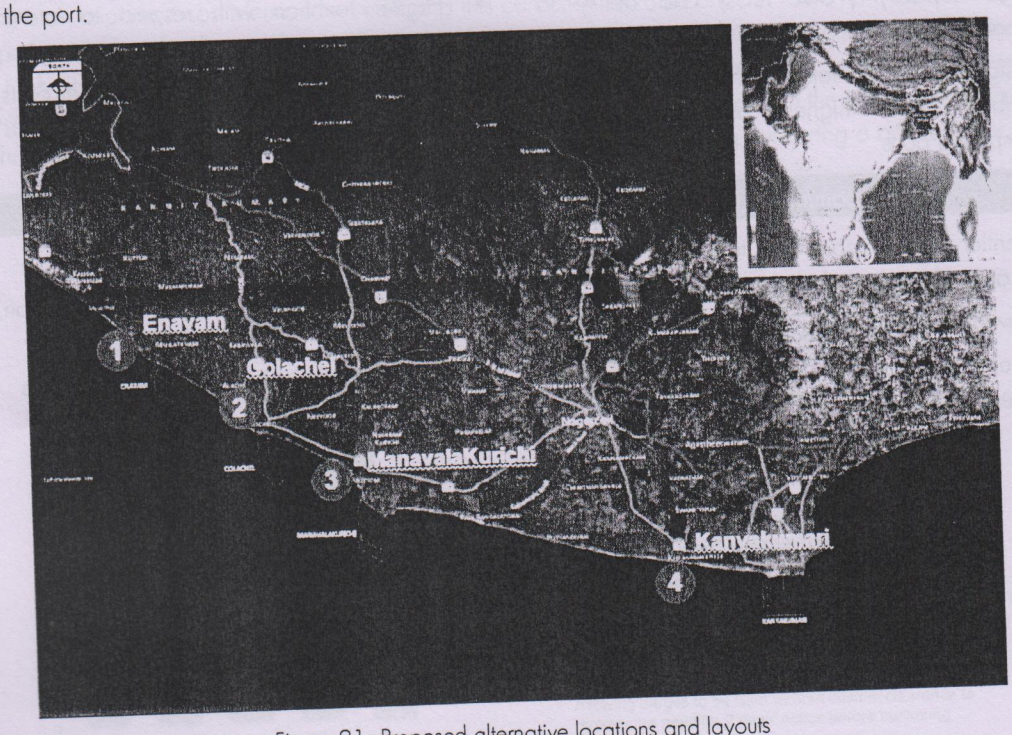


Figure 21: Proposed alternative locations and layouts

The following section contains:

- Description of the four alternative port locations, and the key advantages and disadvantages of each location.
- A general environmental description of each locations with comparative analysis
- A multi-criteria analysis to objectively select the best option for the project.

5.2. PROPOSED LOCATIONS

5.2.1. Alternative 1: Enayam

Enayam is a small fishing and agricultural village located about 8 km northwest of Colachel.

The population is concentrated near a small cape formed by a few emerged rocks. Two big beaches can be found there which serve as a stranding zone for fishing boats. These beaches rely on recently-built breakwaters which run perpendicular to the coast.

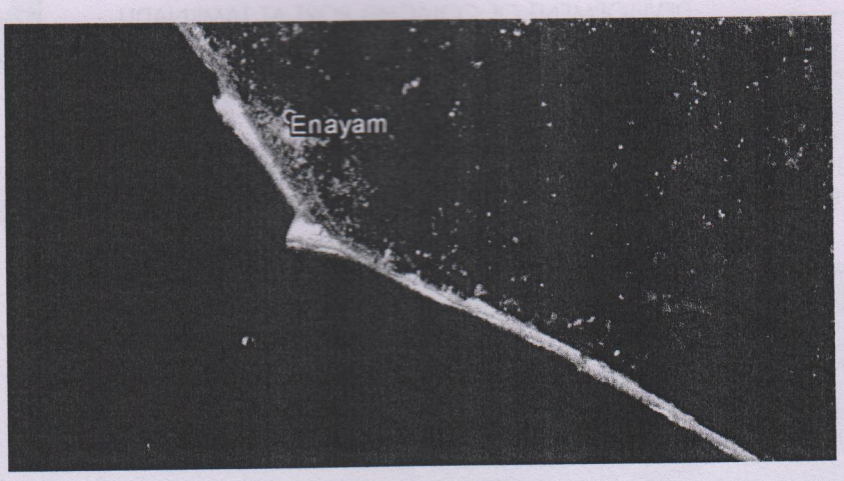


Figure 22: Area of Enayam

Going to the east of the village centre, which is the area where the port is located, the population density decreases, and the land becomes mainly occupied by coconut tree plantations and other crops.

In this section of the coast, the beaches are disappearing and moving backwards. Due to this, , some of the coconut tree plantations are disappearing and the government has built several rock walls to protect the housing near the shoreline in order to reduce the risks of tsunami.

Regarding the geometry of the seabed, the bathymetry shows that the only irregularities corresponding to rocky outcrops are off the cape mentioned above and the remaining area affected by the port infrastructure has a mild slope (softer the greater the depth) and a sandy nature. The -20.0 m depth line is about 1,500-2,000 m from the shoreline.

- Port description

The port configuration is parallel to the coast, typical of Mediterranean ports such as Genoa (Italy) Barcelona (Spain) and Marseille (France). The berths are located parallel to the coast, and protected by a breakwater which is also parallel.

The advantages of this distribution are well known in terms of terminal continuity, ease of port expansion and connectivity between terminals and land transport network.

The disadvantages are its direct impact on the shoreline, although in this case, most of the impact has been reduced by moving the port to the east.

The main breakwater is perpendicular to the prevailing south-west swell and almost parallel to the coastline at the -20.0 m depth line. The secondary breakwater, joining the coast and the main breakwater on the north-west part of the port, is designed to allow wave incidence on the beaches as much as possible -and therefore still keeping a similar coastal dynamics as the current one. The first section of this breakwater is perpendicular to the coast to gain port area without affecting significantly the dynamics.

A rubble mound breakwater is designed from the coastline to the -15.0 m depth line and a vertical breakwater when the seabed is deeper in order to optimize costs. The vertical breakwater can also be used as a berth without additional works, thus increasing port capacity.

The basin is designed with a width of 1000 meters. This distance is enough for the manoeuvring of vessels up to 400 m, the largest expected, and even if new berths were needed on the port side of the breakwater, such as liquid bulk berths.

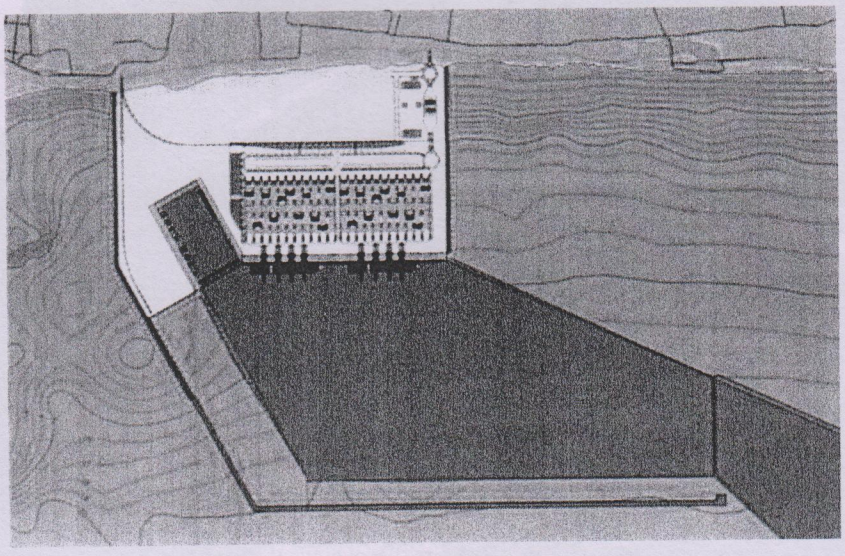


Figure 23: Enayam port layout. Phase 1

Another breakwater has been designed perpendicular to the coast on the east border of the port, both to create a barrier for the sand that can get transported to the port due to littoral drift ,and, at the same time, better protect the harbour basin.

The berths and terminal distribution for Phase 1 are as follows:

- Container Terminal: Located in the northern part of the basin, the one nearest to land, as it is the one with the best connection to the land transport network. Moreover, this position facilitates future expansions of the container terminal.
- Solid Bulk Terminals: Although coal traffic is not expected in Phase 1, the needed space has been reserved at the back of the north-south breakwater section. Since bulk transportation is expected through conveyors and loaders, the distance to land should not be a serious obstacle to the operation in future.
- Multipurpose and ancillary berths: In the most protected and shallowest part of the basin, a small 400 x 200 m basin has been designed to accommodate ancillary vessels and any other ship that can be expected in the future such as cruises, police and customs launches, navy ships, bunkering, etc.

For Phases 2 and 3, both the breakwater and the container berths are expanded towards the east of the coast. The closing breakwater is moved to the east too.

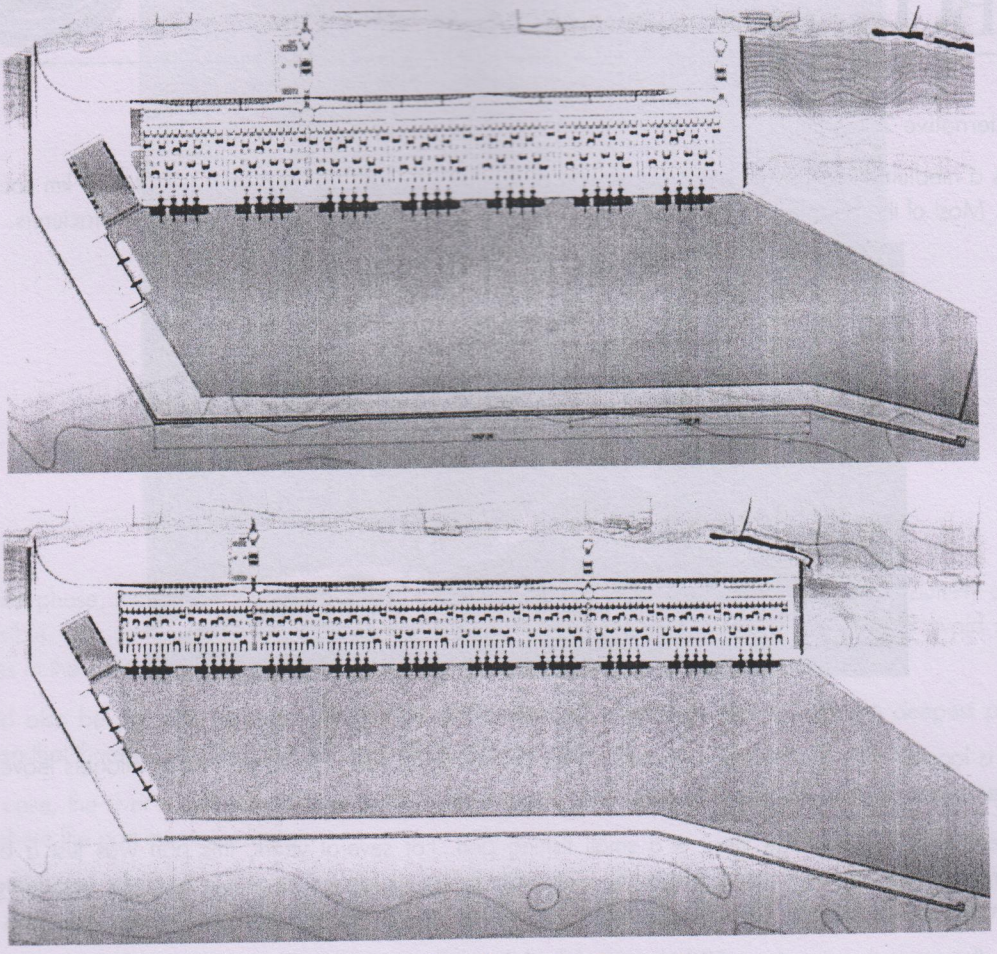


Figure 24: Phase 2 and 3 for Enayam Port

The main figures of this alternative are mentioned in the following table:

Item	Units	Phase 1 (2018-2020)	Phase 2 (2021-2025)	Phase 3 (2026-2030)
Rubble mound breakwater	m	2,133	2,842	3,402
Vertical breakwater	m	2,506	4,395	5,502
Reclaimed land	Ha	93	249	379
Berths total lengh	m	1,400	3,800	5,400
Dredging	Cu.m	6,819,280	13,151,903	14,973,171

Table 2: Enayam port main figures (cumulative quantities)

5.2.2. Alternative 2: Colachel

Colachel is a medium-sized town, with a population of around 25,000, located approximately 8 km southeast of Enayam. Most of the people are fishermen or farmers, with a small section of traders and manufacturers.

Figure 25: Area of Colachel

The village is located near the beaches created by the breakwaters along the coast, where villagers leave their fishing boats.

At the eastern end of the village there is a small fishing port. For several years, this port was just a beach defended by a rubble mound breakwater, but it is currently being expanded to add a berth for unloading fish from medium size boats (around 15 m long) working in the area.

A small river flows into the sea about 500 m west of the fishing port. It divides the town into two parts, with some rice plantations standing in between.

Overall, the area near the village is densely populated. One has to travel 1.5 km to the east to find less populated areas.

With regard to the water area, there are some rocky outcrops around the cape and even a small chapel has been built there, but the rest of the coast is sandy. The -20.0 contour line is located approximately 2,000 or 2,500 m from the coast.

- Port description

The proposed port location is supported by the small cape on the coast and goes out toward deeper waters via a north-south oriented breakwater until reaching the -20.0 m level. Upon reaching this depth, the breakwater turns eastward to maintain the same depth until it is long enough to protect the inland waters from the southern waves.

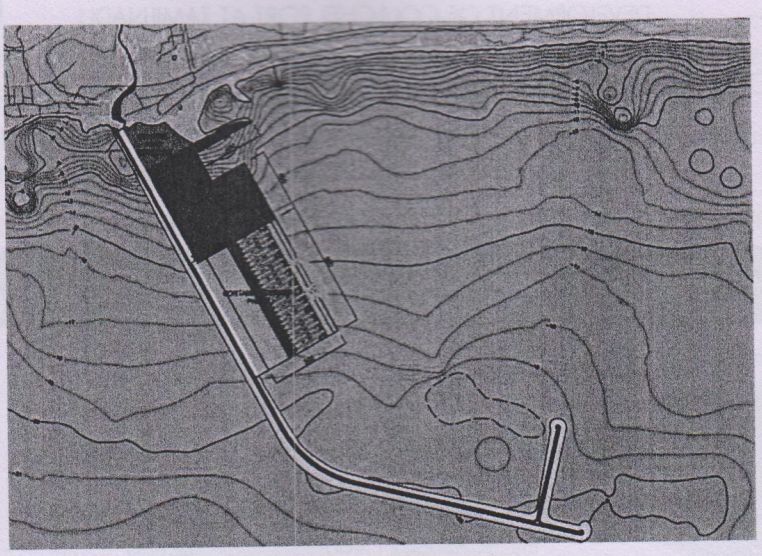


Figure 26: Colachel port layout. Phase 1

In the first phase, the berths are located in the area closest to the shore to connect to land as quickly and easily as possible. This configuration also helps to ensure a simple future expansion of the port and avoid significant changes in the distribution of terminals as the traffic increases.

It would also be possible to begin the construction of the berths and the terminals at the deepest part of the basin, so that there is less dredging but more filling material required.

In any case, the river mouth would have to be moved slightly toward the west to stop it from interfering with the point where the port meets the coast.

For the second phase of operation, corresponding to the year 2025, it would be necessary to build 1.600 meters of berth to expand the container terminal.

In the third phase, the main breakwater would have to be extended by about 1,500 m and another 1,200 meters of berth would have to be built for containers.

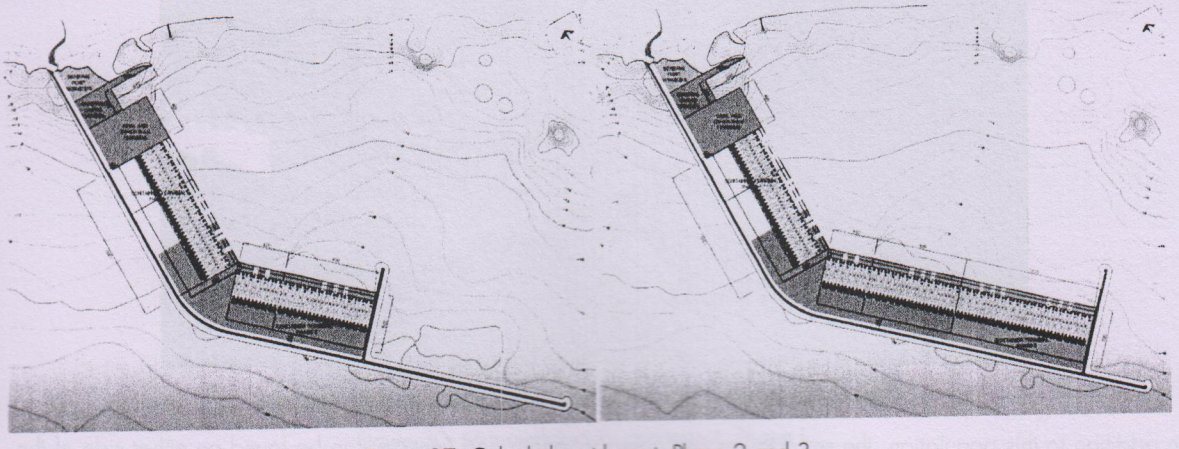


Figure 27: Colachel port layout. Phase 2 and 3

The main figures of this alternative are captured in the following table:

Item	Units	Phase 1 (2018-2020)	Phase 2 (2021-2025)	Phase 3 (2026-2030)
Rubble mound breakwater	m	1,025	1,025	1,025
Vertical breakwater	m	3,898	5,567	6,955
Reclaimed land	Ha	929	203	272
Berths total lengh	m	1,400	3,800	5,400
Dredging	Cu.m	15,343,800	-	-

Table 3: Colachel port main figures (cumulative quantities)

5.2.3. Alternative 3: Manavalakurichi

The name of the alternative comes from Manavalakurichi, a small town located between Colachel and Muttom, where the proposed port meets the land.

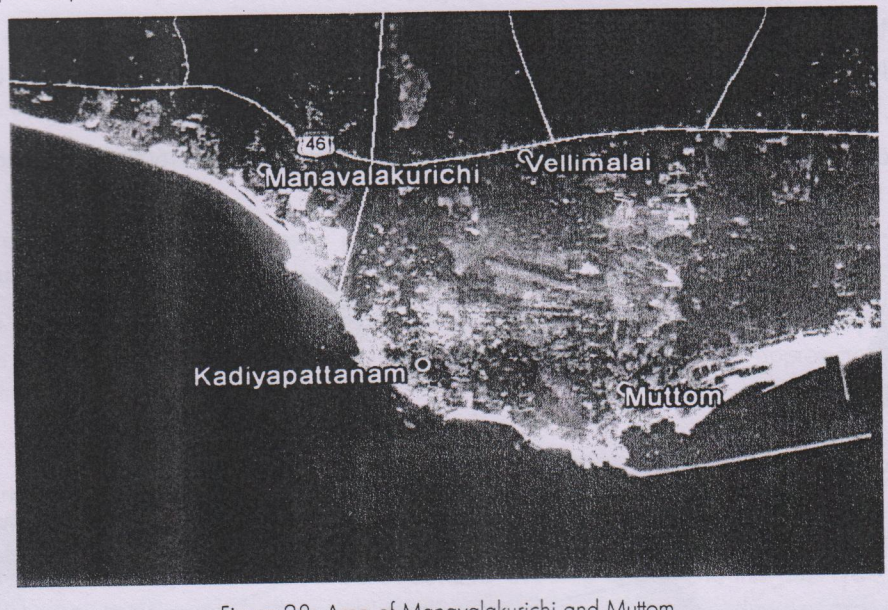


Figure 28: Area of Manavalakurichi and Muttom

In addition to this population, the small towns of Kadiyapattanam and Muttom can be found on either side of the cape. There, as in the rest of the towns along this coast, most people live off fishing and agriculture.

This location features two special elements. On the one hand, the facilities of the state-owned company Indian Rare Earths Limited (IRE Ltd.), where minerals are removed from the sands of the nearby beaches through mechanical processes. The facilities are located inside Manavalakurichi, surrounded by a population cluster

which has grown over the past few years. They occupy around 96 acres (40 ha) of state-owned land which could be used for port activities.

On the other side of the cape, next to Muttom, is a private fishing port called Jeppiaar Fishing Harbor. The port is for unloading and selling fish and was built through Public-Private Partnership (PPP).

In the water area, the coast is quite irregular, and there are many rocks in the vicinity that could hamper the dredging works and complicate port access navigation.

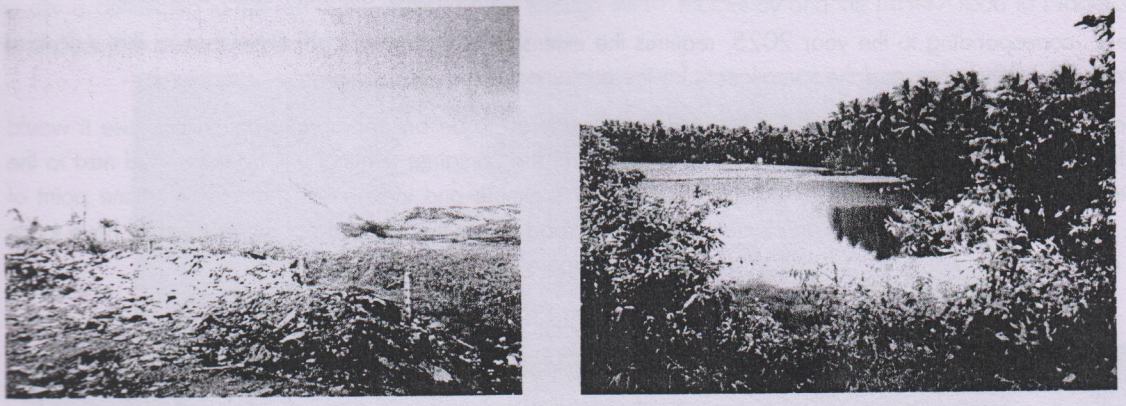


Figure 29: Washed sand stock from IRE Ltd. (left) and river mouth near Manavalakurichi

- Port description

As in the rest of the ports proposed, the main breakwater with northwest-southeast orientation is located at bathymetric level -20.0 to enable vessel access and minimize the need for maintenance dredging. To reach this depth, an offshore port has been proposed which links to land via a bridge about 1.200 m long. This typology is similar to what we can find in Shanghai's new container terminals.

Figure 30: Manavalakurichi port layout. Phase 1

A north-south oriented slope breakwater has been designed next to the bridge to protect the berths from waves coming from the west, typical of the monsoon season.

In phase 1 of the port development, the bulk and container terminals are located in the deepest area, while the berths for auxiliary or smaller vessels are located along the slope breakwater with north-south orientation.

Phase 2, corresponding to the year 2025, requires the extension of the main breakwater toward the south-east by around 1,600 meters, and the same length for the container berth.

In Phase 3, extending the main breakwater was not considered to be an appropriate option because it would greatly affect the coastal dynamics of the beach. Therefore, the container terminal will be expanded next to the private fishing port breakwater. Even though this solution is simple and inexpensive from the maritime point of view, land accessibility would be problematic because a road link to the land side of the port would have to be built, either running through the town or surrounding the cape along the coast.

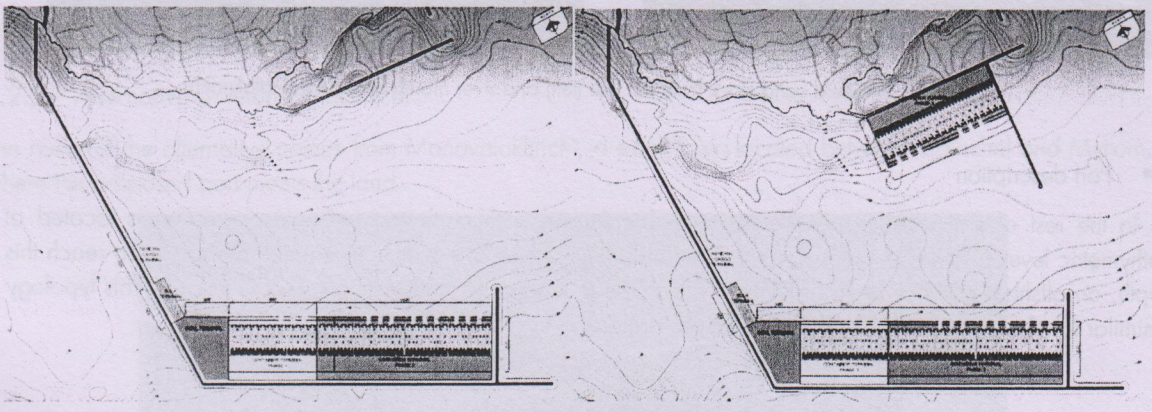


Figure 31: Manavalakurichi port layout. Phase 2 and 3

The main figures of this alternative are included in the following table:

Item	Units	Phase 1 (2018-2020)	Phase 2 (2021-2025)	Phase 3 (2026-2030)
Rubble mound breakwater	m	1,411	1,411	2,650
Vertical breakwater	m	3,527	5,134	5,134
Reclaimed land	Ha	78.1	166	226
Berths total lengh	m	1,400	3,800	5,400
Dredging	Cu.m	12,805,900	-	-

Table 4: Manavalakurichi port main figures (cumulative quantities)

5.2.4. Alternative 4: Kanyakumari

Kanyakumari is a town of about 20,000 inhabitants which is situated at Cape Comorin, the most southern point of the Indian subcontinent.

Because of this geographical fact as well as the temples and beaches existing in the area, the city has become a tourist and pilgrimage destination within and outside India, which has led to urban, infrastructure and trade development in recent years.

The city is connected to the rest of the state by road through NH-7 motorway and the NH-47 road to Nagercoil. By rail, it is also connected to the rest of the country.

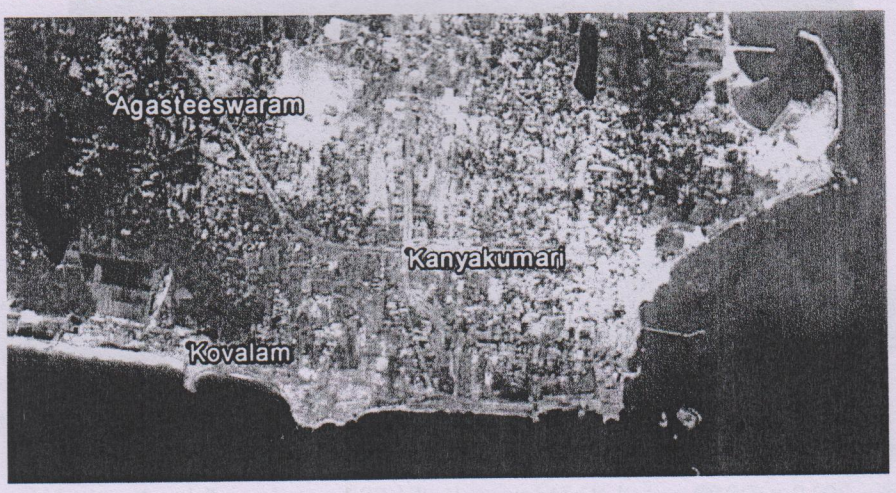


Figure 32: Area of Kanyakumari and Cape Comorin

The coast is rocky in the southern part of the city, which is where the port would be located. In fact, there are both rock outcrops east -Vivekananda Rocks, where the pilgrimage temple is located- and west, where a touristic point exists due to the views of the sunset.

In deeper water the bottom relief softens and is sandy.

- Port description

In this case the port will be just next the coastline, with an L-shaped breakwater that protects against the swell from the south and west. As in the rest of the alternatives, the breakwater reaches the -20.0 m depth line with a north-south orientation, and turns east to run parallel to the coast. In contrast, in this case the depth reached is slightly greater than 20 m, to get an easy access and maneuverability for vessels and to reduce the quantity of required dredging.

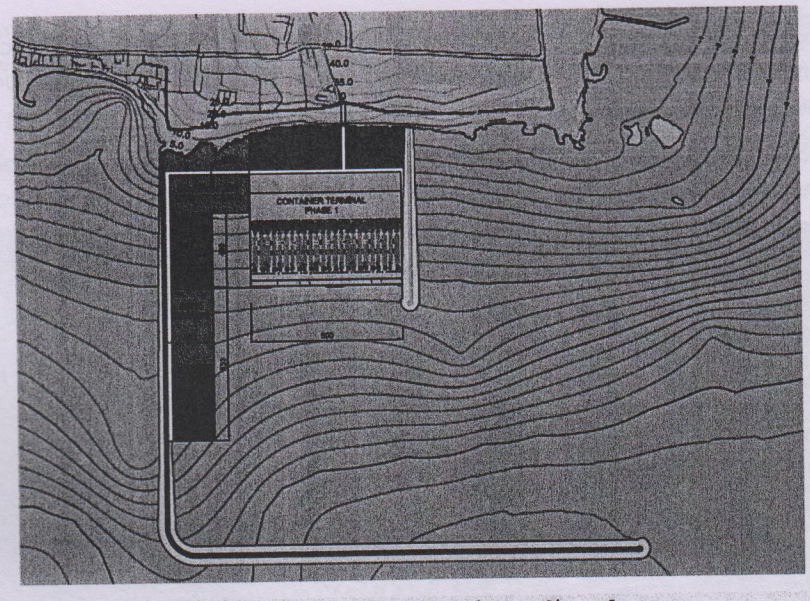


Figure 33: Kanyakumari port layout. Phase 1

In Phase 1, for the 2018 to 2020 period, the container berths are located parallel to the coast along the -10 m depth line, while solids bulk berths are placed attached to the eastern breakwater. The remaining berths are in a small basin between them.

In Phases 2 and 3, the container berth expansion runs on the back of the south breakwater. This causes building a breakwater at the eastern end of the south breakwater to protect the new berths.

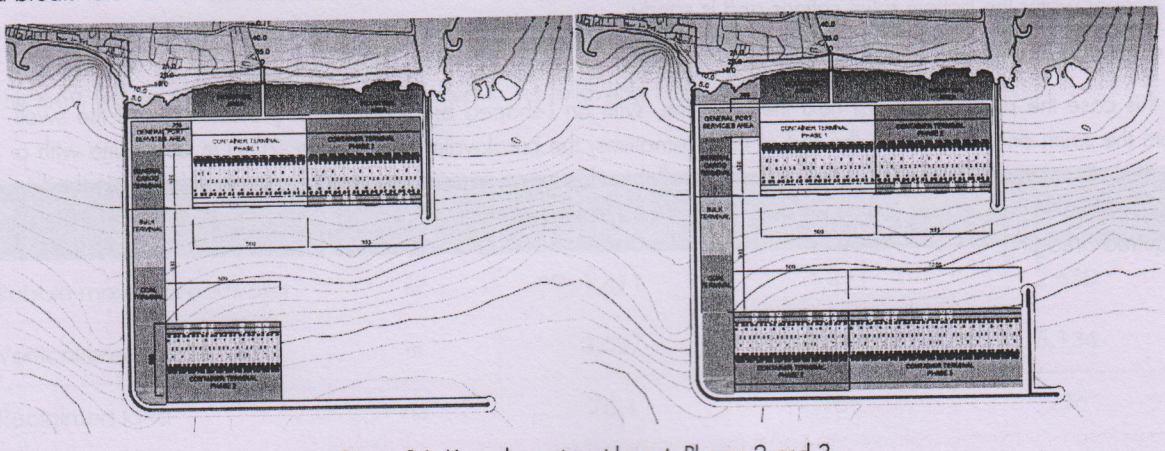


Figure 34: Kanyakumari port layout. Phases 2 and 3

Main figures of this alternative are included in the following table:

Item	Units	Phase 1 (2018-2020)	Phase 2 (2021-2025)	Phase 3 (2026-2030)
Rubble mound breakwater	m	2,760	2,760	2,975
Vertical breakwater	m	2,971	3,788	6,077
Reclaimed land	Ha	117	216	282
Berths total lengh	m	1,400	3,800	5,400
Dredging	Cu.m	7,692,000	-	-

Table 5: Kanyakumari port main figures (cumulative quantities)

5.2.5. Cost estimates

The following table shows the rough cost estimates for **Phase 1** for each alternative.

	Item	Enayam	Colachel	Manavala Kurichi	Kanyakumari
1	Preliminaries	23.63	23.63	23.63	23.63
2	Breakwaters	1,124.35	1,406.33	1,608.34	1,259.21
3	Berths	429.18	429.18	429.18	429.18
4	Dredging and Reclamation	809.12	1,145.94	943.30	824.65
5	Yards	347.29	384.64	378.76	385.83
6	Equipment	1,247.40	1,247.40	1,247.40	1,247.40
7	Buildings	27.44	27.44	27.44	27.44
8	Networks And Utilities	131.04	131.04	131.04	131.04
9	Connectivity	273.42	268.38	255.84	25.20
10	Land Acquisition	70.69	68.29	65.34	6.30
	Others				
11	Engineering And Project Management (7.5%)	336.27	384.92	383.27	326.99
	Provision For Contingencies (15%)	672.53	769.84	766.54	653.98
	Grand Total (Cr Rs.)	5,492.35	6,287.02	6,260.08	5,340.85

Table 6: Cost estimates (in Crore Rupees) for Phase 1 of all alternatives

5.3. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

5.3.1. Introduction

The main objective of the environmental assessment is to undertake an environmental and social analysis of the proposed alternatives giving each alternative an environmental and social dimension.

The assessment of alternatives is based on an estimation of discriminating impacts; i.e. impacts which can distinguish between alternatives.

Hence, common or identical impacts that do not make any difference among proposed alternatives will not be included in the analysis.

The methodology used to evaluate each alternative is based on the following steps:

- Identification of main Project impacts
- Identification of synthetic impact magnitude indicators
- Alternatives assessment
- Summary of adverse impacts of each alternative

After the possible design impacts are identified, the potential environmental and social effects of every design alternative has been assessed based on the estimation of synthetic impact magnitude indicators. These impact magnitude indicators have been designed to allow discrimination between the proposed alternatives.

Such indicators are grouped according to the environmental/social element affected. The values obtained are included in an alternatives analysis where physical, biotic and social sub-factors will carry different weights.

This process assigns an environmental and social value to every alternative considered, enabling their comparison in terms of environmental and/or social impact.

Analysis of each location is developed in the Initial Environmental Examination, included as Annexure 5 of this Report. The following sections summarize the procedures and conclusions of this analysis.

5.3.2. Impacts identification and description

Impacts have been categorized into environmental and social. All these impacts have been evaluated using objective criteria and numerical values in order to facilitate the comparison among all proposed alternatives.

Environmental impacts are:

- Impacts on coastal geomorphology (sediment transport, beach dynamics) due to the new breakwaters and reclamation. Evaluation is made analyzing the quality and length of impacted shoreline.
- Impacts in Marine ecosystems due to dredging, land reclamation and port operation. Evaluation is made through the amount of dredging and land reclamation needed in each alternative.
- Impacts in Hydrology due to the increase of water supply and inland facilities (new road and railway). Assessment is made taking into account the length of inland new networks and distance to towns and villages.
- Impacts in vegetation and terrestrial ecosystems. Evaluation is made by assigning an ecological value to each type of vegetation and calculating the possible area that will likely get altered by the new port.

Social impacts can be summarized as follows:

- Impacts on transport networks (roads) due to material transport during construction. Road length and villages crossed by them are the criteria to asses this impact.
- Impacts on land ownership and displacement of people. The total population that could be affected by the new port has been estimated for each port location.
- Impacts on fisheries due to construction works, occupation of shoreline and port activities. This impact has been evaluated by counting the boats that would be relocated by each port.
- Impacts on tourism. A qualitative criteria has been used taking into account the resorts and touristic places of each location.
- Impacts on coastal planning. The Coastal Zone Management Plan of Tamil Nadu has been used to evaluate the sensitive areas that could be impacted by the new ports.

Further information regarding description and assessment of impacts is included in Section 4.3 of Initial Environmental Evaluation (Annexure 5 to this Report).

5.3.3. Impacts evaluation

Impacts evaluation study, evaluation criteria and detailed description of each ones are included Annexure 6. A brief summary is presented here.

5.3.3.1. Gross impacts evaluation

The following table summarizes the estimated adverse impacts on each alternative.

Estimated adverse impacts on each alternative

Factors	Sub-factor	Adverse Impact	Estimated Impact score Alternatives			
			1 Enayam	2 Colachel	3 Manavala kurichi	4 Kanyakumari
Coastal geomor - phology	Sediment transport, beach dynamics	Changes in erosion and accretion patterns along the coast	78,8	84,8	35,5	48,1
Marine ecosystems	Marine water quality	Increase in turbidity. Change in marine water quality due to aqueous discharges	6230070	15343819	12805893	7692053
	Marine ecology	Removal of benthic communities. Decrease in species diversity				
Hydrology	Water resources	Impact on existing water resources, specially ground water, scarcity	50	100	70	100
	Drainage network	Disturbance to natural drainage pattern due to road widening	13,5	11,6	14	3,5
Vegetation/ terrestrial ecosystems	Vegetation/ land cover	Loss of agricultural land. Loss of natural vegetation,	46808,3	44835,5	46615,5	29358,5
Socio - economic	Road network	Strain on existing infrastructure	50	60	75	20
	Land ownership	Properties loss, displacement of people	2130	6146	2908	4264
	Fisheries	Impact on fishing . Loss of fish landing sites. Decrease of fisheries activities	1170	1557	1145	881
	Tourism	Impact on tourism. Depreciation of tourism areas, impact on cultural heritage and landscape	10	70	40	100
	Coastal Planning	Impact on CRZ-I areas	0	70	0	100

Table 7: Estimated adverse impacts on each alternative

5.3.3.2. Sensitivity analysis

With these values, we proceed to achieve a global impact magnitude value for each of the alternatives. That alternative scoring a lesser gross-magnitude impact value would be the better in terms of environmental and social feasibility.

To obtain that final impact value for each of the alternatives, based on different *weightings* of the estimated impacts values, we considered three different scenarios in order to evaluate the performance of the alternatives in each of them. These are the following:

- Environmental and social factors weight the same. 50%-50%
- All the environmental and social sub-factors weigh the same, i.e. all the adverse impacts weight the same.
- A different weight is given to factors and sub-factors, i.e. to the adverse impacts, based on an expert judgement.

To carry out this sensitivity analysis, first we proceed to normalize (homogenization) the impact values, converting them into a 0-100 range, the highest value corresponding to the negative impact of greater magnitude and therefore the lower valuation of the alternative. The results of the homogeneous evaluation are showed in the following table:

Estimated impact ranged to a 0-100 interval						
Factors	Sub-factor	Adverse Impact	Estimated Impact score			
			Alternatives			
			1 Enayam	2 Colachel	3 Manavala kurichi	4 Kanyakumari
Coastal geomor - phology	Sediment transport, beach dynamics	Changes in erosion and accretion patterns along the coast	92,9	100,0	41,9	56,7
Marine ecosystems	Marine water quality	Increase in turbidity. Change in marine water quality due to aqueous discharges	40,6	100,0	83,5	50,1
	Marine ecology	Removal of benthic communities. Decrease in species diversity				
Hydrology	Water resources	Impact on existing water resources, specially ground water, scarcity	50,0	100,0	70,0	100,0
	Drainage network	Disturbance to natural drainage pattern due to road widening	96,4	82,9	100,0	25,0
Vegetation/ terrestrial ecosystems	Vegetation/ land cover	Loss of agricultural land. Loss of natural vegetation,	100,0	95,8	99,6	62,7
Socio - economic	Road network	Strain on existing infrastructure	66,7	80,0	100,0	26,7
	Land ownership	Properties loss, displacement of people	34,7	100,0	47,3	69,4
	Fisheries	Impact on fishing . Loss of fish landing sites. Decrease of fisheries activities	75,1	100,0	73,5	56,6
	Tourism	Impact on tourism. Depreciation of tourism areas, impact on cultural heritage and landscape	10,0	70,0	40,0	100,0
	Coastal Planning	Impact on CRZ-I areas	0,0	70,0	0,0	100,0

Table 8. Estimated adverse impacts valuation per alternative - Homogeneous evaluation

For the sensitivity analysis I, all the factors are equally weighted (0.5) and the impact scored is calculated. The results are as follows:

Sensitivity analysis 1: Environmental and social factors weigh the same. 50%-50%

Factors		Sub-Factors		Adverse Impact	Estimated Impact score Alternatives			
	Weights		Weights		1 Enayam	2 Colachel	3 Manavala kurichi	4 Kanyakumari
Coastal geomor - phology	0,5	Sediment transport, beach dynamics	0,125	Changes in erosion and accretion patterns along the coast	11,6	12,5	5,2	7,1
Marine ecosystems		Marine water quality	0,125	Increase in turbidity. Change in marine water quality due to aqueous discharges	5,1	12,5	10,4	6,3
		Marine ecology		Removal of benthic communities. Decrease in species diversity	0,0	0,0	0,0	0,0
Hydrology		Water resources	0,063	Impact on existing water resources, specially ground water, scarcity	3,1	6,3	4,4	6,3
		Drainage network	0,063	Disturbance to natural drainage pattern due to road widening	6,0	5,2	6,3	1,6
Vegetation/ terrestrial ecosystems		Vegetation/ land cover	0,125	Loss of agricultural land. Loss of natural vegetation,	12,5	12,0	12,4	7,8
Socio - economic	0,5	Road network	0,100	Strain on existing infrastructure	6,7	8,0	10,0	2,7
		Land ownership	0,100	Properties loss, displacement of people	3,5	10,0	4,7	6,9
		Fisheries	0,100	Impact on fishing . Loss of fish landing sites. Decrease of fisheries activities	7,5	10,0	7,4	5,7
		Tourism	0,100	Impact on tourism Depreciation of tourism areas, impact on cultural heritage and landscape	1,0	7,0	4,0	10,0
		Coastal Planning	0,100	Impact on CRZ-I areas	0,0	7,0	0,0	10,0
					57,0	**90,4**	**64,8**	**64,3**

Table 9. Estimated adverse impacts valuation per alternative - Sensitivity analysis I

For the sensitivity analysis II, all the sub-factors (11) are equally weighted (0.09). The results are as follows

Sensitivity analysis 2: All the environmental and social sub-factors weigh the same

Factors	Sub-factor	weights	Adverse Impact	Estimated Impact score Alternatives			
				1 Enayam	2 Colachel	3 Manavala kurichi	4 Kanyakumari
Coastal geomor - phology	Sediment transport, beach dynamics	0,09	Changes in erosion and accretion patterns along the coast	8,4	9,0	3,8	5,1
Marine ecosystems	Marine water quality	0,09	Increase in turbidity. Change in marine water quality due to aqueous discharges	3,7	9,0	7,5	4,5
	Marine ecology	0,09	Removal of benthic communities. Decrease in species diversity	0,0	0,0	0,0	0,0
Hydrology	Water resources	0,09	Impact on existing water resources, specially ground water, scarcity	4,5	9,0	6,3	9,0
	Drainage network	0,09	Disturbance to natural drainage pattern due to road widening	8,7	7,5	9,0	2,3
Vegetation/ terrestrial ecosystems	Vegetation/ land cover	0,09	Loss of agricultural land. Loss of natural vegetation,	9,0	8,6	9,0	5,6
Socio - economic	Road network	0,09	Strain on existing infrastructure	6,0	7,2	9,0	2,4
	Land ownership	0,09	Properties loss, displacement of people	3,1	9,0	4,3	6,2
	Fisheries	0,09	Impact on fishing . Loss of fish landing sites. Decrease of fisheries activities	6,8	9,0	6,6	5,1
	Tourism	0,09	Impact on tourism. Depreciation of tourism areas, impact on cultural heritage and landscape	0,9	6,3	3,6	9,0
	Coastal Planning	0,09	Impact on CRZ-I areas	0,0	6,3	0,0	9,0
			TOTAL	**51,0**	**80,9**	**59,0**	**58,2**

Table 10. Estimated adverse impacts valuation per alternative - Sensitivity analysis II

For the sensitivity analysis III, all factors and sub-factors are equally weighted by the 3 environmental expert criteria, resulting from the previous impact analysis and experience. The results are as follows:

Sensitivity analysis 3: Expert judgement								
Factors		Sub-factor		Adverse Impact	Estimated Impact score			
					Alternatives			
	weights		weights		1 Enayam	2 Colachel	3 Manavala kurichi	4 Kanyakumari
Coastal geomor - phology	0,2	Sediment transport, beach dynamics	0,2	Changes in erosion and accretion patterns along the coast	13,9	15,0	6,3	8,5
Marine ecosystems	0,15	Marine water quality	0,15	Increase in turbidity. Change in marine water quality due to aqueous discharges	8,1	20,0	16,7	10,0
		Marine ecology	0	Removal of benthic communities. Decrease in species diversity				
Hydrology	0,1	Water resources	0,05	Impact on existing water resources, specially ground water, scarcity	2,5	5,0	3,5	5,0
		Drainage network	0,05	Disturbance to natural drainage pattern due to road widening	4,8	4,1	5,0	1,3
Vegetation/ terrestrial ecosystems	0,2	Vegetation/ land cover	0,2	Loss of agricultural land. Loss of natural vegetation,	15,0	14,4	14,9	9,4
Socio - economic	0,35	Road network	0,04	Strain on existing infrastructure	3,3	4,0	5,0	1,3
		Land ownership	0,07	Properties loss, displacement of people	3,5	10,0	4,7	6,9
		Fisheries	0,1	Impact on fishing . Loss of fish landing sites. Decrease of fisheries activities	7,5	10,0	7,4	5,7
		Tourism	0,07	Impact on tourism. Depreciation of tourism areas, impact on cultural heritage and landscape	1,0	7,0	4,0	10,0
		Coastal Planning	0,07	Impact on CRZ-I areas	0,0	3,5	0,0	5,0
				TOTAL	**59,7**	**93,0**	**67,5**	**63,1**

Table 11. Estimated adverse impacts valuation per alternative - Sensitivity analysis III

The following table and figure summarize the results that express a ***global impact magnitude*** of the impact of each of the alternatives considered. Again, the higher the value obtained the bigger the magnitude of the global negative impact. The best alternative is, therefore, that one with a lower score.

Analysis	Estimated Impact score			
	Alternatives			
	1. Enayam	2. Colachel	3. Manavalakurichi	4. Kanyakumari
All the factors weight the same	51.0	80.9	59.0	58.2
Environmental and social factors weights the same	57.0	90.4	64.8	64.3
Expert judgement.	59.7	93/0	67.5	63.1
Average value			63.8	61.9

Table 12: Total estimated adverse impacts score per alternative

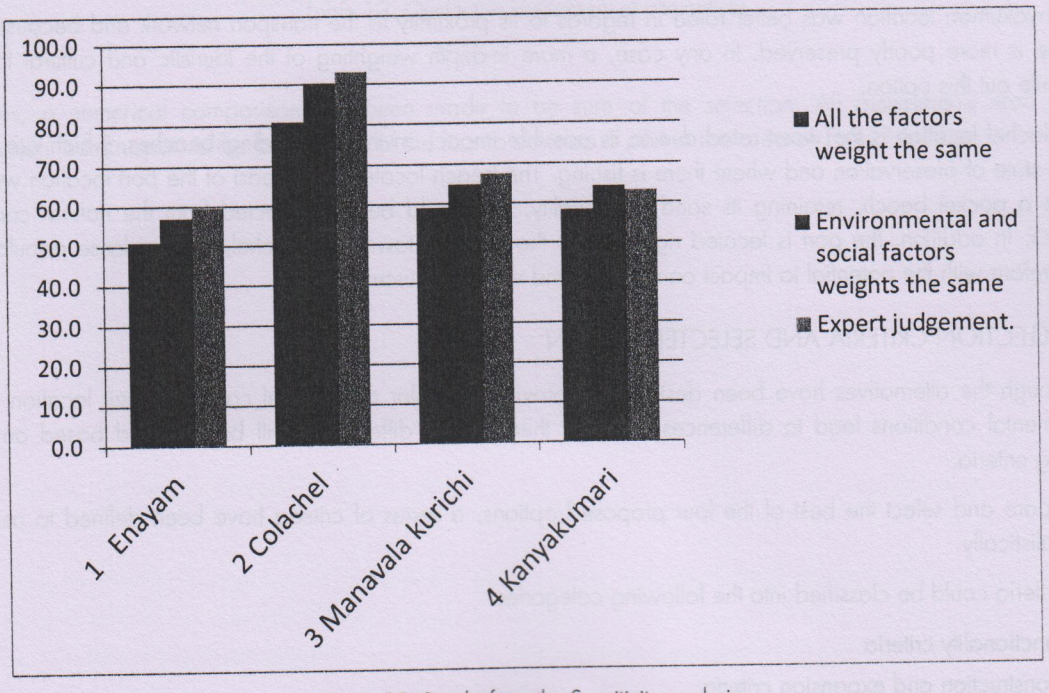


Figure 35: Results from the Sensitivity analysis

5.3.4. Conclusions on environmental impact

The best rated alternative for location, with the lowest environmental and social impact, is Enayam, while the worst rated one, with the highest impact, is Colachel. Kanyakumari and Manavalakurichi obtained similar intermediate ratings. The Enayam location has lower environmental impacts than the others with respect to dredging, cultural sites and its low impact on property due to its low population. Port expansion will not need a wide extra inland area since the land reclamation area will provide room for port facilities and industries.

The Manavalakurichi location has lower environmental impacts than Kanyakumari with respect to, tourism and cultural sites. Manavalakurichi has lower environmental impacts than Enayam with respect to coastline and fishing. This is due to its special configuration whereby the port is not attached to the coastline and connects inland via a bridge that allows the transport of sediments and therefore has a lower effect on coastal processes. Its inland population density which could be affected by the expansion of the port is lower than in Colachel and Kanyakumari.

The Kanyakumari location was better rated in regards to its proximity to the transport network and because the coastline is more poorly preserved. In any case, a more in-depth weighting of the touristic and cultural factor would rule out this option.

The Colachel location is the worst rated due to its possible impact on the surrounding beaches, which are in a suitable state of preservation and where there is fishing. The beach located to the east of the port location would become a pocket beach, retaining its sand and quality, but would be disconnected from the natural coastal dynamics. In addition, the port is located right next to the heritage town of Colachel, with a dense population and therefore with the potential to impact on underground water resources.

5.4. SELECTION CRITERIA AND SELECTED OPTION

Even though the alternatives have been designed to provide a similar operational capacity, their location and environmental conditions lead to differences between them. These differences will be assessed based on the following criteria:

To compare and select the best of the four proposed options, a series of criteria have been defined to assess them realistically.

These criteria could be classified into the following categories:

- **Functionality criteria**
- **Construction and expansion criteria**
- **Connectivity criteria**
- **Environmental criteria**, which includes:
  - i. Environmental impact
  - ii. Social Impact

Other criteria like construction costs and maintenance costs have been evaluated.

The table below is the result of applying these criteria to each option:

	Enayam	Colachel	Manavalakurichi	Kanyakumari
Population Density	Low	Very high	High	Very high
Accessibility & manoeuvrability	Good vessel operability	High vessel operability	High vessel operability	Good vessel operability
Expandability	Easy to expand, even beyond phase 3	Difficult to expand	Difficult to expand	Easy to expand
Environmental & social impact	Low impact	High impact	Medium impact	Medium impact
Land availability	Higher possibility of land acquisition	Lower possibility of land acquisition	Lower possibility of land acquisition (*possibility of acquiring ¬100 acre of IRE land)*	Lower possibility of land acquisition
Impact of tourism and housing	Low impact; shoreline free of houses	High impact on housing	High impact on housing	High impact on tourism
Hinterland Connectivity	Longer distance to NH -7 and rail line	Longer distance to NH -7 and rail line	Longer distance to NH -7 and rail line	Best connectivity to NH 7 and rail line

Table 13: Qualitative assessment of alternatives

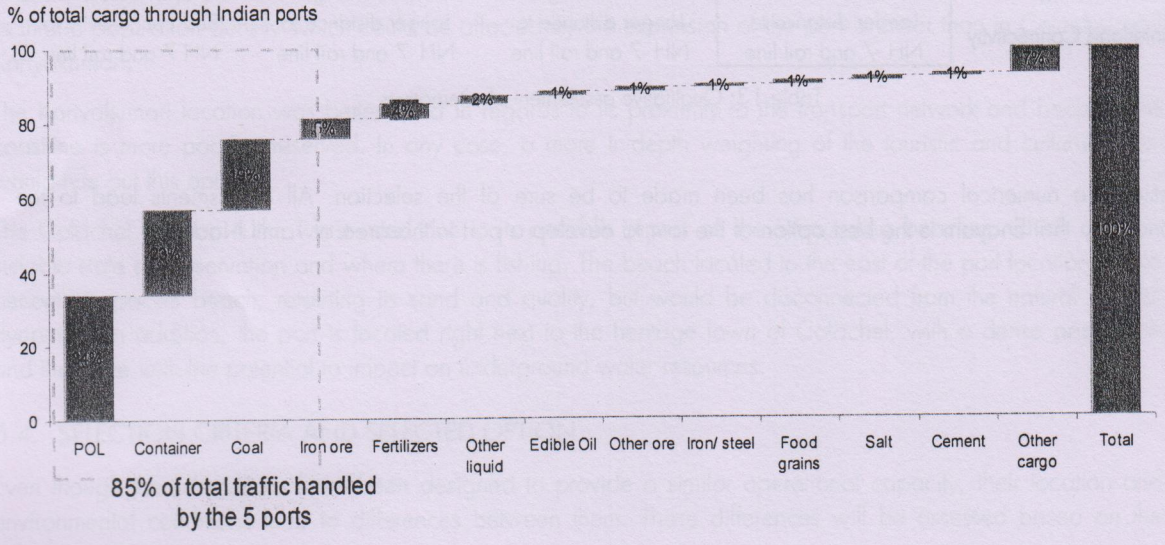
Besides, a numerical comparison has been made to be sure of the selection. All assessments lead to the conclusion that **Enayam is the best option** of the four to develop a port in this area of Tamil Nadu.

6. TRAFFIC AND MARKET STUDY

6.1. APPROACH

A detailed traffic modelling and analysis has been conducted to arrive at the traffic estimates for the port. Based on the overall analysis of the current traffic, it has been assessed that the principal commodities that contribute to majority of the cargo volumes in the region are: POL (petroleum, oil and lubricants), Container and Coal.

Hence, this traffic study has been further detailed out for these three principal commodities.

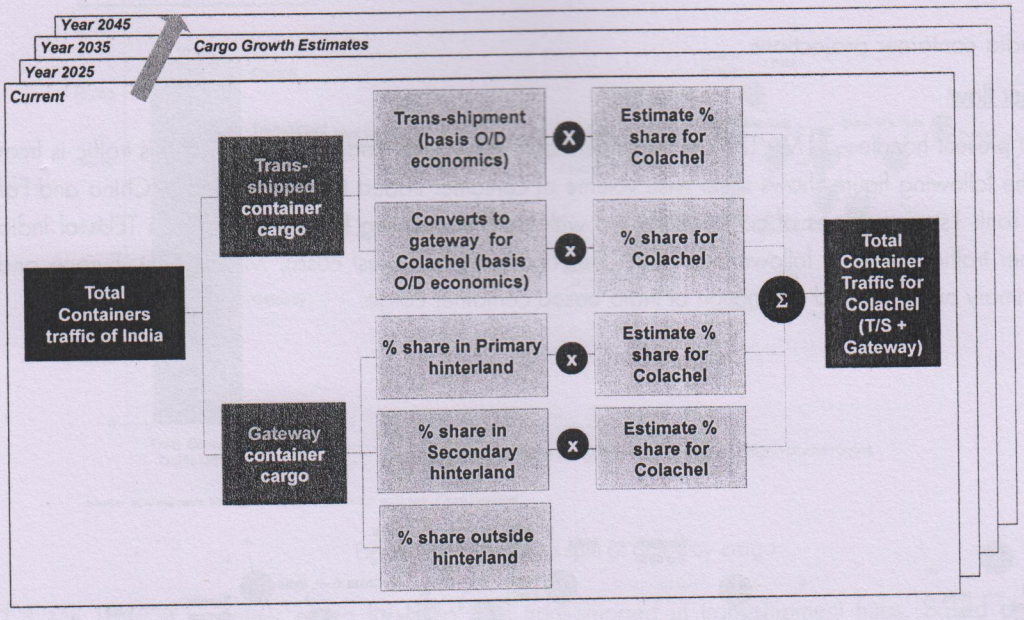


Source: IPA data on major ports, BCG analysis

Figure 36: Commodity wise cargo split from Indian ports

Further, the container traffic has been studied in detail in two categories: trans-shipment traffic and gateway separately, keeping in mind that the one of the key objectives of this port project is target and gain back share of the Indian container cargo being trans-shipped outside India.

A comprehensive study has been undertaken for container traffic forecasts. The detailed methodology followed for container traffic forecast has been summarised below:



Coal traffic projections have been undertaken based on the detailed analysis of the region. The key steps in the methodology for coal traffic forecast have been summarized below:

1. Power demand-supply gap for Tamil Nadu estimated by mapping all announced power plant plans and projecting future power demand in the state
2. Feasibility of Enayam as a location, to cater to already planned power plants
3. Feasibility and timing for setting a new captive power plant for Enayam has been evaluated

In order to assess the POL traffic, the methodology followed focuses on the feasibility of Enayam for catering to any planned petroleum refineries in the country.

6.2. TRAFFIC PROJECTIONS

6.2.1. Container traffic projections

Containers are expected to be the key traffic drivers for Enayam port. Enayam has been proposed with the aim to capture traffic that today gets transported through Colombo and other trans-shipment hubs. This section projects container traffic for Enayam. First, an overall view of India's container traffic flow is built and India's container traffic is projected based on key traffic growth drivers. Then, hinterland for Enayam is identified; the existing industries in the hinterland are studied and potential industrialization is explored. Finally, Enayam's share of both trans-shipment and gateway traffic has been estimated.

6.2.1.1. India container projections

Indian container flow

Indian ports at present handle ~11Mn TEUs of container traffic every year and around 95% of this traffic is from EXIM trade. The following figure shows route wise volume of container traded to and from India. China and Far East countries rank 1st on volumes of container traded with India accounting for around 2.7 Mn TEUs of India based container traffic. China is followed by North America (east and west costs), Middle East, Europe and S.E.Asia as primary origin or/and destination of India based container cargo.

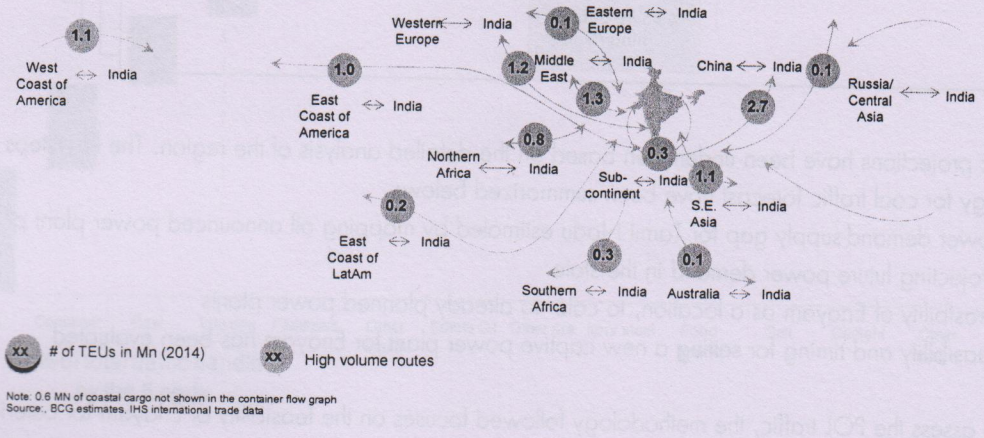
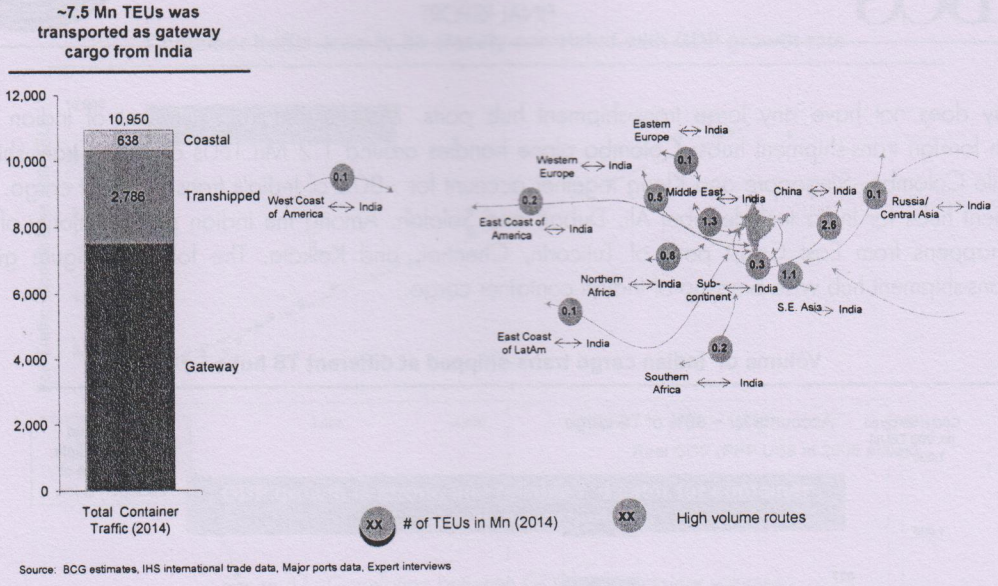


Figure 37: Trade route wise split of container traffic

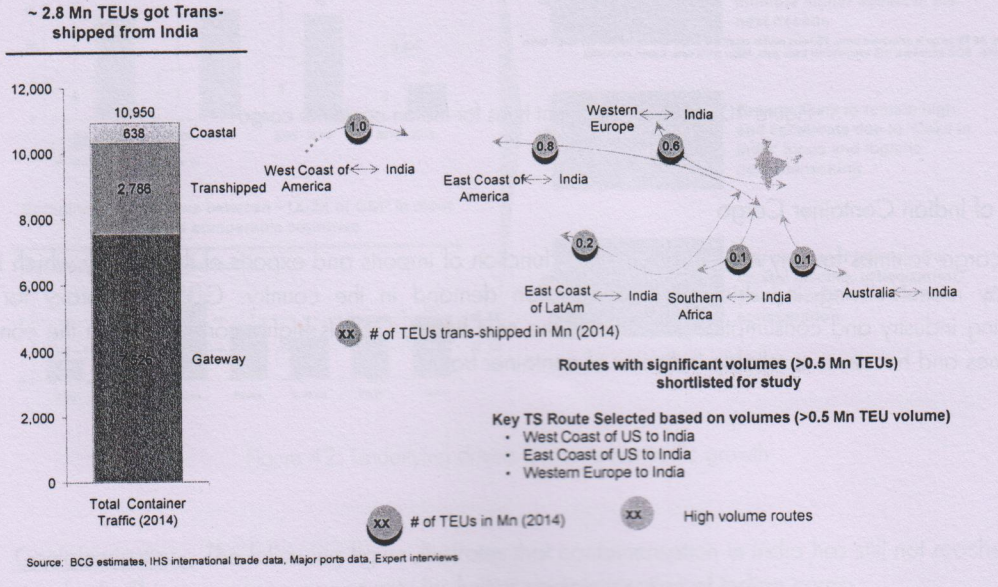
Around 7.5 Mn TEUs of container cargo is directly shipped to Indian ports from the origin ports. Cargo to/from China is almost entirely direct Gateway cargo which today comes to JNPT, Mundra and other Indian ports. Similarly cargo to Middle East, Africa, and S.E.Asia are also direct gateway traffic.



Source: BCG estimates, IHS international trade data, Major ports data, Expert interviews

Figure 38: Route wise split of gateway cargo

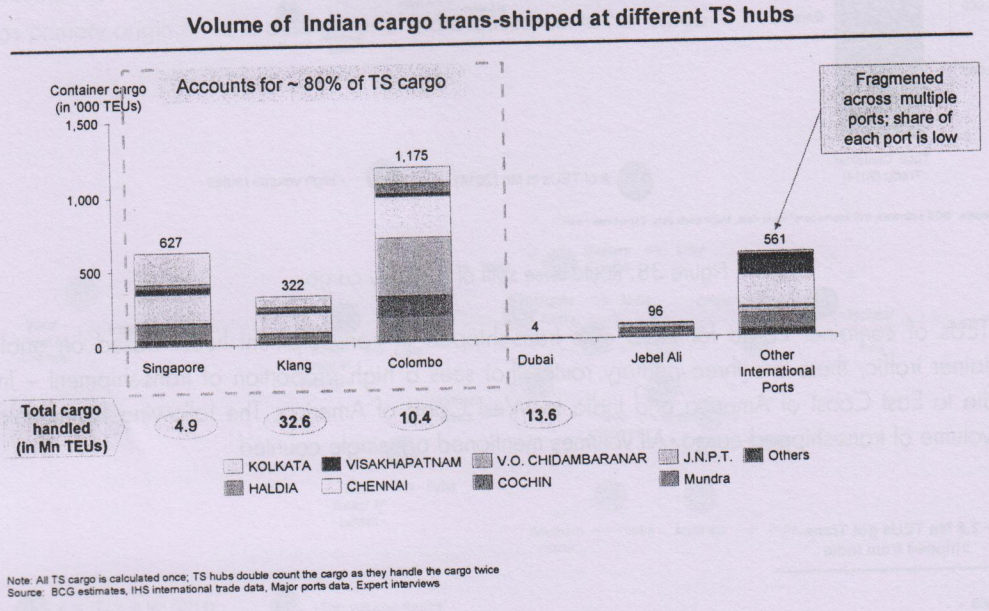
~2.8 Mn TEUs of container cargo for India gets trans-shipped in trans-shipment hubs. Based on analysis of global container traffic, there are three primary routes that sees a high proportion of trans-shipment – India to Europe, India to East Coast of America and India to West Coast of America. The following figure details out route wise volume of trans-shipped cargo. All volumes mentioned are single counted.



Source: BCG estimates, IHS international trade data, Major ports data, Expert interviews

Figure 39: Route wise split of trans-shipment cargo

India today does not have any large trans-shipment hub ports. Most of the trans-shipment of Indian cargo happens in foreign trans-shipment hubs. Colombo alone handles around 1.2 Mn TEUs of India's trans-shipment cargo, while Colombo, Singapore and Klang together account for ~80% of India's trans-shipment cargo. Other trans-shipment hubs for India include Jebel Ali, Dubai, and Salalah. Among the Indian ports, majority of trans-shipment happens from East Coast ports of Tuticorin, Chennai, and Kolkata. The following figure gives a detailed trans-shipment hub wise breakup of Indian container cargo.



Note: All TS cargo is calculated once; TS hubs double count the cargo as they handle the cargo twice
Source: BCG estimates, IHS international trade data, Major ports data, Expert interviews

Figure 40: Key trans-shipment hubs for Indian container cargo

Projections of Indian Container Cargo

Container cargo volumes for any country are a direct function of imports and exports of the country which in turn is driven by manufacturing industries and consumption demand in the country. GDP is a proxy for both manufacturing industry and consumption. As seen in the next figure, GDP is highly correlated with the container traffic volumes and hence, is a reliable indicator of container traffic.

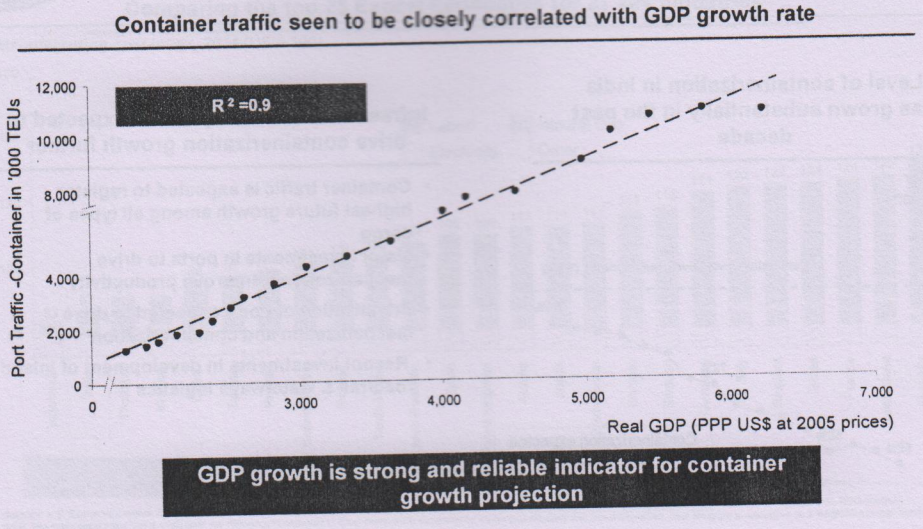


Figure 41: Correlation between GDP and container volumes

Historical trends for container traffic volume shows that container traffic outgrows GDP growth. The reason of higher container traffic growth is due to three key factors, as described in the figure below:

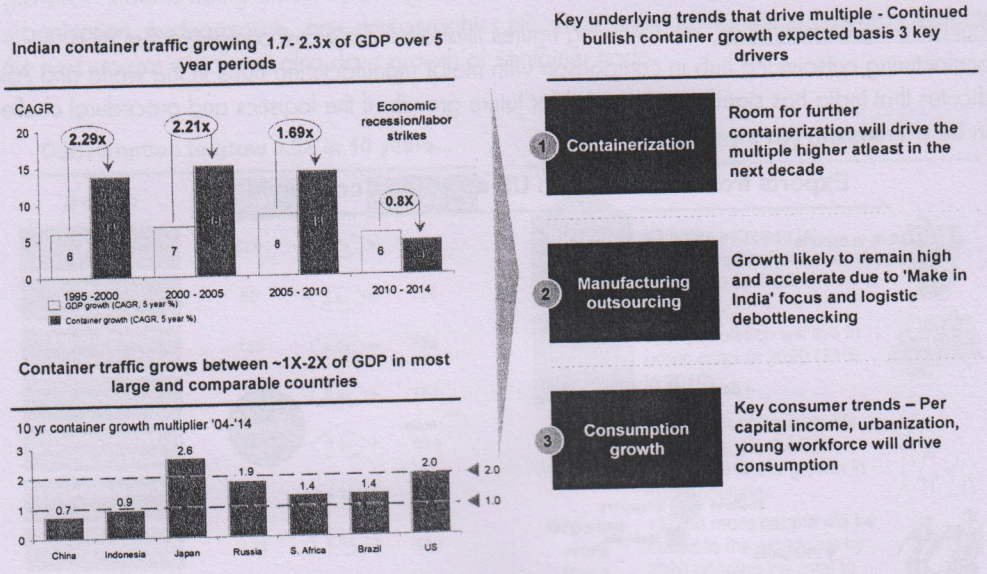


Figure 42: Underlying drivers for container traffic growth

1. Containerisation: The following figure illustrates that containerisation in India has still not reached global standards. This presents an opportunity for further containerisation of Indian cargo.

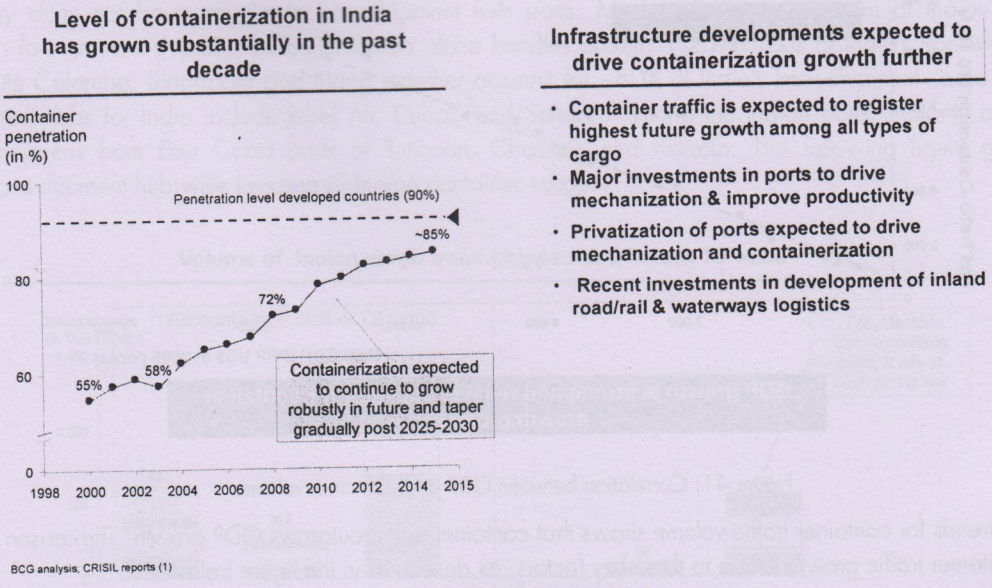


Figure 43: Containerisation trend

2. Manufacturing Outsourcing: The following figures illustrate India's cost competiveness as a manufacturing outsourcing hub in comparison with major manufacturing hubs in the world and Asia. It indicates that India has significant potential for future growth, if the logistics and procedural challenges can be overcome.

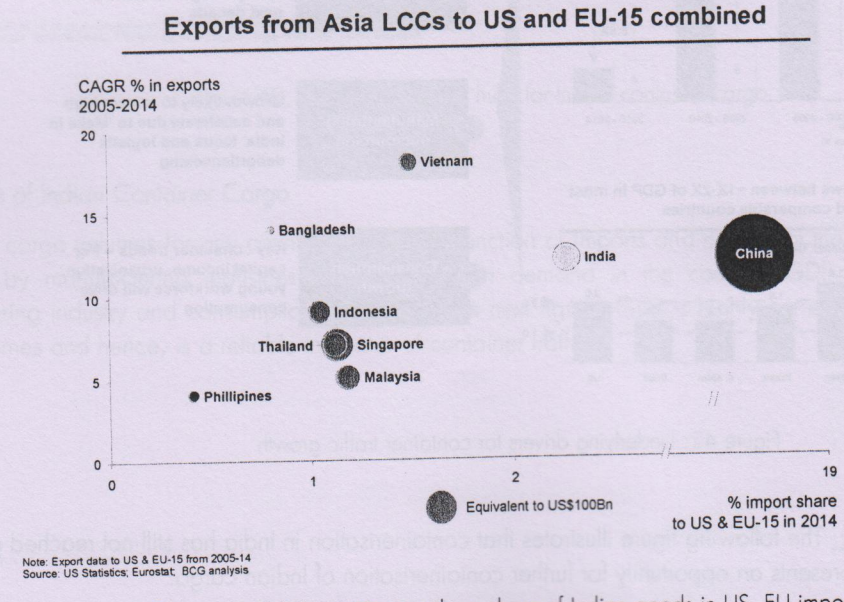


Figure 44: India's export growth vs. share of Indian goods in US, EU imports

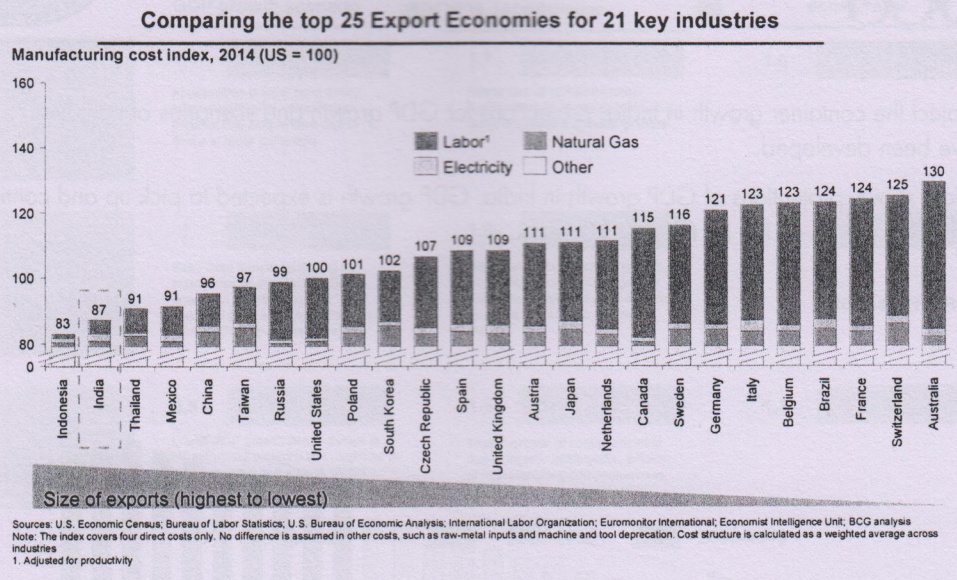


Figure 45: Manufacturing cost benchmark for top export economies

3. Consumption: The following figure illustrates the key drivers of consumption in India. The consumption growth in India is being driven by strong macroeconomic and demographic trends such as urbanization, nuclearization, age demographics etc. Thus, rapid consumption growth is expected over the next several which will also drive growth of container trade.

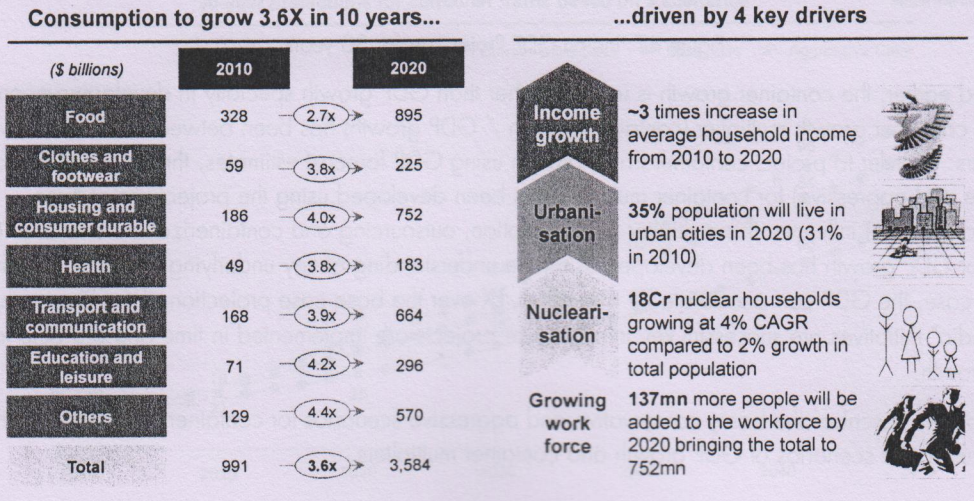


Figure 46: Consumption growth in India

In order to project the container growth in India, projections for GDP growth and scenarios of container multipliers have been developed.

The figure below shows projections of GDP growth in India. GDP growth is expected to pick up and continue to be strong at an average of ~6.5% for the next 10 years.

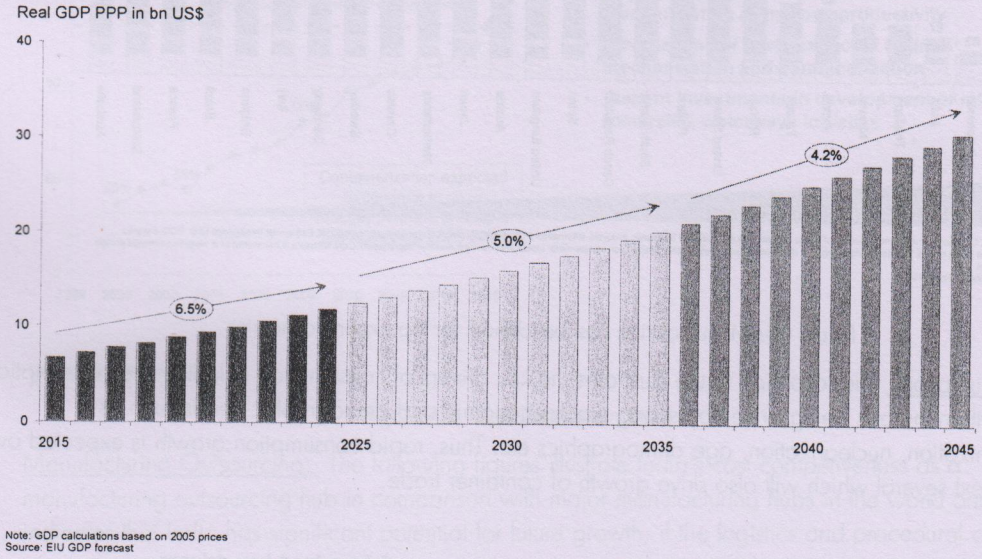


Figure 47: Indian GDP Projections for 30 years

As discussed earlier, the container growth is usually higher than GDP growth specially in developing economics. In India the container growth multiplier (container growth / GDP growth) has been between 1.7 – 2.3 over the last 20 years. In order to project container traffic growth using GDP forecast estimates, three scenarios (base, conservative and aggressive) for container multiplier has been developed using the projections of three underlying drivers that influence this multiplier – consumption, outsourcing and containerization. Similarly, three scenarios for GDP growth has been developed using the understanding of key underlying trends. e.g. . In aggressive case, the GDP can accelerate by a factor 1.1X over the base case projection of 6.5% growth, if "Make in India" initiatives are successful key infrastructure projects are implemented in time and are able to spur industrial growth.

The figure below describes the base, conservative and aggressive scenarios for container traffic projection developed using the scenarios of GDP growth and container multipliers.

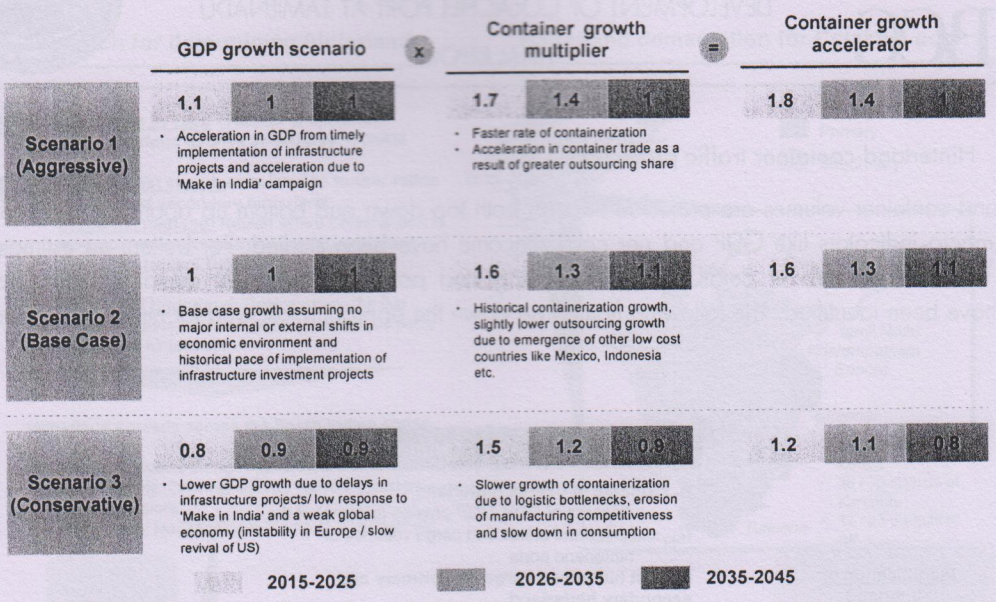


Figure 48: Assumptions for scenario analysis

The scenarios have then modelled and developed into container volume forecasts. The traffic forecast over the next 30 years has been detailed out in the following figure. In 2030 India's container volumes are expected to reach 35-54 Mn TEUs in the base case

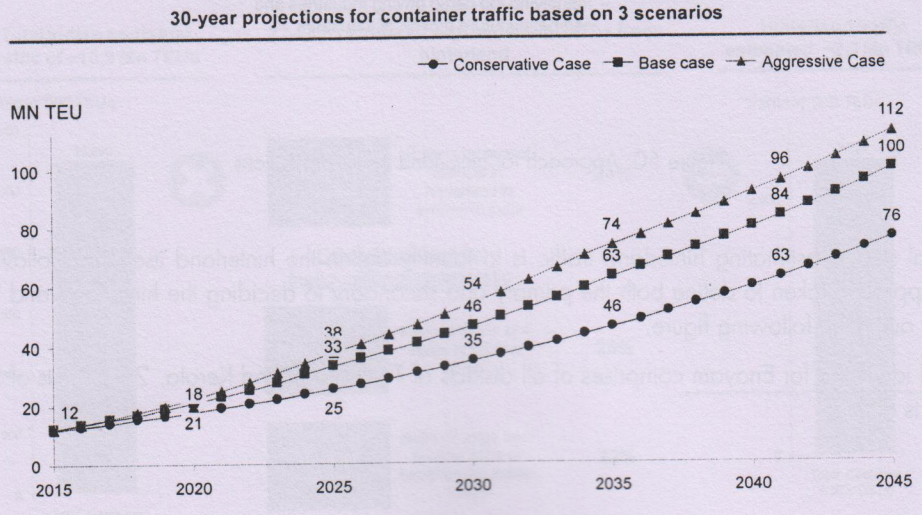


Figure 49: 30 year projection of Indian container cargo

6.2.1.2. Hinterland container traffic projections

The hinterland container volumes are projected through both top down and bottom up approach. For top down estimates, macro indicators like GDP and per capita income have been studied. For bottom up estimates, the hinterland has been studied in detail and both existing and potential sources of container traffic from the hinterland have been identified. The following figure lays down the approach followed for hinterland projections.

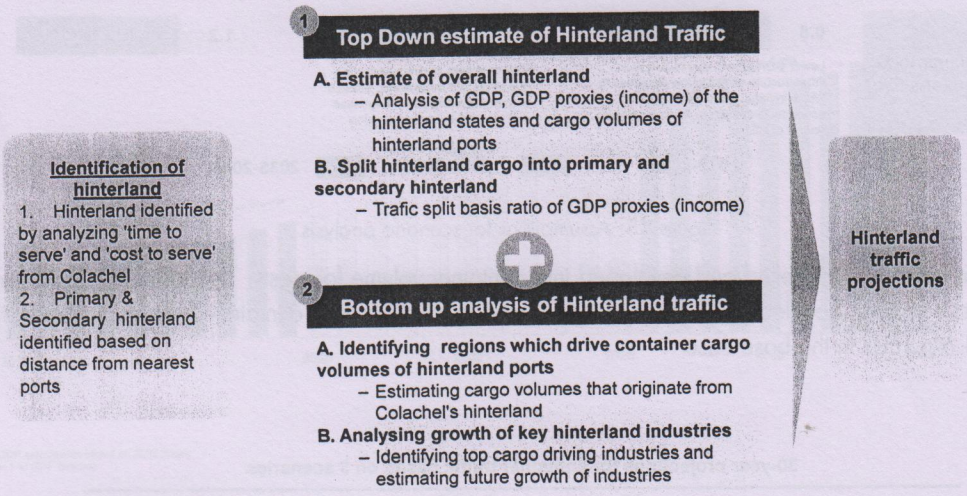


Figure 50: Approach for hinterland traffic projections

The first critical step in estimating hinterland traffic is to identify define the hinterland itself. The following figure presents the approach taken to define both the primary and secondary to deciding the hinterland and further has been detailed out in the following figure.

The hinterland identified for Enayam comprises of all districts of TamilNadu and Kerala, 26 districts of Karnataka and 12 districts of AP.

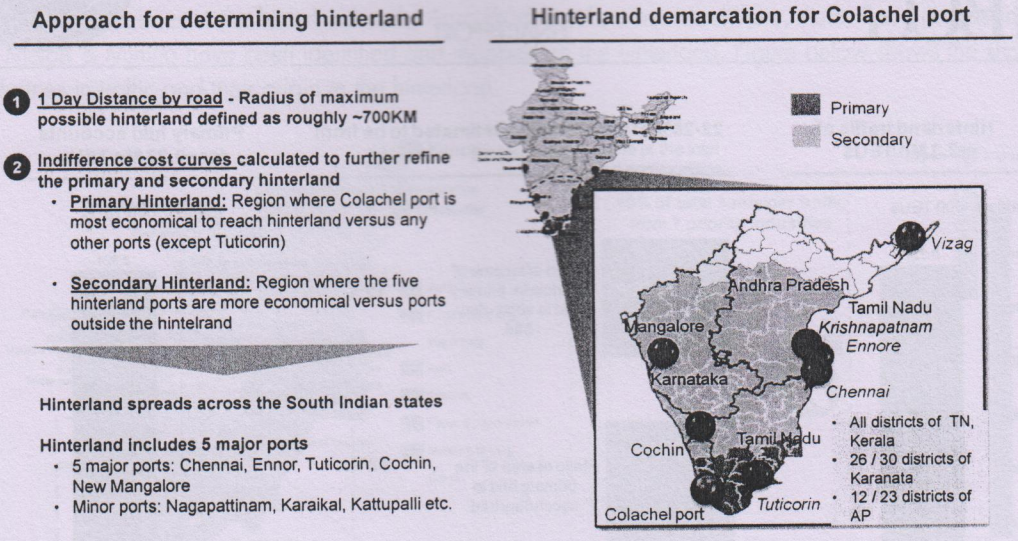


Figure 51: Hinterland identification for Enayam

For this hinterland, the top down and bottom up traffic estimates have been analysed as detailed below.

Top down estimate of hinterland traffic:

The approach taken for estimating of container traffic originating from the hinterland through top-down estimates is explained in figure below. Using this approach, the current hinterland traffic has been estimated as ~2.3 MN TEUs.

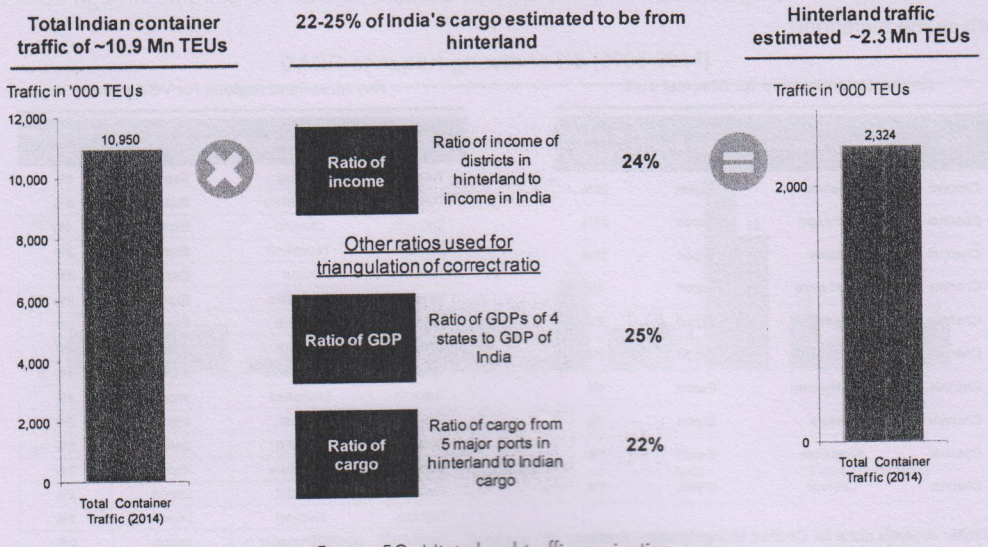


Figure 52: Hinterland traffic projection

Primary hinterland accounts for ~12% of hinterland traffic, rest originates from secondary hinterland, as described in the analysis shared in figure below.

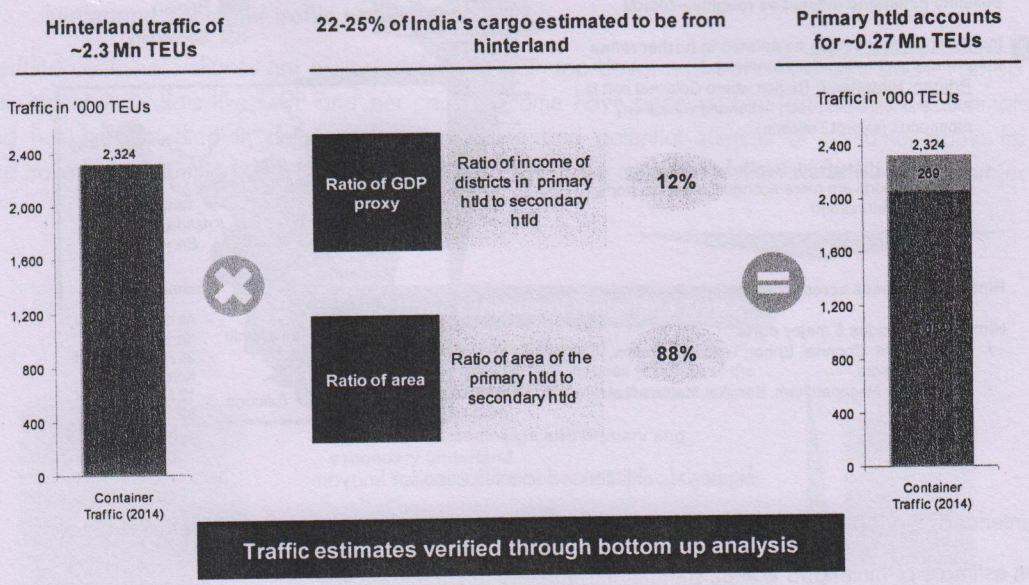


Figure 53: Split of hinterland traffic into primary and secondary hinterland

Bottom up estimate of hinterland traffic:

In bottom-up analysis, the hinterland regions that drive container traffic for the existing hinterland ports have been identified first. As seen from the figure below, 10 -15 districts account for 60-70% of traffic through each of the existing ports in the hinterland.

Key hinterland region for Chennai port

Port	Origin/ Destination	Import or Export	% of total cargo
Chennai	Chennai	Export	26%
Chennai	Krishnagiri	Export	21%
Chennai	Nellore	Export	14%
Chennai	Coimbatore	Export	4%
Chennai	Medak	Export	2%
Chennai	Khammam	Export	2%
Chennai	Kanchipuram	Export	1%
Chennai	Vellore	Export	1%
Chennai	Bangalore	Export	1%
Chennai	Chennai	Import	1%

Similar analysis done for Cochin; Mangalore and Ennore have negligible container traffic

Key hinterland regions for VOC port

Port	Origin/ Destination	Import or Export	% of total cargo
Tuticorin	Tirupur	Export	8%
Tuticorin	Coimbatore	Export	6%
Tuticorin	Chennai	Export	4%
Tuticorin	Tirunelveli	Export	3%
Tuticorin	Karur	Export	3%
Tuticorin	Bangalore	Export	2%
Tuticorin	Madurai	Export	2%
Tuticorin	Chennai	Import	4%
Tuticorin	Coimbatore	Import	4%
Tuticorin	Tirunelveli	Import	4%
Tuticorin	Kollam	Import	3%
Tuticorin	Madurai	Import	2%
Tuticorin	Bangalore	Import	2%
Tuticorin	Dindigul	Import	2%
Tuticorin	Sivakasi	Import	2%
Tuticorin	Virudhunagar	Import	2%

Key cargo driving regions fall within the hinterland areas of the ports

Figure 54: Sources of hinterland traffic

Further, the key industries in the hinterland such Agro Products, Textiles, Machinery, Auto, Food processing, Paper, Metals & Mining have been identified and mapped on the hinterland. Figure below shows the share of key industries in traffic and their origin in the hinterland.

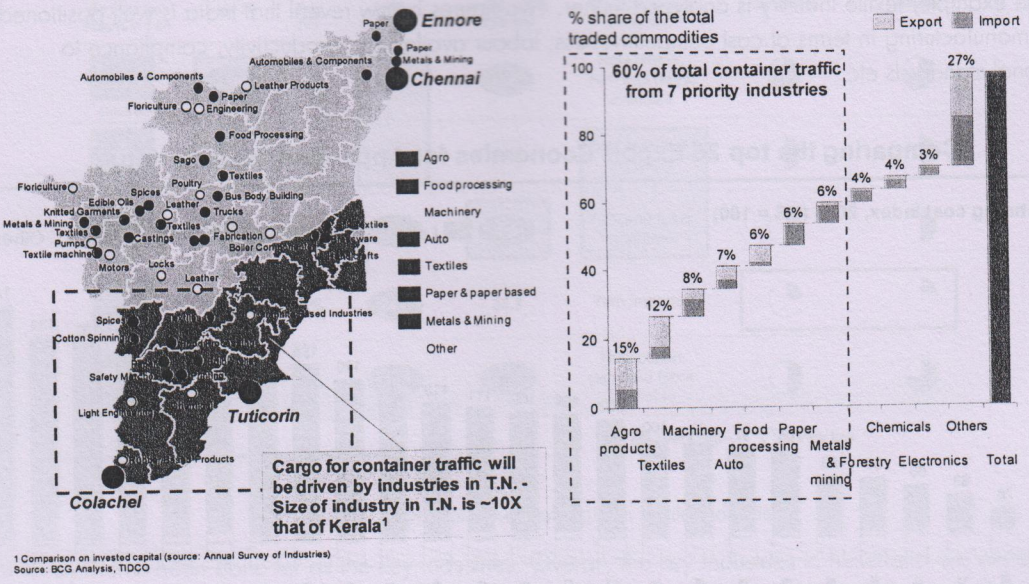


Figure 55: Map of hinterland industries and volumes from the industries

The export growth trends for the shortlisted industries have then been analyzed. India has seen consistent > 10% growth in most of the industries in the last decade.

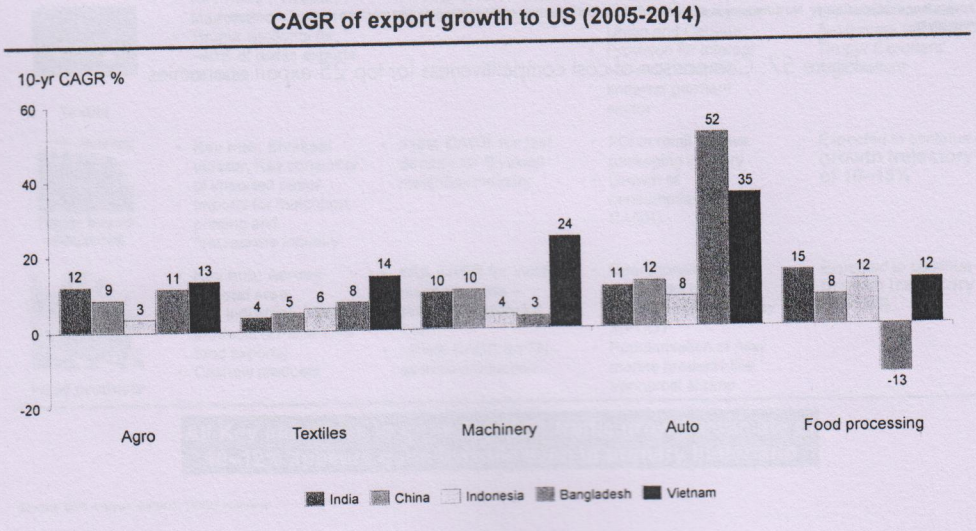
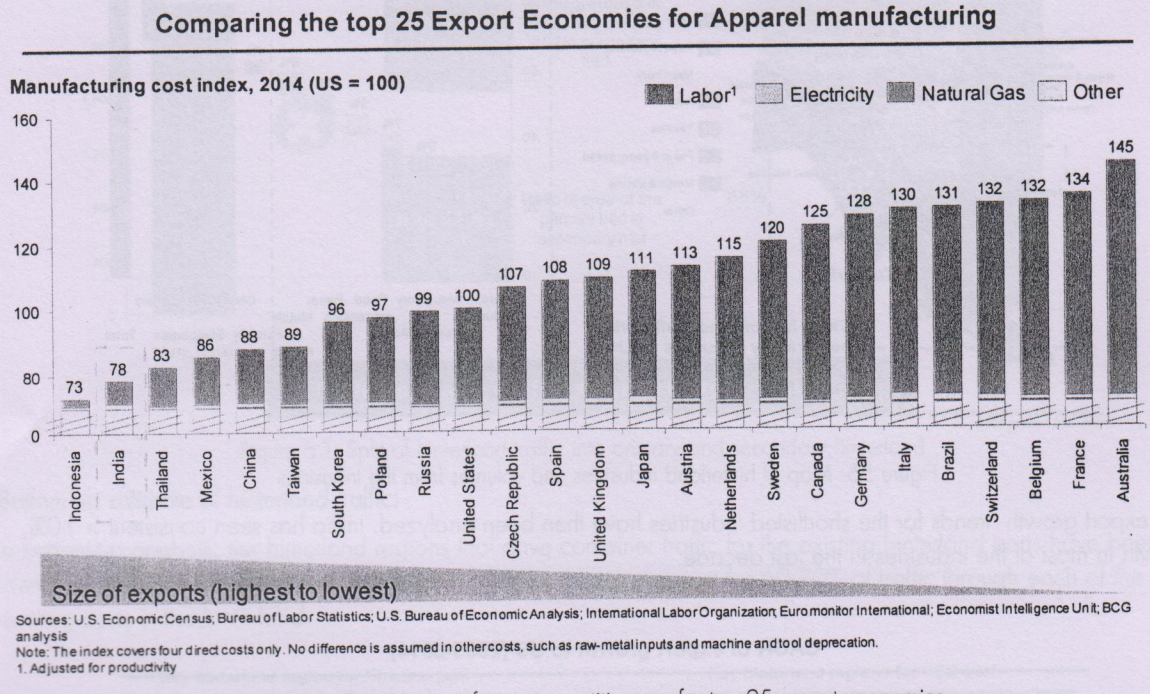


Figure 56: Export trends for the key hinterland industries

As a case example, textile industry is analyzed further. Two figures below reveal that India is well positioned in apparel manufacturing in terms of cost competitiveness, labour availability, productivity, compliance to international standards etc.



Sources: U.S. Economic Census; Bureau of Labor Statistics; U.S. Bureau of Economic Analysis; International Labor Organization; Euromonitor International; Economist Intelligence Unit; BCG analysis
Note: The index covers four direct costs only. No difference is assumed in other costs, such as raw-metal inputs and machine and tool deprecation.
1. Adjusted for productivity

Figure 57: Comparison of cost competitiveness for top 25 export economies

Country	Labour rate, productivity and Inflation			Labour pool	Raw material availability	Compliance levels	Country Stability
Figures in brackets are the 2012 knit exports in $ bn	*Monthly labour wage ($)*	*Labour productivity (%)*	*Wage Inflation (2008-2013) (%)*	*Economically active pop. aged 20 – 39 in '12 (in mn)*	*Availability of raw cotton, yarn and fabric for apparel production*	*Environment, safety and health compliance*	*Economic and political stability*
China (47)	330	70%	15%	[illegible]	Raw cotton, yarn and fabric available	◕	◕
Vietnam (4)	170	55%	9%	20.2	Yarn and fabric imported	◑	◑
Cambodia(1)	[illegible]	55%	28%	4.5	Yarn and fabric imported	◑	◑
B'desh (9)	[illegible]	50%	24%	35.3	Yarn imported	◔	◔
India (4)	140	50%	[illegible]	[illegible]	Raw cotton, yarn and fabric available	◑	◕

● - Very high ○ - Very low

Source: EIU country data, Expert interviews, Press search, BCG analysis.

Figure 58: Competitiveness of India in textile industries

Similar analysis has been done for all the key industries. Overall, the key industries in hinterland are expected to grow by 10-12 % as summarized in figure below. Overall, an estimate of 10 – 12% growth across the key industries over the next 10 – 15 years has been arrived at through this analysis.

Industry	Profile of the key hubs	Past growth trends	Key unlocks for further growth	Projected expected growth
Textile	• **Key hubs : Tirupur, Madurai** • Tirupur accounts for ~40% of textile exports of India	• **15-18% CAGR** for last 10 years for Tirupur	• Possibility of renewal of FTA with European Union and Canada • Provision for interest subvention for the knitwear garment sector	• **15-20% growth** expected over next 5–10 years (as per Tirupur Exporters' Association)
Paper based industries	• **Key hub: Sivakasi cluster,** Key consumer of imported paper • Imports for matchbox, printing and firecrackers industry	• **>10% CAGR for last decade** for Sivakasi matchbox industry	• FDI in retail to drive packaging industry • Growth of consumption (14% CAGR)	• Expected to continue **growth trajectory of 10–15%**
Food products	• **Key hub: Across coastal area** • Key industries- Marine products (27% of TN's food exports) • Cashew products	• **18% CAGR** for Indian marine exports – similar trajectory for T.N. • ~9%% CAGR for TN cashew production	• Operationalization of agro parks in Nilakottai, Dindugul. by SIPCOT • Popularisation of new marine products like Vannamei shrimp	• Expected to continue **growth trajectory of ~10%**

All Key industries to grow at >10%; traffic growth estimate of 10–12% appears quite feasible even in primary hinterland

Sources: BCG Analysis, SIPCOT, TIDCO interviews

Figure 59: Description of key hinterland industries

Demand in Enayam will not only come from existing hinterland industriesand the development of the port will also spur new industries and accelerate development in earmarked SEZ and industrial zones. The following figure describes the potential of development of planned SEZ and Industrial parks. Basis, this analysis it is expected that a further 1 – 2% of additional growth is possible through the emergence of SEZ clusters and new industries. This upside has been captured in the aggressive growth scenario.

Key SEZs/ industrial hubs planned in the primary hinterland of the port

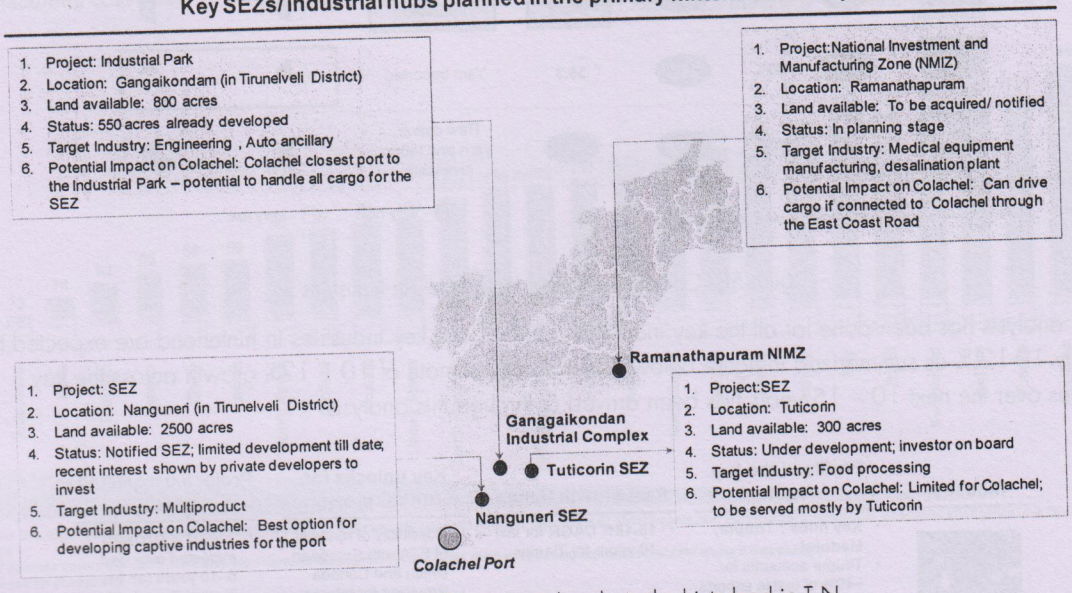


Figure 60: Potential SEZ, industrial parks in the hinterland in T.N.

Finally, both top down and bottom up hinterland traffic growth estimates have been compared and there is good convergence in both these estimates. Thus, these assumptions have been taken to project hinterland traffic growth. Hinterland traffic is projected to at 7.3 -11.5 Mn TEU in 2030 (figure below).

	1 Top down estimates	2 Bottom up estimates
Traffic volumes for hinterland *(2014 traffic)*	**2.3 Mn TEUs**	**2-2.5 Mn TEUs**
Growth of hinterland cargo	**10-11 %** *(to taper down over time)*	**10-12 %**

Hinterland container traffic projections

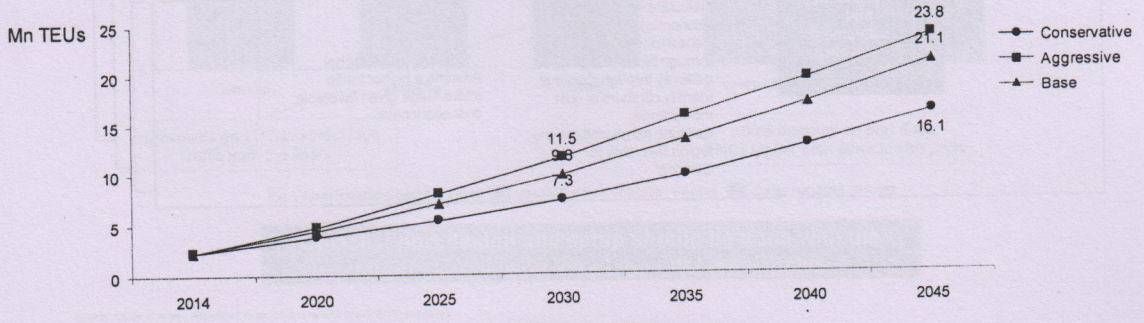


Figure 61: Hinterland traffic projections

6.2.1.3. Enayam container traffic projections

Container traffic for Enayam is projected by estimating traffic using the following approach

1. Trans-shipment cargo
   a. Continues to be trans-shipment cargo - Estimation of the likely share of Enayam from the existing trans-shipment traffic in the region.
   b. Gets converted to gateway cargo - Conversion of current trans-shipment traffic originating from hinterland into gateway traffic due to lower cost of logistics at Enayam (due to single port handling).

2. Gateway cargo

Enayam would also capture some of the existing gateway cargo that would get diverted from other hinterland ports due to proximity / lower cost of logistics.

The following figure describes the methodology for container traffic projection for Enayam.

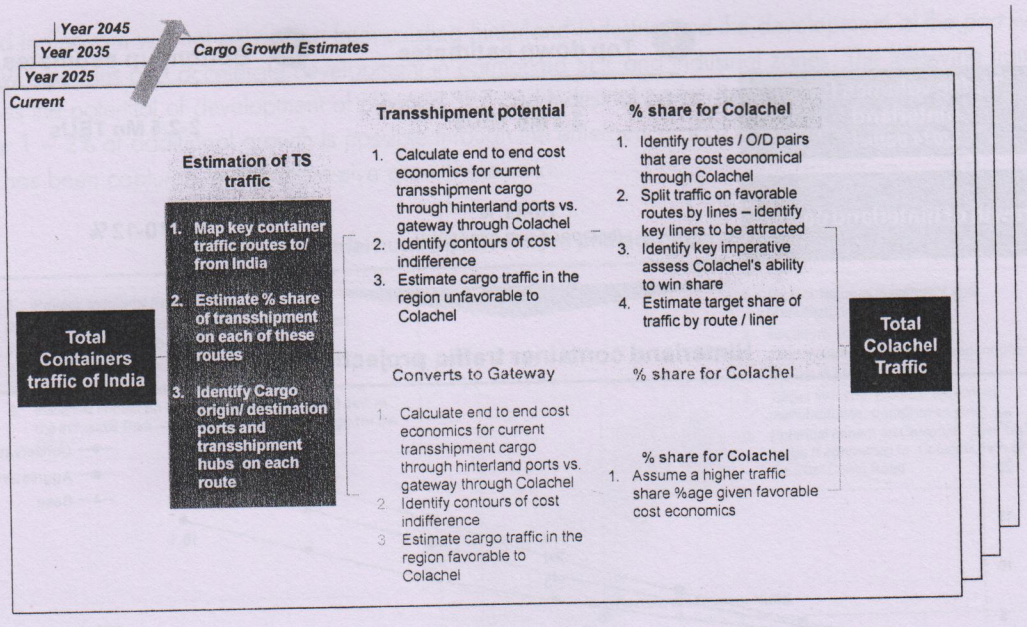


Figure 62: Description of methodology

1. Trans-shipment cargo
    a. Continues to be trans-shipment cargo

Enayam would need to not only match port charges of Colombo but offer ~15% discount in the first few years in order to become competitive and attract traffic from Colombo Port. This imperative has been assumed which estimating the traffic share for Enayam.

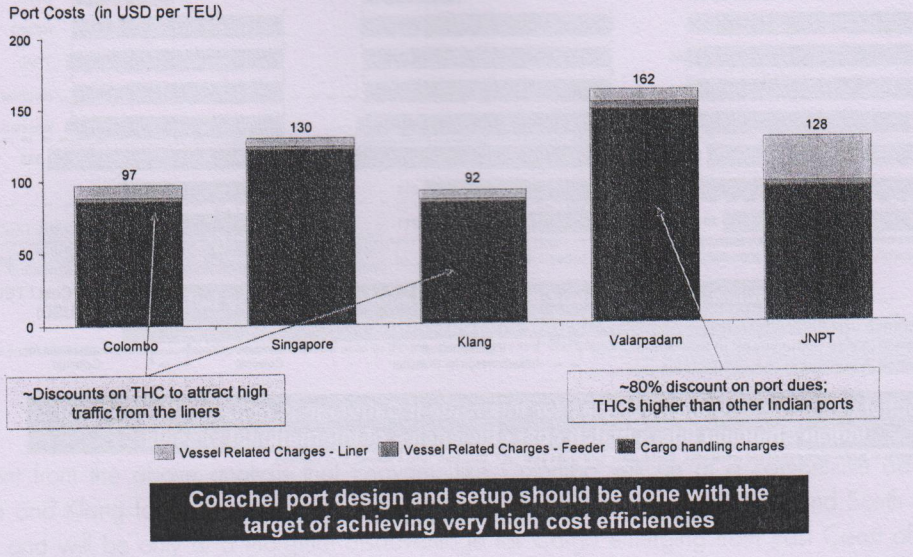
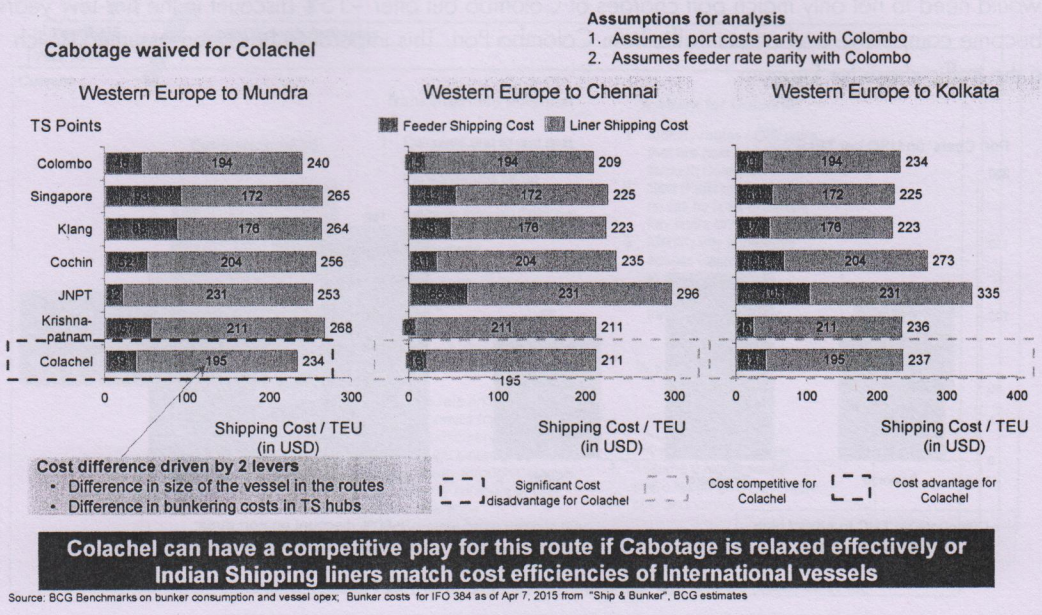


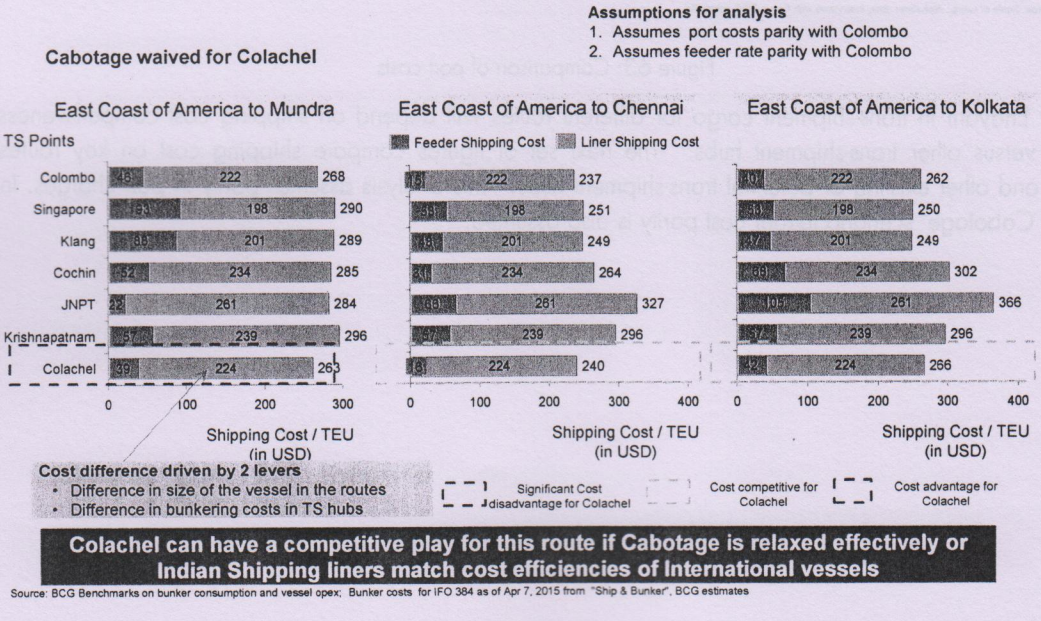
Figure 63: Comparison of port costs

Share of Enayam in trans-shipment cargo for different routes will depend on shipping cost competitiveness for Enayam versus other trans-shipment hubs. The next set of figures compare shipping cost on key routes for Enayam and other existing or potential trans-shipment hubs. This analysis assumes parity in port charges. In the "Without Cabotage" scenario feeder cost parity is also assumed.



Source: BCG Benchmarks on bunker consumption and vessel opex; Bunker costs for IFO 384 as of Apr 7, 2015 from "Ship & Bunker", BCG estimates

Figure 64: Comparison of shipping costs (1)



Source: BCG Benchmarks on bunker consumption and vessel opex; Bunker costs for IFO 384 as of Apr 7, 2015 from "Ship & Bunker", BCG estimates

Figure 65: Comparison of shipping costs (2)

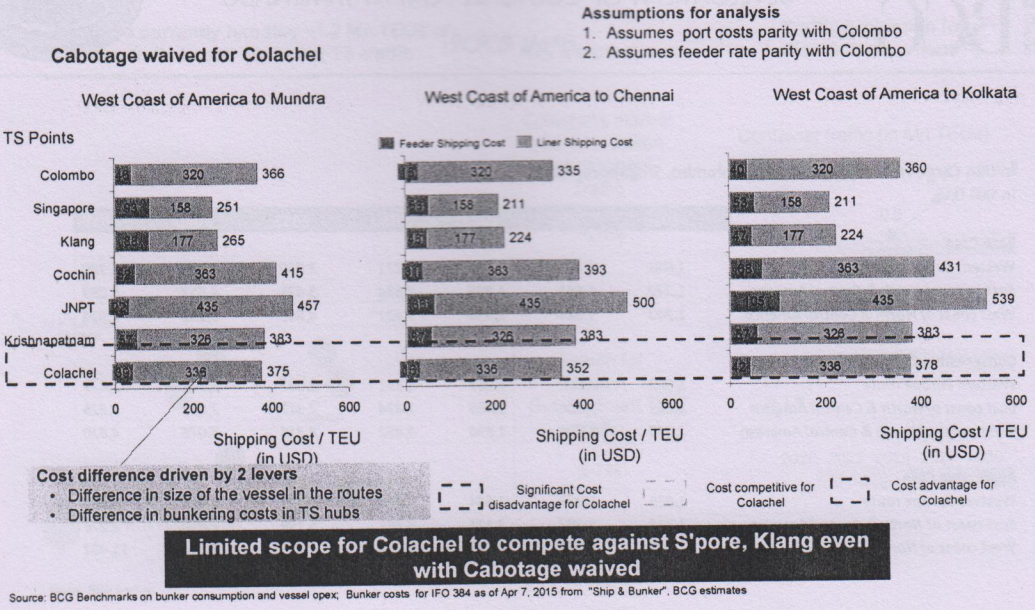


Figure 66: Comparison of shipping costs (3)

It is evident from the above analysis that Enayam, like Colombo will be at a competitive advantage versus Singapore and Klang for traffic moving to East Coast of US and Europe from West and South Coast of India (Chennai) and will be only at a marginal disadvantage for Cargo emerging from East Coast of India. On the other hand, Enayam will be at a significant disadvantage for the traffic moving to West Coast of America versus Singapore and Klang. These findings have been incorporate while building traffic share estimates for Enayam.

Further, the scale of operation impact has also been studied to determine the share potential. Currently, Singapore and Klang have significant scale which makes it attractive for liners to use as aggregation and relay hub for cargo across many routes. This is to bring down overall cost for liners, even if it increases cost on this specific route. This factor has also been incorporated while estimating target share for Enayam

Traffic Share Assumptions

- Traffic moving to East Coast of America and Europe
  - Share of current traffic through Colombo: ~50% can be moved to Enayam in base case
  - Share of current traffic through Singapore/ Klang: 25% can be moved to Enayam in base case
- Traffic moving to West Coast of America
  - Share of current traffic through Colombo: ~50% can be moved to Enayam in base case
  - Share of current traffic through Singapore/ Klang: <5% can be moved to Enayam in base case

The following figure shows different route wise projections for the Indian container traffic trans-shipped through the existing trans-shipment hubs

Indian Cargo transhipped through Colombo, Singapore, Klang
in '000 TEUs

	2018	2020	2025	2030	2035	2040	2045
Base Case							
Western Europe route	1,046	1,285	1,573	2,221	3,050	4,086	5,180
East coast of North & Central America	1,340	1,641	1,846	2,554	3,473	4,653	5,899
West coast of North & Central America	1,240	1,524	2,334	3,421	4,666	6,251	7,924
Conservative Case							
Western Europe route	1,025	1,202	1,267	1,591	2,042	2,544	2,879
East coast of North & Central America	1,313	1,536	1,485	1,824	2,313	2,873	3,225
West coast of North & Central America	1,215	1,426	1,896	2,492	3,216	4,076	4,810
Aggressive Case							
Western Europe route	1,025	1,337	1,844	2,911	4,471	6,513	8,046
East coast of North & Central America	1,313	1,707	2,171	3,367	5,139	7,510	9,276
West coast of North & Central America	1,215	1,586	2,693	4,334	6,480	9,263	11,454

1. *All estimates excluding TS cargo that is expected to be converted to gateway cargo in 2018*
2. *All containers double counted due to TS*

Note: Assumptions - % of trans-shipment remains same
Source:, IHS international trade data, BCG estimates

Figure 67: Traffic on different routes for Indian trans-shipment traffic

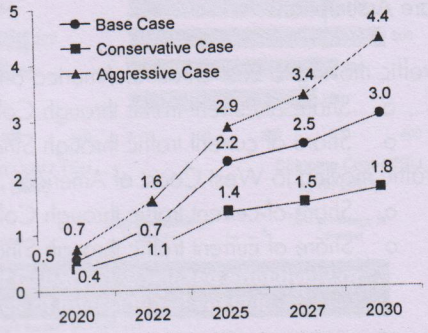
Traffic Projections

The following figure describes the projections for the trans-shipment traffic for Enayam. The traffic shares for Enayam are multiplied with the traffic estimates for each route to arrive at Enayam's traffic.

Key Assumptions for traffic projections

	Assumptions				Basis of assumptions
Colachel's share of TS traffic	*Colombo All routes*	10-50% rampup	~50%	50-65%	• Assuming 2 of the leading liners shift to Colachel • Low traffic in the initial years – shifting of routes to happen over a period of time
	S'pore, Klang Transatlantic routes	5-25%	~25%	25-40%	
	S'pore, Klang Transpacific routes	1-5%	~5%	5-20%	
Container traffic growth	*CAGR of container traffic (%)*	10-12%	6-8%	4-6%	• Higher GDP growth rate 6-7% in first 5 years, tapers down to 4%
		2015-2025	2026-2035	2035-2045	

Traffic projections for India based TS



1. Traffic estimated only includes TS traffic for India
2. Traffic excludes TS traffic from Chennai, VOC & Cochin that would get converted to Gateway traffic of Colachel (analysis in later pages)

Figure 68: trans-shipment traffic projections

Beyond India's traffic, Enayam would also gain share of Indian subcontinent traffic getting trans-shipped through Colombo. The following figure shows traffic projections for Indian subcontinent trans-shipment traffic that can be captured by Enayam.

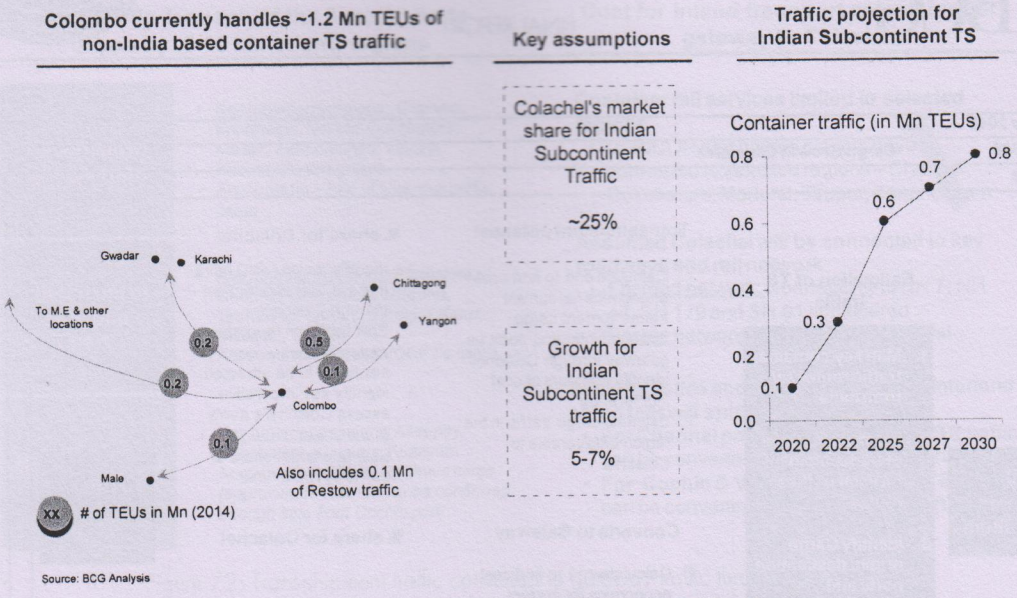


Figure 69: Indian sub-continent trans-shipment traffic for Enayam

The next step is to estimate the gateway traffic for Enayam. This is a combination of existing trans-shipment traffic at other Indian port, becoming gateway traffic for Enayam and gateway traffic captured from the hinterland. The estimations for gateway traffic at Enayam is discussed in the next sections.

Coastal traffic

Coastal container traffic for Colachel would be driven primarily by the feeder network carrying the trans-shipped EXIM cargo to other Indian ports. It will be ~1.5 Mn TEUs in 2030 (already included in the figure 84). Domestic coastal cargo expected to be handled in Colachel is negligible (at present, only ~0.6 Mn TEUs for domestic coastal cargo is handled across Indian ports).

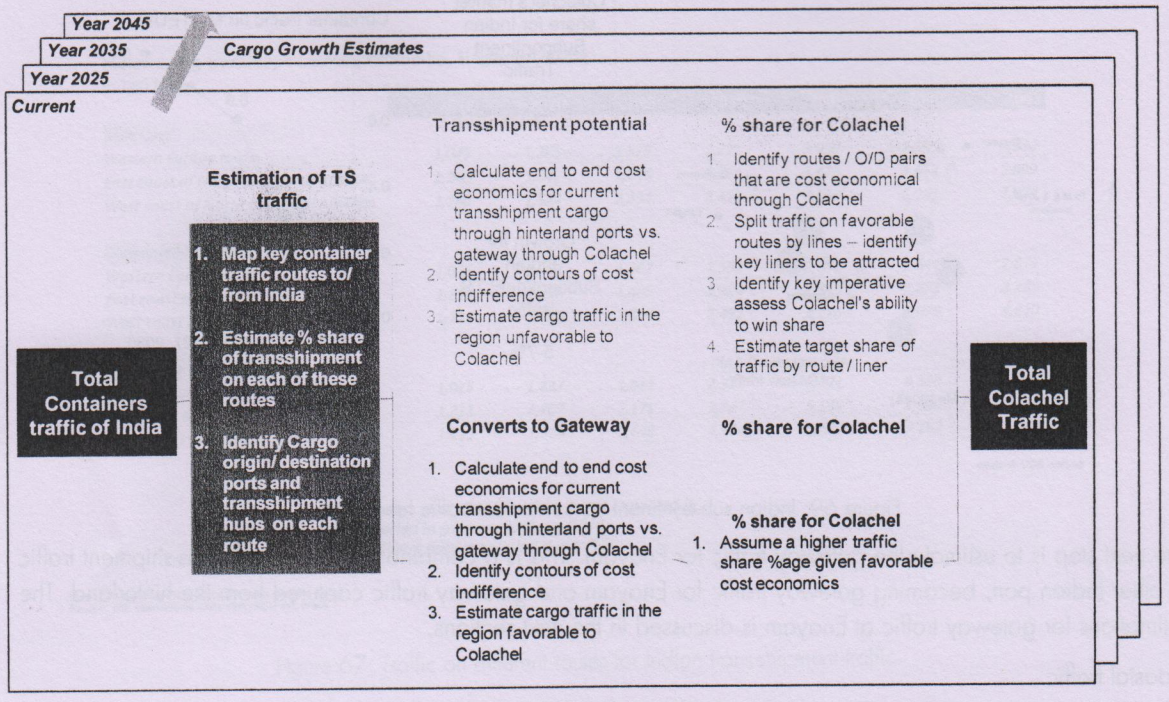


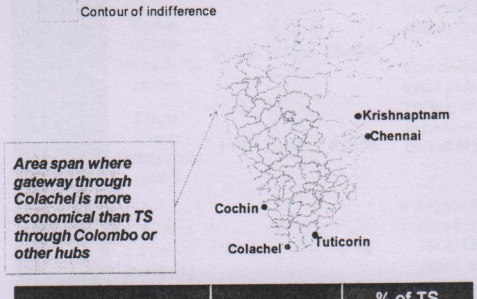
Figure 70: Description of methodology

2. Trans-shipment cargo

b. Trans-shipment cargo getting converted to gateway cargo

Direct shipment of containers through Enayam instead of trans-shipment through Colombo will have a cost advantage for most exporters/ importers in the hinterland. The cost- benefit analysis is explained in figure below.

Potential to convert 40-50 % of TS traffic from South Indian ports to gateway



Port in hinterland	TS cargo (in '000 TEUs)	% of TS converted to direct cargo
CHENNAI	810	20-40%
V.O. CHIDAMBARANAR	433	>90%
COCHIN	204	>90%

Note: New Mangalore not considered for analysis as there is is no TS container cargo from New Mangalore

Economic simulation: ~ 30 % cost savings for cargo from Madurai district

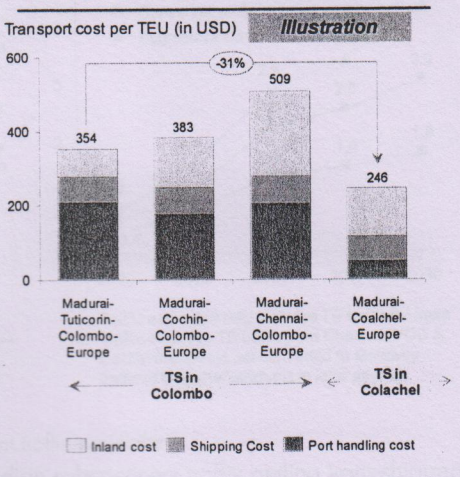


Figure 71: Trans-shipment traffic converted to gateway traffic through Enayam (I)

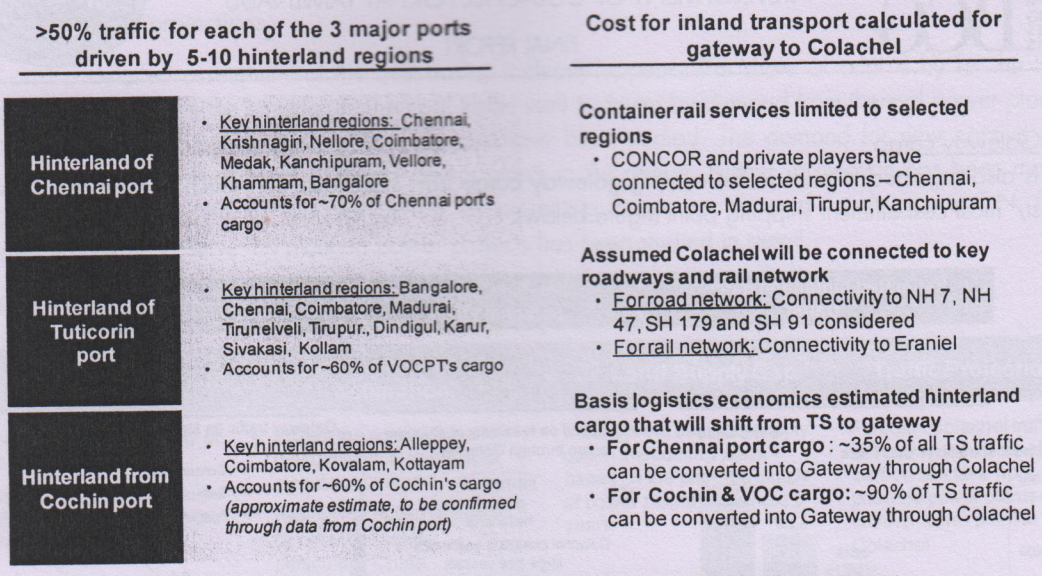


Figure 72: Trans-shipment traffic converted to gateway traffic through Enayam (II)

A detail district wise estimation has been done to identify the regions in the hinterland that will have a cost advantage to ship from Enayam. Basis this analysis, it is expected that~90% of exporters/ importers currently using Tuticorin or Cochin port for trans-shipment through Colombo are expected to shift to Enayam and ~35% of transporters using Chennai port are likely to shift as well. This has been then used to estimate the traffic for Enayam as explained in figure below.

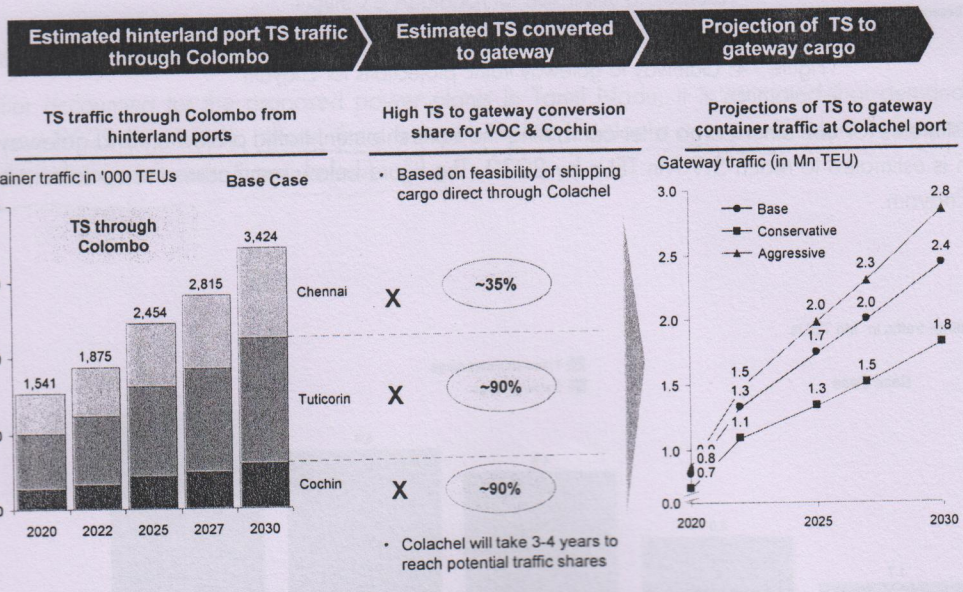


Figure 73: Trans-shipment to gateway traffic projections

3. Gateway cargo

Enayam is also expected to capture the existing gateway cargo from hinterland, for which Enayam will now be the closest/ most cost efficient shipping point (figure below)

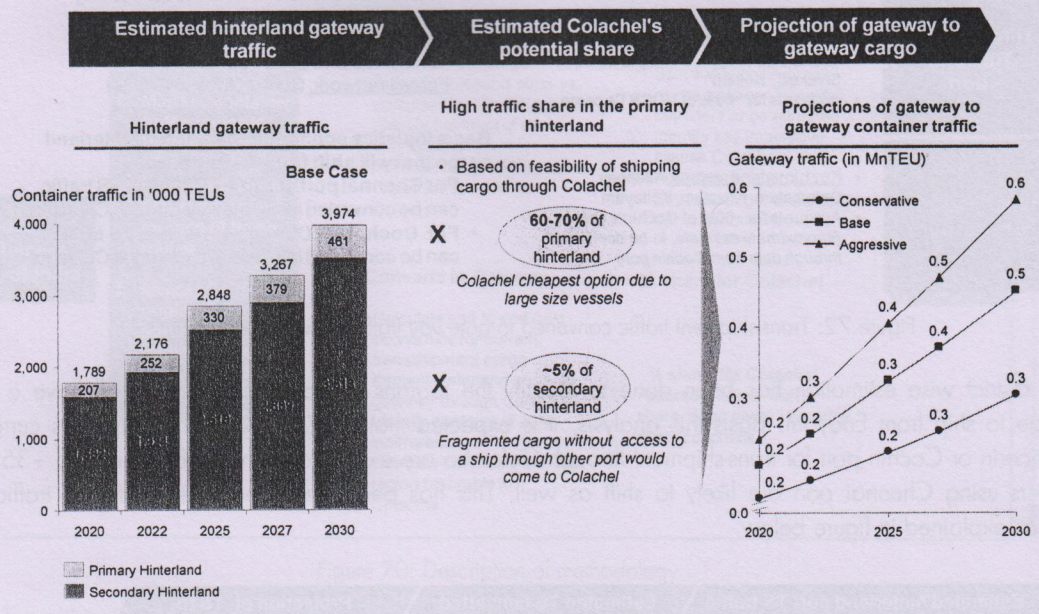


Figure 74: Gateway to gateway traffic projections for Enayam

Overall traffic estimates for container cargo after combining the trans-shipment traffic projection and gateway traffic projection is estimated to reach 5.9 Mn TEUs by 2030. The figure below summarises the container traffic projections for Enayam.

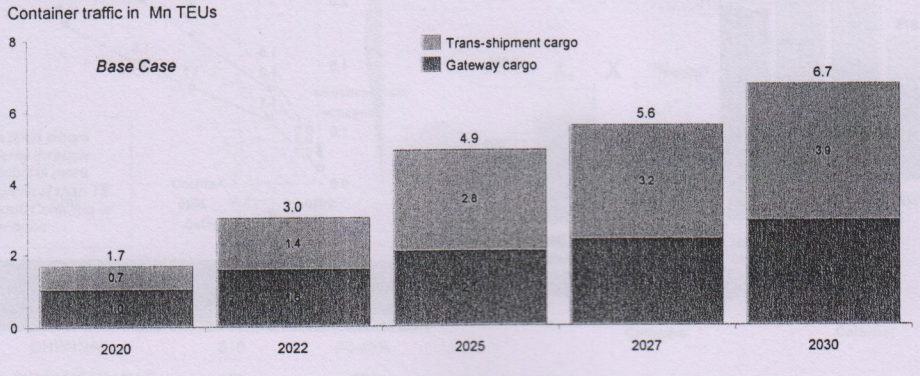


Figure 75: Container traffic projections for Enayam

6.2.2. Bulk traffic projections

Based on the detailed assessment of the bulk traffic, it clearly appears that share of coal is by far the highest amongst all bulk cargo in the hinterland. The coal traffic itself is driven by demand from thermal power plants. To project coal traffic in Enayam, two types of sources have been studied. The demand for new captive power plants and the demand for already planned power plants in the region. Further, projection has been made for new captive plants, beyond the planned period, by projecting the power demand supply gap in T.N. Finally, feasibility of Enayam to serve the planned power projects has been studied in detail.

The approach for bulk traffic estimation is described in the following figure.

Key driver of bulk traffic	Power consumption estimation	Demand-Supply Gap	Traffic Projection
• Coal traffic drives majority of the traffic in the region • Estimate the portion of coal traffic in total and the drivers for coal traffic	• Project the power demand using historical trends and global benchmarks • Assess the pattern followed by other countries, particularly China	• Estimate the demand-supply gap in the coming years based on the planned supply of power plants in the next 5 years	• Forecast Colachel traffic by assessing the share of traffic it can take from planned power plants and captive power plant at Colachel

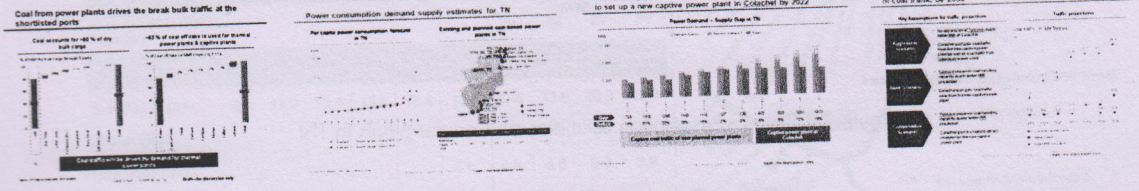
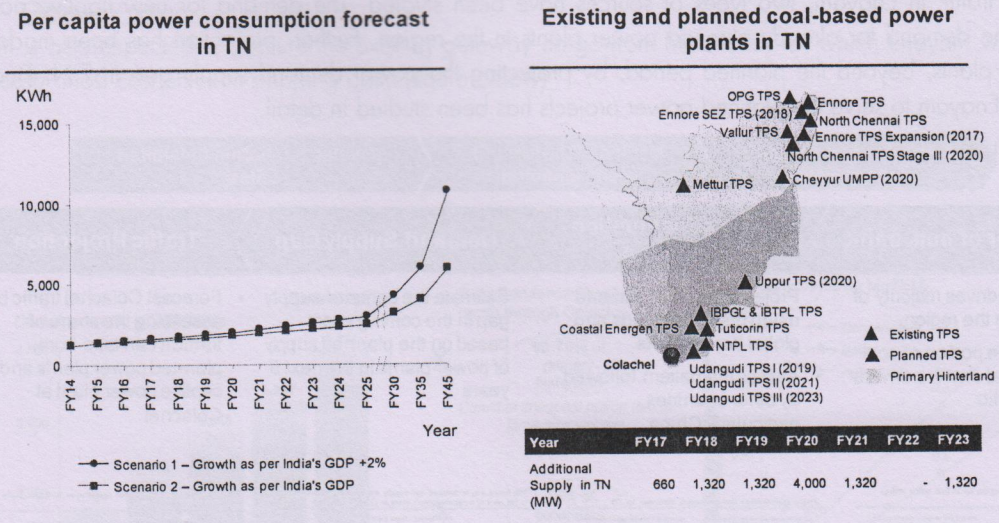


Figure 76 Approach for bulk traffic projections

1. Captive Power Plants

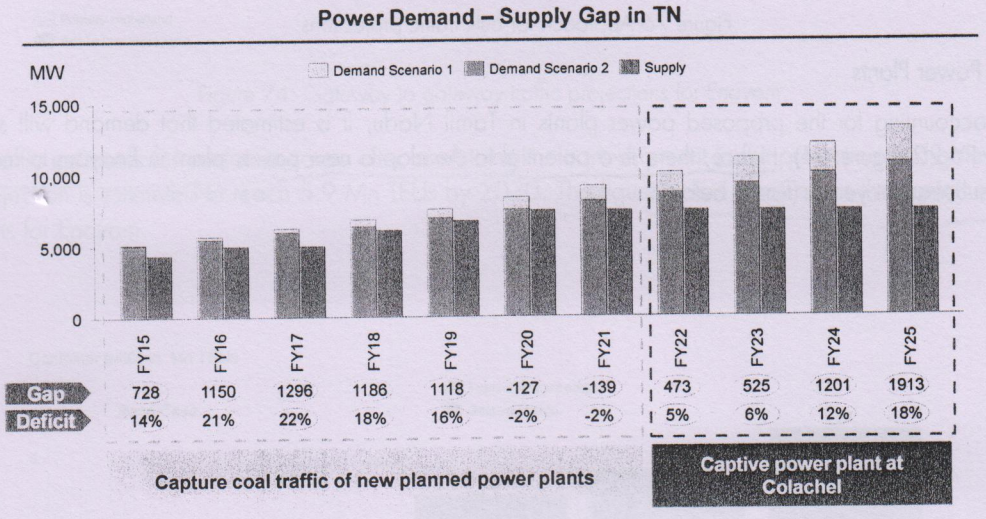
Even after accounting for the proposed power plants in Tamil Nadu, it is estimated that demand will surpass supply post FY 22 (figure 64). Hence, there is a potential to develop a new power plant in Enayam to meet the gap in the subsequent years. (figure below).



Year	FY17	FY18	FY19	FY20	FY21	FY22	FY23
Additional Supply in TN (MW)	660	1,320	1,320	4,000	1,320	-	1,320

Source: BCG analysis, Tamil Nadu Electricity Board

Figure 77 Power consumption estimates and power plants in TN



Source: BCG analysis

Figure 78 Projection of power demand supply gap in T.N.

Given the demand-supply gap projections, , it has been proposed that a unit of 660 MW each will be constructed starting from 2019, 2024 and 2028, each taking 3 years to construct (as per discussions with experts and TNEB officials) and operationalize in 2022, 2027 and 2031. Assuming an approximate requirement of 5000 tonne of coal per MW, each unit will require ~3 million tonne of coal in 2022, 2027 and 2031 onwards, totalling to ~9 million tonnes of coal requirement.

The exact details of land availability and ownership structure of this captive power plant can only be assessed in future. Keeping this in mind, a polyvalent berth has been planned, so that the same berth has the flexibility to be used for container traffic in case coal traffic does not materialise from captive power plant. Also, the berth has been designed for a capacity of 6 million tonne considering only the traffic expected till 2030 and can be expanded later depending on actual traffic till that point.

2. Existing planned power plants

Among the currently planned power plants, Enayam can potentially serve the Udangudi power plants. This is subject to Udangudi not getting serviced by the Tuticorin port due to capacity constraints and the captive jetty project in Udangudi not getting implemented. Hence, this is accounted in only the aggressive traffic scenario for Enayam.

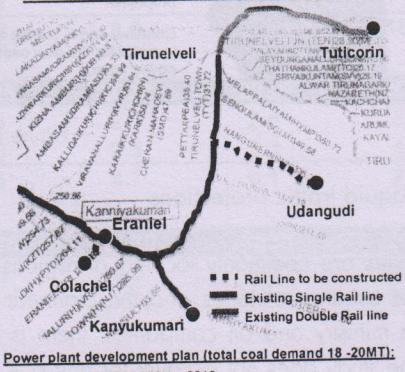
Traffic and capacity plan for Tuticorin

Coal Traffic (MTPA)	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23
VOC Capacity	24	24	24	24	24	24	24	24	24	24
VOC Outer harbor capacity [1]							20	20	20	20
Total demand	6.8	13.8	13.8	13.8	13.8	20.4	28.4	35	35	41.6
Existing Traffic	6.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
Uppur TPS							8	8	8	8
Udangudi TPS I						6.6	6.6	6.6	6.6	6.6
Udangudi TPS II								6.6	6.6	6.6
Udangudi TPS III										6.6

More economical for Udangudi to source coal from VOC or through captive coal jetty; however both projects require high initial investments

1. Outer harbor expected to add 20 MTPA capacity in 2019-30 and further 10 MTPA capacity post FY 30
Source: BCG analysis, IPA team Report on VoPT Outer Harbour Development

Udangudi TPS potential opportunity for Colachel



Power plant development plan (total coal demand 18 -20MT):

- Phase 1: 2 x 660 MW by 2019
- Phase 2: 2 x 660 MW by 2021
- Phase 3: 2 x 660 MW by 2023

Potential options for servicing the power plant

- Option 1: Captive Jetty with a capex of Rs. 2000 Cr
- Option 2: From Tutiorin through rail; distance of ~ 100 kms
- Option 3: From Colachel through rail; distance of ~120 kms

Figure 79 Evaluation of options for Enayam to cater to Udangudi

The following figure describes the three scenarios for coal traffic projection and gives projection of Coal traffic for the port in each scenario.

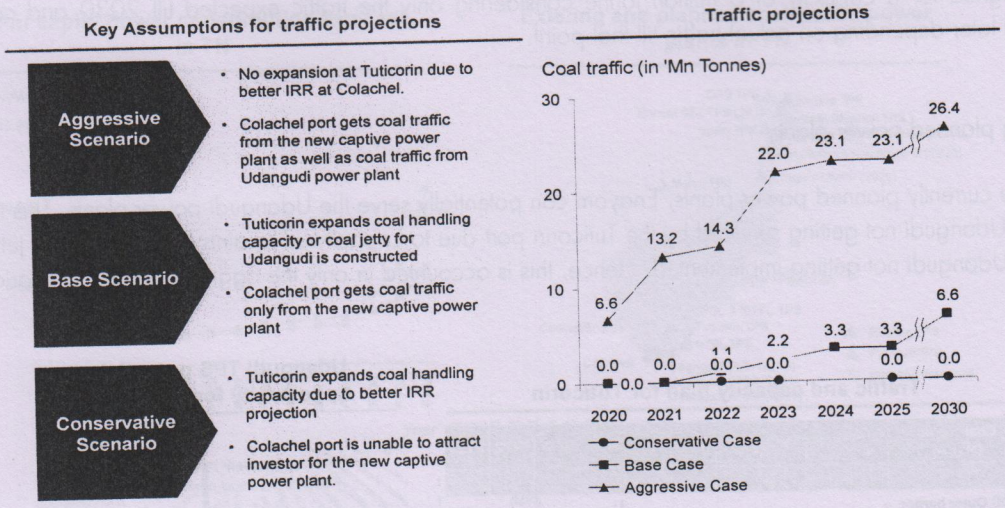


Figure 80 Coal traffic projections

6.2.3. Liquid traffic projections

Oil refineries are commonly located at regions with close access to ports. However, as seen in the following figure, the existing refineries and the planned ones are not in proximity to Enayam port location. As per the petroleum ministry and oil companies, there is limited possibility of deviating from the planned refinery rollout. Hence, the study does not account for any POL traffic for the port. However, possibility of POL traffic can be re-evaluated at a later date.

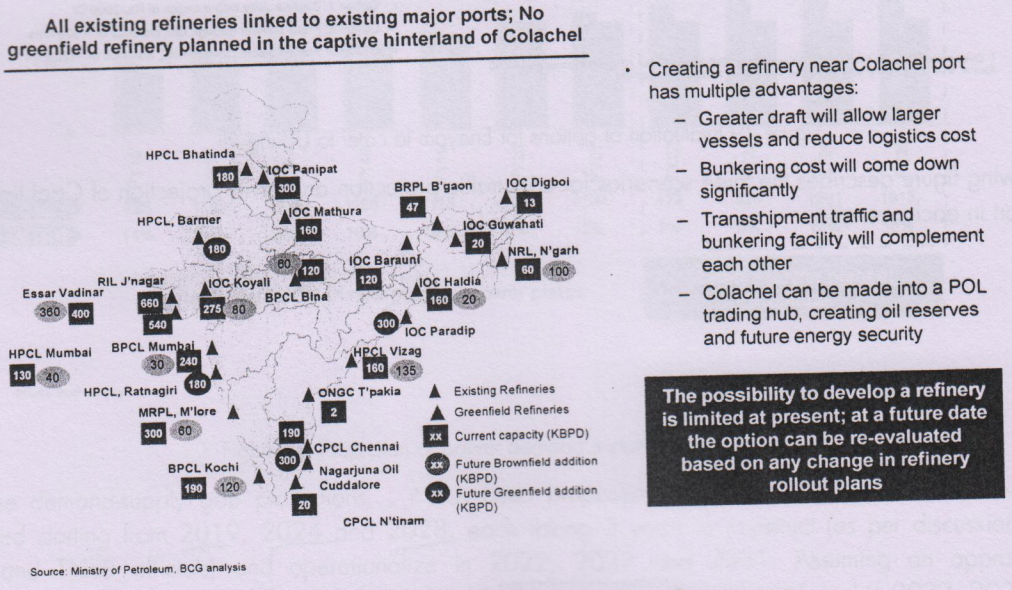


Figure 81: Feasibility of refinery in proximity to Enayam port

6.3. SUMMARY OF TRAFFIC ESTIMATES

The following figure summarises the traffic estimates for the Enayam port. As per the base case, the port will see container traffic of 6.8 Mn TEU (2.9 Mn of Gateway traffic and 3.9 Mn of trans-shipment traffic) and coal traffic of 6.6 MMTPA in 2030. The port layout and phasing of capacity for the port is planned as per the traffic estimates.

Container Cargo						
Base Case						
	units	**2020**	**2025**	**2030**	**2035**	**2040**
Gateway	*in Mn TEU*	1.0	2.1	2.9	3.9	5.0
Trans-shipment	*in Mn TEU*	0.7	2.8	3.9	5.2	8.0
Total		**1.7**	**4.9**	**6.7**	**9.1**	**12.9**
Aggressive Case						
	units	**2020**	**2025**	**2030**	**2035**	**2040**
Gateway	*in Mn TEU*	1.1	2.4	3.4	4.7	5.8
Trans-shipment	*in Mn TEU*	0.9	3.5	5.2	8.8	13.1
Total		**2.0**	**5.9**	**8.6**	**13.5**	**18.9**
Conservative case						
	units	**2020**	**2025**	**2030**	**2035**	**2040**
Gateway	*in Mn TEU*	0.9	1.6	2.1	2.8	3.7
Trans-shipment	*in Mn TEU*	0.5	2.0	2.6	3.3	4.2
Total		**1.4**	**3.5**	**4.7**	**6.1**	**7.8**
Bulk Cargo (Coal)						
	units	**2020**	**2025**	**2030**	**2035**	**2040**
Base Case	*in Mn MT*	-	3.3	6.6	9.9	9.9
Aggressive Case	*in Mn MT*	6.6	23.1	26.4	29.7	29.7
Conservative Case	*in Mn MT*	-	-	-	-	-

Figure 82: Traffic Projections

6.4. FEASIBILITY OF ANCILLARY INDUSTRIES

Creation of a major hub port also creates the opportunity to develop allied industries around the port. This would lead in creation of more jobs and will provide a major boost to the local economy. The possible industries include ancillary industries to support shipping activities, shipping related services and other industries that can develop in proximity to the port area. The following figure lists down the possible allied industries.

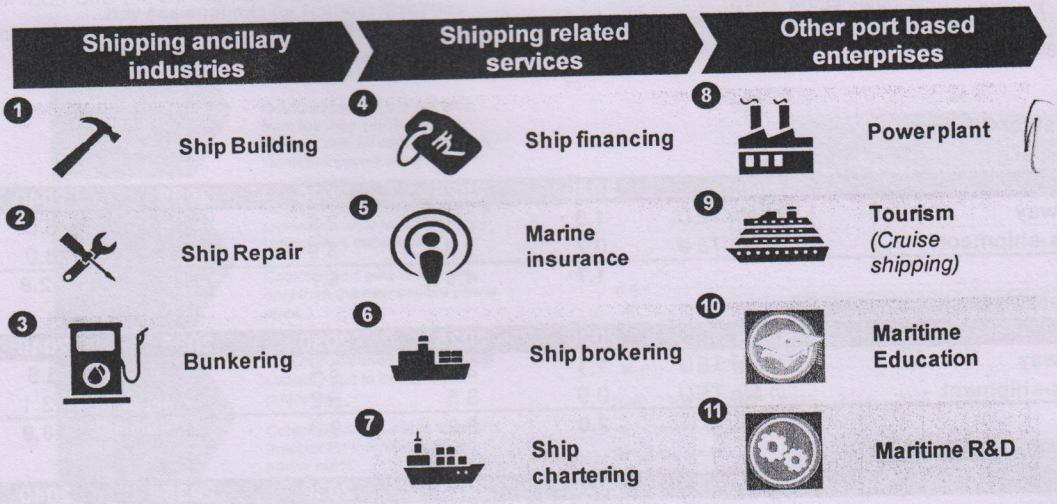


Figure 83: Allied Industries

This section analyses feasibility of each of the industries in context of the Enayam port.

1. Shipbuilding

Globally, the shipbuilding industry is struggling with overcapacity leading to closures and bankruptcies of ship building companies.

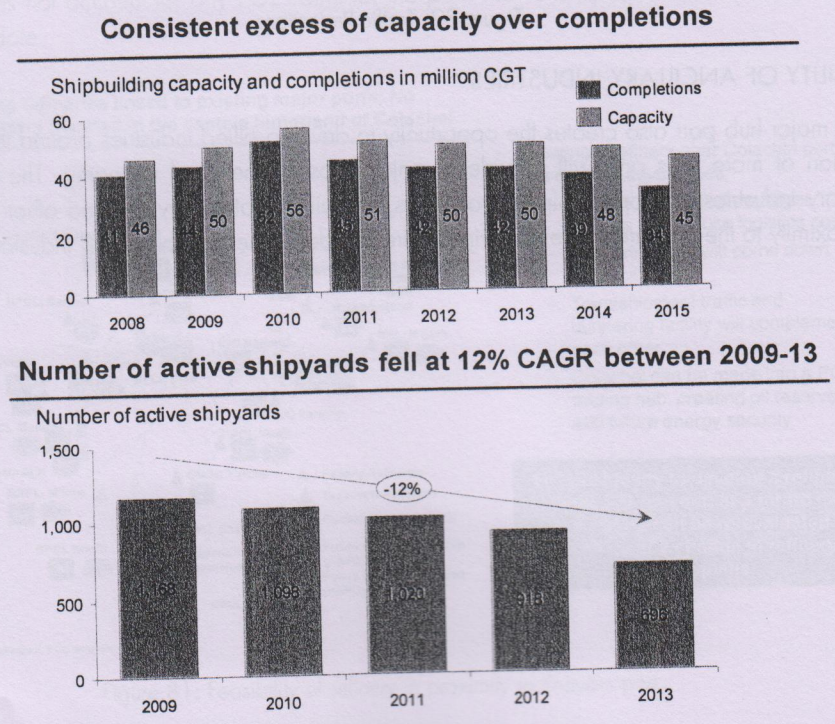


Figure 84: Global overcapacity in shipbuilding

Many shipyards have been closing amid the demand glut.

- STX Finland closed the world's leading ferry builder
- 1/3rd of China's yards may close by 2018 – according to trade association for China's shipbuilding industry
- Chinese shipbuilder Ronsheng laid off 80% of workforce in 2 years
- Number of active shipyards fell from 1168 in 2009 to 696

The situation is expected to continue as majority of current fleet would not get replaced in the next 5-10 years. Hence, the effects of surplus tonnage are long-term.

Amongst the four main shipbuilding sub sectors, only defence looks feasible for Enayam.

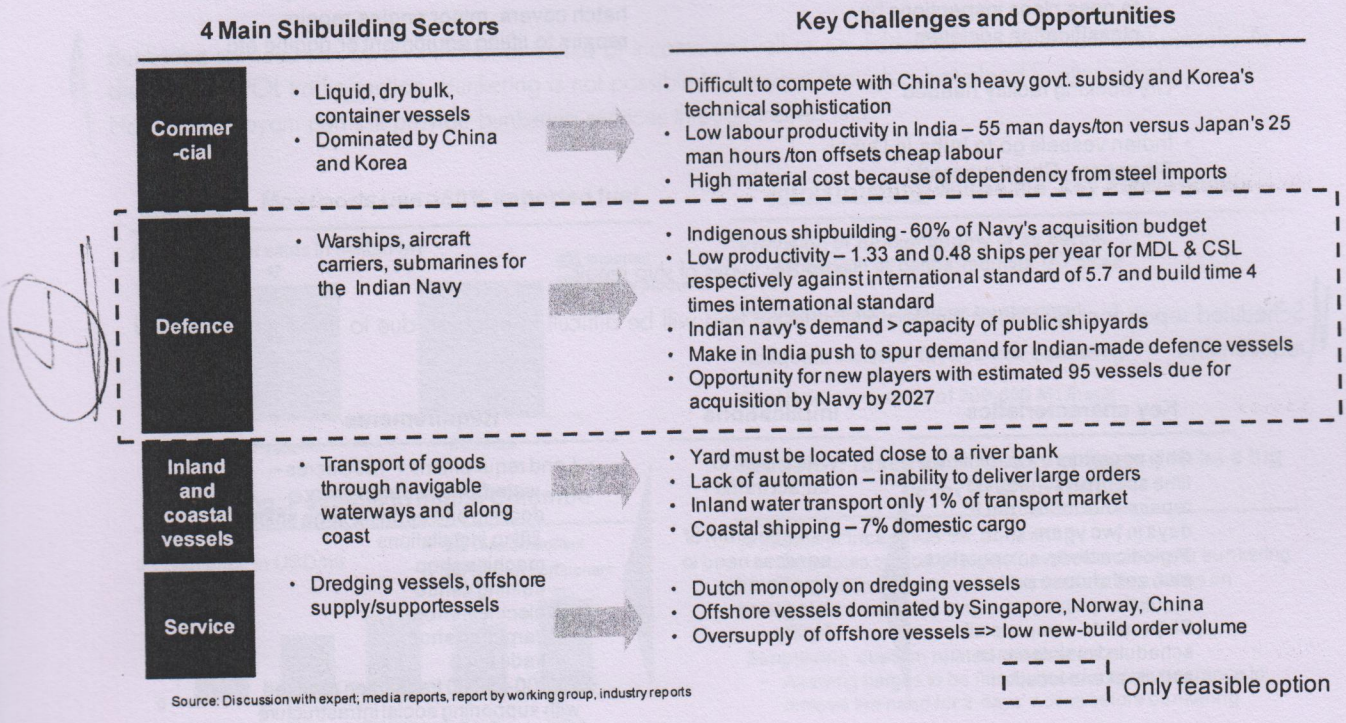


Figure 85: Main shipbuilding sub sectors

2. Ship repair

Ship repair can be broadly classified into two types – scheduled and unscheduled.

Scheduled ship repairs	Unscheduled ship repairs
• Pre-planned, scheduled maintenance activities for vessels • Schedule ship repair required - – to ensure seaworthiness – to keep ship in optimum operating condition to maximize earning capacity – to pass class inspections by classification societies • Dry docking facility needed • Indian vessels go to hubs in Dubai, Singapore, China currently	• Includes minor repairs, which are defined as those limited to the vessel's superstructure, deck and hull above the waterline • Minor repairs do not need dry dock • Examples: replacement of seals on hatch covers, minor engine repairs, repairs to lifting equipment or rigging etc

Figure 86: Types of ship repair

Scheduled repair facility is not critical to attract traffic and will be difficult to establish due to investment and land requirements

Key characteristics	Implications	Requirements
• Ship operators try to minimize time spent on scheduled repairs– not more than 9 days in two years • Periodic activity, so operators plan and choose port as required • Ships aim to complete all scheduled maintenance activity at one location	• Not critical to attract traffic • Full spectrum of services need to be offered in integrated facility	• Land requirement > 1000 acres – – waterfront acreage for dry docking and berthing large ships – lifting installations – machine shop – training centre – electrical shop – carpenter shop – trade shop • 20,000-25,000 tradesmen required with supporting social infrastructure

Comparison with Colombo

- Ship repair traffic only ~5% of vessel traffic -Most vessels port do not call because of availability of scheduled repair facilities
  - Colombo Dockyard serves ~200 vessels annually while over 3870 vessels handled overall

Figure 87: Scheduled ship repair

However, minor ship repair services can be offered by Enayam port. Minor ship repairs would also help the port to be competitive. Minor ship repairing services includes:

- Inspection and degasification of tanks
- Certification
- Cleaning

- De-rusting of pipes
- Spare parts
- Replacement of seals on hatch covers
- Minor engine repairs

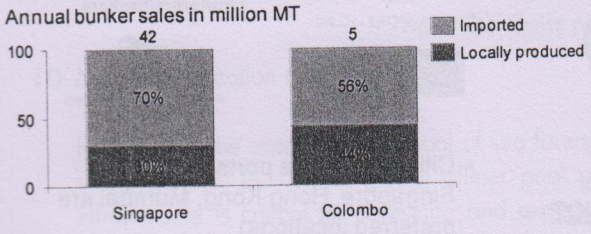
The requirements to set up a facility for minor ship repairs are:

- Inventory of spare parts and components
- Ship repair berth
- Simplified custom bonding process to save on time and cost

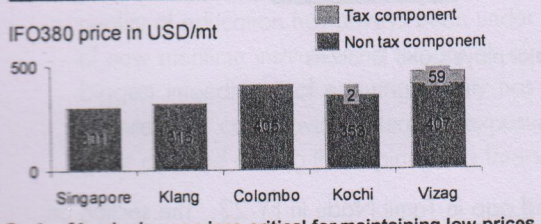
3. Bunkering

Bunkering services can be an additional source of income as well as an added service to attract liner vessels. As discussed in POL traffic section, Bunkering is not possible in Enayam through a hinterland bunker supply. However, Enayam can still provide bunkering services through traded fuel.

Sourcing: Most ports use >50% imported fuel



Pricing: Possible to match Colombo



Scale of bunkering services critical for maintaining low prices
- Allows buying in large parcel sizes at lower rates
- Assured demand allows flexibility on purchase decisions

Infrastructure: Will be the key differentiator

Provision of bunker supply in all berths
- Pipeline in all berths; reduces TAT times

Provision for all-weather bunkering

Adequate facilities for mid-sea bunkering

Fuel loading speeds of 300-500 MT/hour

Subsidy, Taxes and Custom charges can be a big lever to drive traffic

Subsidies/ incentives for bunkering
- Subsidies on port charges for vessels calling for bunkering
- Reduction of taxes on bunker (India levies duties on bunker – currently temporarily exempted)

Simplifying custom related processes
- Allowing barges to be filled without custom clearance to remove the need for 2 days' notice before bunkering

Note: Bunker prices as per 18th March 2015. Colombo does not produce IFO 380 bunker locally
Source: BCG Analysis, Interviews with bunker suppliers, spot rates from Sea and Bunker

Figure 88: Possibility of bunkering facility in Enayam

To create a differentiation through bunkering services, it is critical to achieve high process related efficiencies (high fuel loading speeds etc.) and state of the art facilities (all weather bunkering etc.). The industry will also need support in terms of tax and duty breaks at least in the initial years.

4. - 7. Ship related services

Four key ship related services were shortlisted for study – ship financing, marine insurance, ship broking and ship chartering. All the services are dominated by global players in form of major banks, insurers, shipbrokers. Moreover, these services are usually run out of major financial hubs and large metropolitan cities. Hence, feasibility of developing these service industries near Colachel is limited.

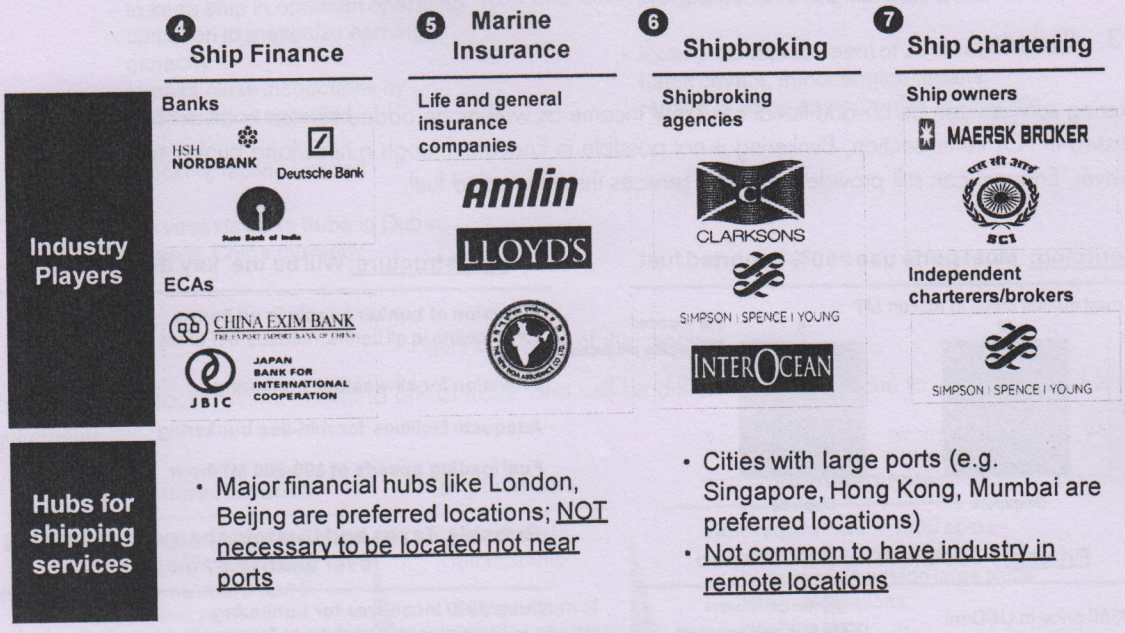


Figure 89: Ship related services – major players and locations

8. Power plant

Power plant would be feasible based on power supply demand gap in Tamil Nadu in FY 22. The section on bulk cargo discusses possibility of power plant in details.

9. Cruise shipping

All cruise shipping centres in India and globally are either home ports or ports-of-call. Enayam/ Colachel has been evaluated for both home port and port-of-call. Enayam lacks both cruise destinations and major cities in the vicinity of the port, making it difficult for Enayam to attract cruise shipping industry.

Homeport Attractiveness

Parameter	Colachel attractive?	Reason
Access to major markets	No	Distance from major cities: nearest metro >700 km Nearest airport 65 km away
Lodging	No	Mostly 2 and 3 star hotels – not attractive to cruise passengers
Crew travel cost	No	Cost high because of distance from major hubs
Overall attractiveness	**No**	

Port-of-call Attractiveness

Parameter	Colachel attractive?	Reason
Range of tourist attractions	No	Main tourist sports are Thomaiyar Kovil church and Padmanabhapuram palace
Adventure/activities	No	No major hotspots in and around Colachel
Depth of port	Yes	20 m deep draft available
Overall attractiveness	**No**	

Figure 90: Cruise port attractiveness

10. Maritime education and R&D centre

Indians form the second largest pool of sea farers in the world accounting for 10-15% of global pool of shipping crew (~15% for global officer pool and ~10% of global rating pool). Marine education infrastructure is critical for sustaining and expanding the Indian sea farer base. India today has more than 120 marine education institutes which are recognized by DG Shipping (~70 % of the institutes are part of engineering colleges). Although the no. of seats in India for marine education is adequate, the quality of education has always been under scrutiny. The DG Shipping had imposed a ban on opening of new maritime institutes and expansion of existing ones in 2012 to control quality of the institutes. The biggest impediment of ensuring quality has been shortage of training berths on ships for the students. Institutes that can provide adequate exposure to the students by providing training berths would be in great demand among the aspiring sea farers.

Enayam provides an opportunity to set up a best in class maritime education institute. South India is perceived as a major hub of talent for marine crew. There is a strong demand for marine education in the region. The institute can help cater to this demand. It will have an edge over other institutes due to the access it will get to the shipping liners who would operate in the Enayam port. This would allow the institute to provide adequate training berths to its students. The institute can also help develop Indian talent for other forms of shipping businesses like ship broking and maritime law, and can foster entrepreneurship in shipping services among others.

Innovation and R&D centres have been the backbone of maritime clusters across the world including the likes of Singapore and Norway. Norway had started the Norwegian Maritime Knowledge Hub- a collaboration among Norwegian University of Science and Technology, Norwegian Shipowners

Association and Norwegian government to gain competitive edge on shipping technology. Enayam is suited to become a site for a similar maritime knowledge hub through a research & development centre. The R&D and education hubs can prove to be a stepping stone for development of services hub in the region.

7. SITE INVESTIGATION STUDIES

7.1. MET-OCEAN DATA

7.1.1. Introduction

The aim of this section is to define the wave climate in coastal areas at certain locations near the area of study. To design the port structures, the offshore wave climate and its propagation to shallow water areas must be characterized.

The most important objectives are:

- Characterization of the offshore wave climate by analyzing the reanalysis databases from 1950 – '14
- A maximum dissimilarity selection algorithm (MDA) is applied in order to obtain a representative subset of sea states in deep water areas. The reduced number of selected cases spans the marine climate variability, guaranteeing that all possible sea states are represented and capturing even the extreme events.
- These sea states are propagated using a wave propagated model (SWAN) to shallow water areas.
- The time series of the propagated sea state parameters at a particular location are reconstructed using a non-linear interpolation technique based on radial basis functions (RBFs).
- Characterization of wave climate in shallow water at a particular location.

7.1.2. Data Sources

Wind, wave and tide data is obtained through third generation hindcasting models named Climate Forecast System Reanalysis (CFSR), for winds, and WaveWacth 3 (WW3) for waves. The following sections give further information on each:

- Winds

The Climate Forecast System (CFS) is a model representing the global interaction between the Earth's oceans, land, and atmosphere developed by the US National Centers for Environmental Prediction (NCEP). It is a global third generation reanalysis product. The CFSR is a high resolution, coupled atmosphere-ocean-land surface-sea ice system designed to provide the best estimate of the state of these coupled domains over the period from 1979 to 2010 (Saha et al., 2010).

The Climate Forecast System Reanalysis (CFSR) is an effort to generate a uniform, continuous, and best-estimate record of the state of the ocean-atmosphere for use in climate monitoring and diagnostics. CFSR stands out by its high resolution and advances in data assimilation techniques. Here, the near-surface winds from CFSR are freely provided.

- Waves:

The wave generation is obtained by using the WW3 model and the NCEP/NCAR global wind and ice cover databases. In order to check the performance of the wave generation model and the quality of the forcing fields,

a preliminary validation is done using satellite altimetry data. Next stage consists of the calibration of the numerical results using satellite altimetry data.

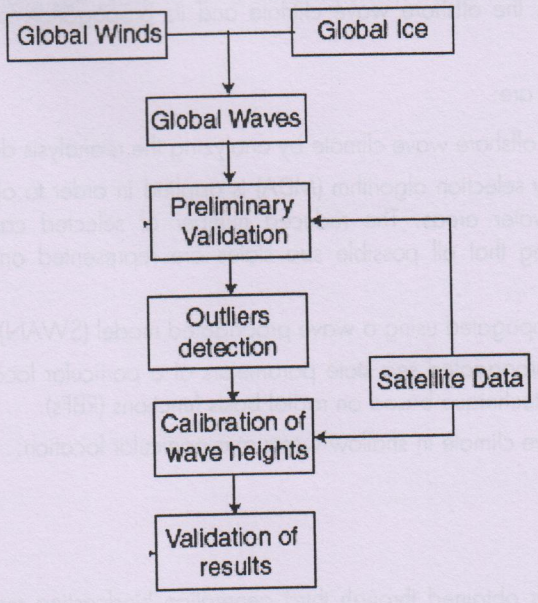


Figure 91: Methodology diagram.

Wavewatch IIII (WWIII, Tolman, 2002) is a third generation wave model developed at NOAA-NCEP. WWIII solves the spectral action density balance equation for wave number direction spectra.

More than 60 years of historical wind-generated offshore waves were performed for the last half century. The wave hindcast outcomes provide hourly time series of significant wave height, mean wave period, peak frequency and mean wave direction for all the grid points of the computed grid.

- Tides

GOT dataset provide hourly time series of astronomical tide for a selected period. It is generated using the harmonic constants derived from the TPXO7.0 global tides model developed by Oregon State University (http://volkov.oce.orst.edu/tides/global.html).

The database includes eight primary constants (M2, S2, N2, K2, K1, O1, P1, Q1), two long period constituents (Mf, Mm), and 3 non-linear (M4, MS4, MN4) harmonic constituents, provided in a global grid of 1440 x 721 points, at 1/4 degree resolution full global grid. This information is used to reconstruct hourly time series of tide in any location worldwide using the tool t_tide (Pawlowicz et al., 2002).

7.1.3. Reanalysis databases

This information has been extracted from two points with hourly temporal resolution:

Southwest India [Lon=76.50°E, Lat=8.00°N]

Southeast India [Lon=78.00°E, Lat=8.00°N]

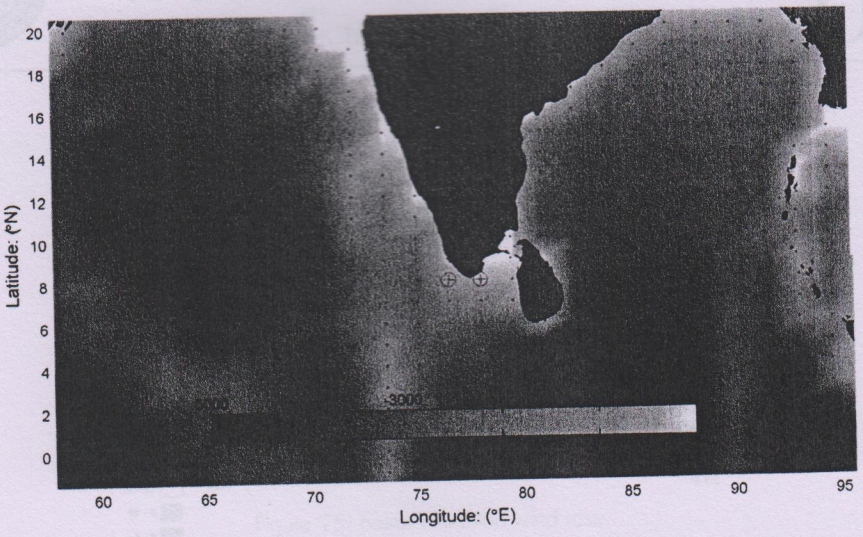


Figure 92: Location of the two points of met-ocean data

The met-ocean information consists of hourly time series of the following parameters of the sea state, wind speed and wind direction and sea level variability due to tide:

- Hs: Significant wave height (meters)
- Tm: Mean wave period (seconds)
- Fp: Peak frequency (Hz). Calculated from the one-dimensional frequency spectrum using parabolic fit around the discrete peak
- θ_{Hs}: Mean wave direction (degree., meteorological convention)
- W: wind speed at 10 meters above the sea surface (m/s)
- Wdir: Wind direction at 10 meters above the sea surface (degree., meteorological convention)
- Tide: tidal level (m) without meteorological effects/storm surge

7.1.4. Wind climate

Two offshore databases are available - one is on the western side and the other on the eastern side of the area of study. Each one has been explained below:

7.1.4.1. Western location

On the western side all wind directions are represented by the wind rose. This figure represents the wind speed, the wind direction and the frequency of occurrence from 1979 to 2010.

In conclusion the predominant directions in these 31 years are west and northwest.

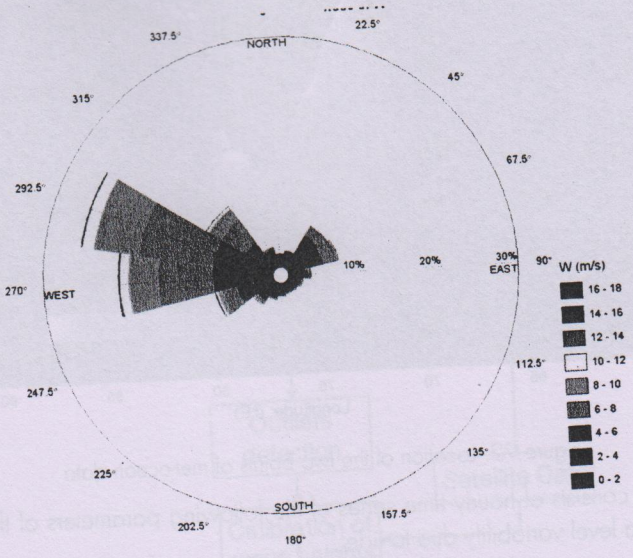


Figure 93: Western location wind rose

A study of winds has been done during the monsoon period, from June to September, and no monsoon period.

The predominant wind direction during the monsoon period in the western location is west to north-west. On the other hand during the non-monsoon periods, the predominant wind direction is from north-east during the morning and west during the evening. The maximum wind speed observed was of the order of 18m/s from westerly direction.

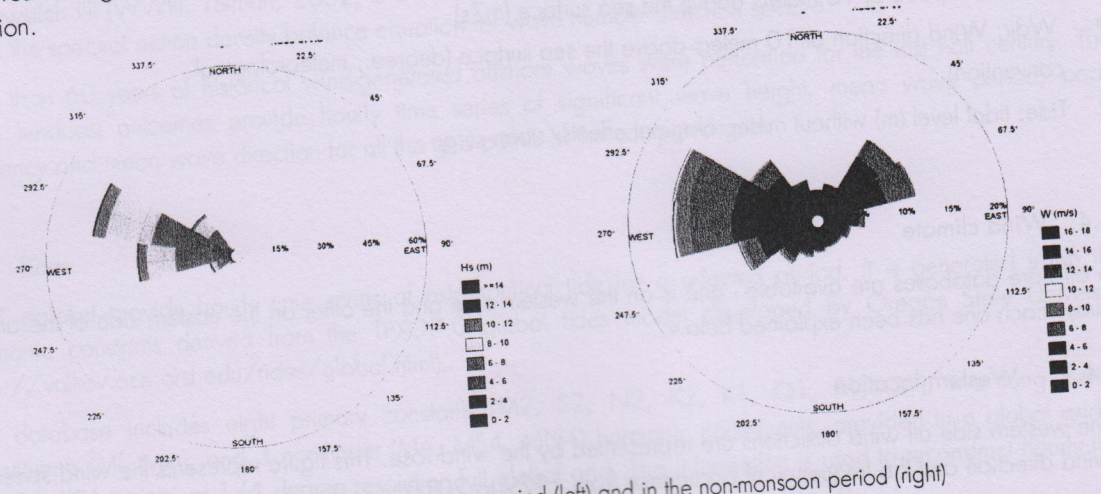


Figure 94: Winds in the monsoon period (left) and in the non-monsoon period (right)

7.1.4.2. Eastern location

A similar study has been done on the other data location; East point differs between monsoon period and no monsoon period. The figure below represents the global wind information from 1979 to 2010.

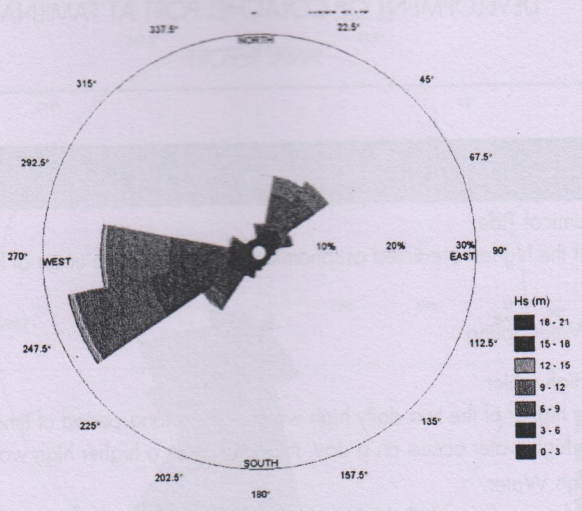


Figure 95: Eastern location wind rose

The predominant wind direction during the monsoon period in the eastern location, from June to September, is west to south-west. On the other hand during the non-monsoon periods, the predominant wind direction is from north-east during the morning and west during the evening.

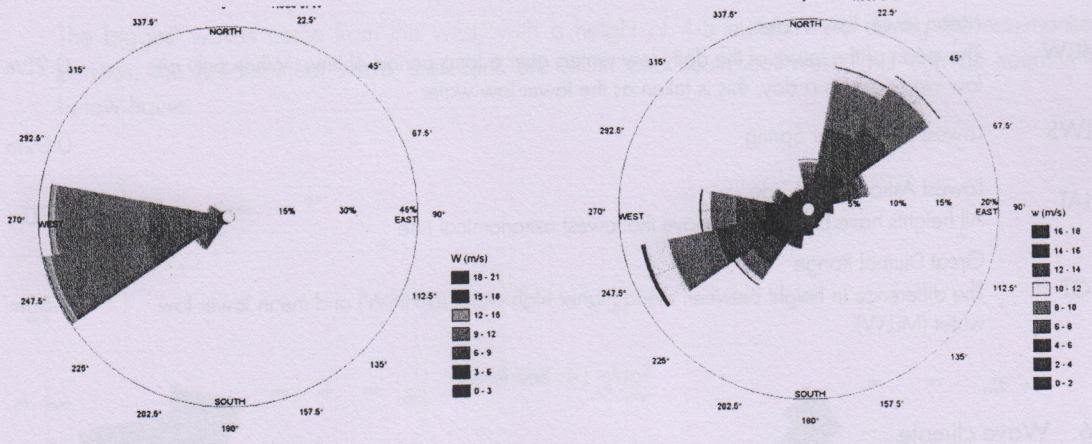


Figure 96: Winds in the monsoon period (left) and in the non-monsoon period (right)

7.1.5. Sea level

The information available of sea level provides hourly time series of astronomical tide data for a selected period (from 1950 to 2014).

Tide information is measured with respect to the Mean Sea Level (MSL). This data have been transformed taking the lowest astronomical tide as the zero value of the tide information, the transfotmation is shown in the below figures. The table below shows the sea levels:

Sea level	Description	Value
HAT:	Highest Astronomical Tide. The elevation of the highest predicted astronomical tide expected to uccur at least once a year	1.05 m
HHWS	Highest High Water Spring	1.04m
MHHW	Mean Higher High water. The mean of the higher of the two daily high waters over a long period of time. When only one high water occurs on a day, this is taken as a higher high water .	0.83m
MLHW	Mean Lower High Water. The mean of the lower of two daily high waters over a long period of time. When only one high water occurs on a day, no value is printed in the MLHW column, indicating that the tide is diurnal .	0.67m
MHLW	Mean Higher Low Water. The mean of the higher of the two daily low waters over a long period of time. When only one low water occurs on a day, no value is printed in the MHLW column, indicating that the tide is diurnal.	0.41m
MLLW	Mean Lower Low Water. The mean of the lower of the daily low waters over a long period of time. When only one low water occurs a day, this is taken as the lower low water	0.25m
LLWS	Lowest Low Water Spring	0.02m
LAT	Lowest Astronomical Tide. All heights have been taken above the lowest astronomical tide	0.00m
GT	Great Diurnal Range The difference in height between mean higher high water (MHHW) and mean lower low water (MLLW).	0.58m

Table 14: Sea levels

7.1.6. Wave climate

7.1.6.1. Deep water wave climate

A brief description is represented by wave roses in each location. In summary, the dominant waves come from the south-south western direction.

These figures represent the wave height, wave direction and the frequency of occurrence from 1950 to 2014.

- Western location wave rose

  The predominant wave direction is from south to south-southwest, but the highest ones come from the south west to the west.

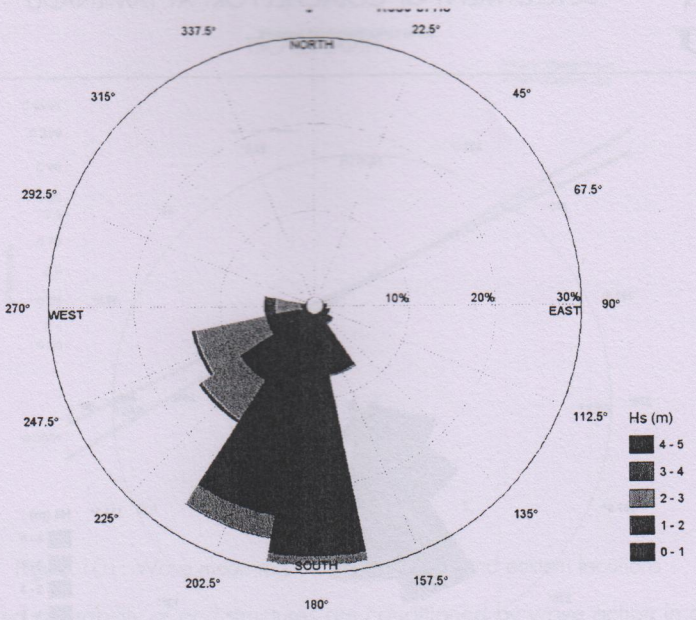


Figure 97: Western location wave rose.

During the monsoon period, the predominant directions are western-south western and south western.

The biggest waves come from the west, with a height of 4-5 meters. And during the non-monsoon periods, the predominant wave directions are south and south-southwest. This can be seen in the below figure

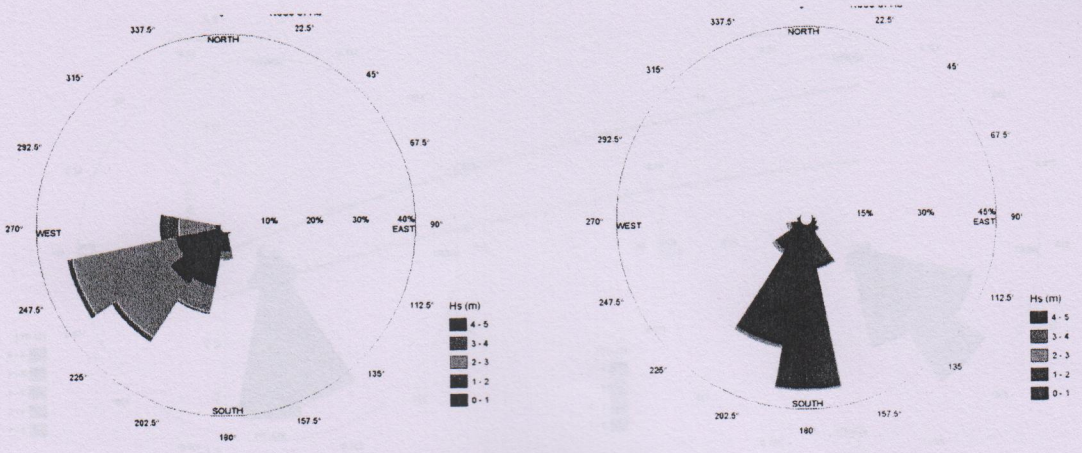


Figure 98: Waves in the monsoon period (left) and in the non-monsoon period (right)

- Eastern location Wave Rose

The same study has been done in the other location point. The below figure represent the height wave, wave direction and frequency of occurrence in eastern location from 1950 to 2014.

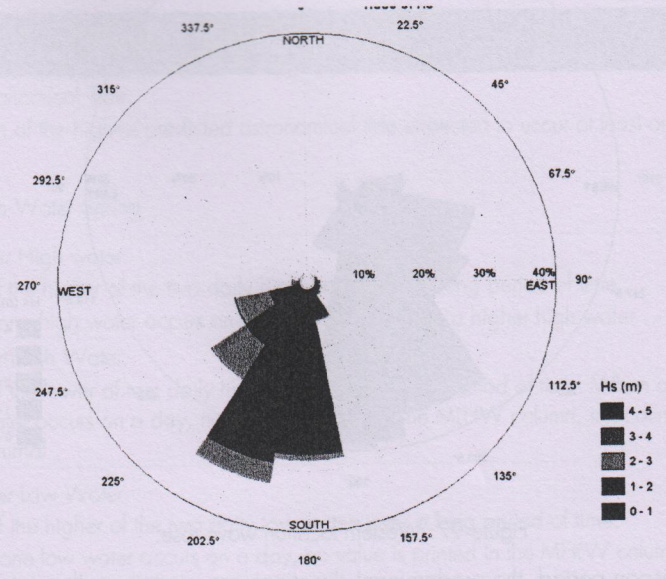


Figure 99: Eastern location wave rose.

The information is approximately the same as in the western location, the predominant direction being from south to south-southwest all year round. The predominant direction is southwest during the monsoon period and south and south-southwest during the non-monsoon periods.

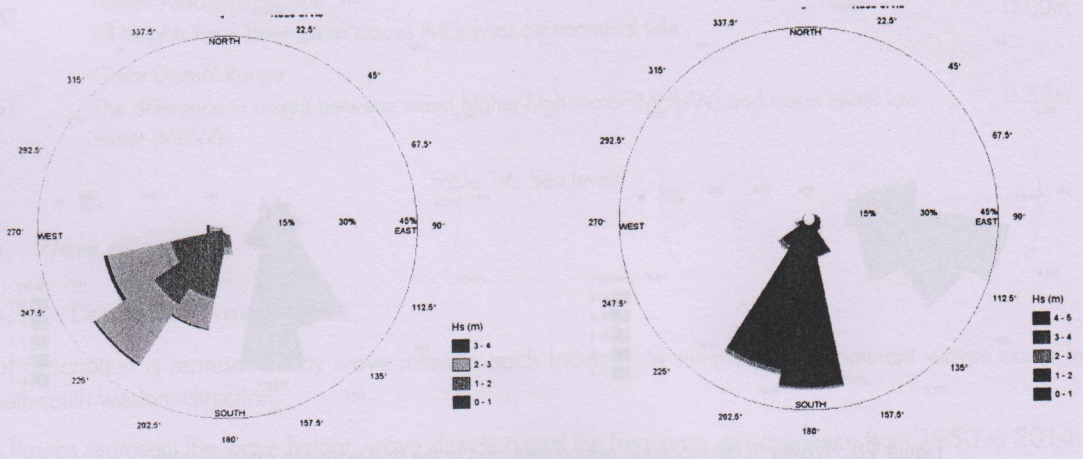


Figure 100: Waves in the monsoon period (left) and in the non-monsoon period (right)

- Mean and extreme regime

The Mean regime of time series is the set of sea states that have more probability of occurrence. The following figures show the long-term distribution of significant wave height (Hs) in mean regime probability in each location:

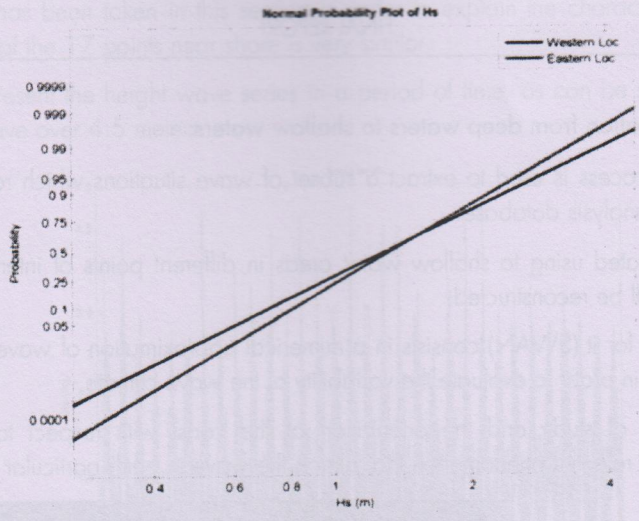


Figure 101: Wave mean regime in the western and eastern locations

The security and operability of port structures are conditioned by wave action in a storm situation.

With the aim of reduce the risk that port structures can suffer because of wave action, is important to know an estimation of the frequency which a storm with a higher wave height could be presented

The extreme regime is a statistic model that describes the probability that a storm can appear with a certain wave height. This is showed in the figure below:

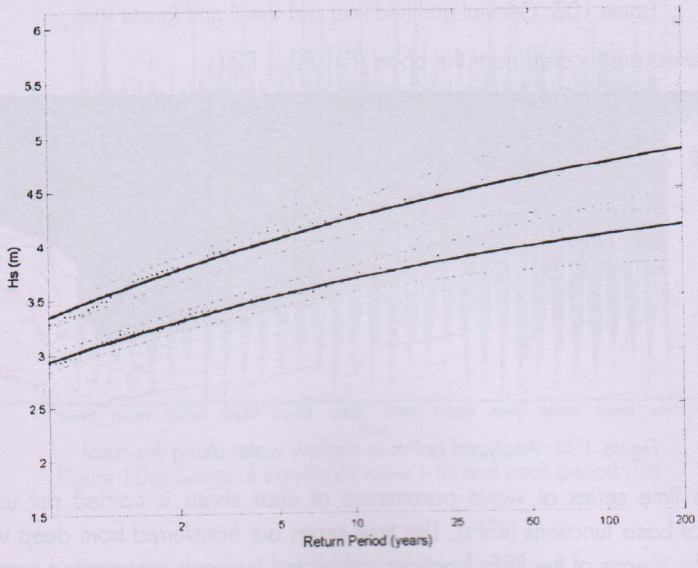


Figure 102: Wave extreme regime in the western and eastern locations

7.1.6.2. Wave transformation from deep waters to shallow waters

As a first step, a selection process is used to extract a subset of wave situations which represent the available ocean conditions from the reanalysis database.

These sea states are propagated using to shallow water areas in different points of interest in which one-time series of wave parameters will be reconstructed.

The propagation model used for it (SWAN) consists in a numerical approximation of waves from deep water to shallow water near the coast in order to evaluate the variability of the wave climate.

The bathymetry of the area of study and the orientation of the coast with respect to the incident waves are both decisive for the most relevant phenomenon that affects the wave in each particular case.

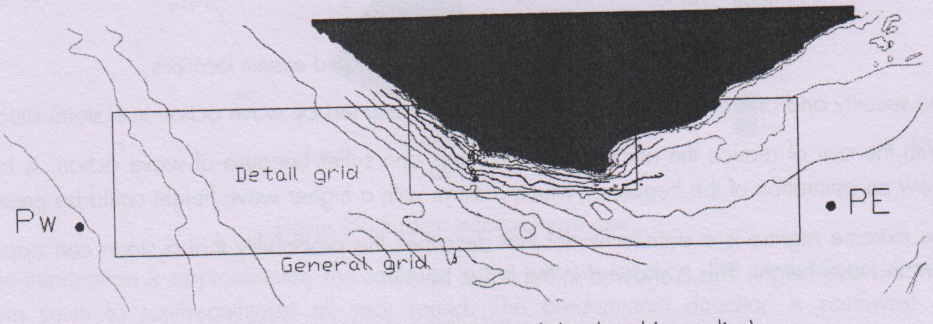


Figure 103: General grid (red line) and detail grid (green line)

A number of points of interest are located near the coast (P1, P2... P21).

Figure 104: Analyzed points in shallow water along the coast

The reconstruction of the time series of wave parameters at near shore is carried out using an interpolation technique based on radial basis functions (RBFs). The time series are transferred from deep water to the points of interest at shallow water by means of the RBFs functions calculated for each propagated parameter.

The RBF technique has proven to be a powerful technique to reconstruct time series of sea state parameters for each sea state at deep water.

7.1.6.3. Shallow water wave climate

When the reconstruction of the time series of wave parameters at the near shore points are carried out, the characterization of wave climate in shallow points can be done.

One point near shore has been taken in this section in order to explain the characterization in shallow water, because the behaviour of the 17 points near shore is very similar.

The below pictures represent the height wave series in a period of time, as can be seen in the enclosed figure, there are few height wave over 4.5 meters.

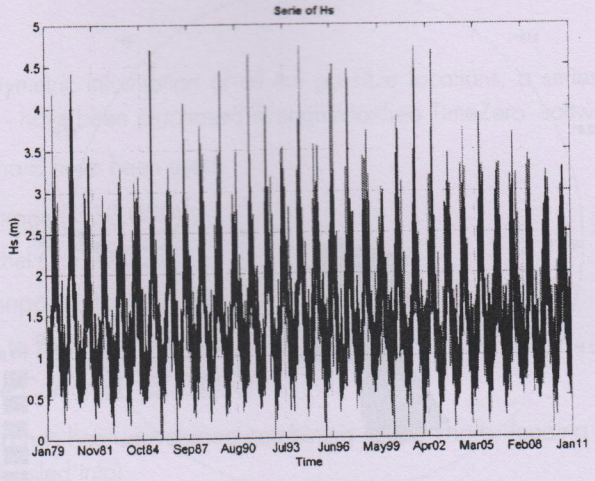


Figure 105: Series of significant wave (Hs)

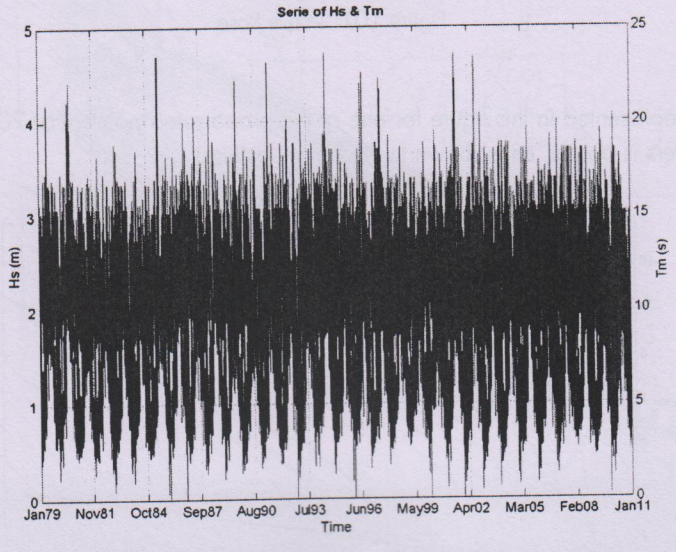


Figure 106: Series of significant wave (Hs) and peak period (Tp)

Wave roses

Wave roses represent wave height, direction wave and frequency of occurrence, all of them are very similar in all points, and the main direction to everyone is from the southwest.

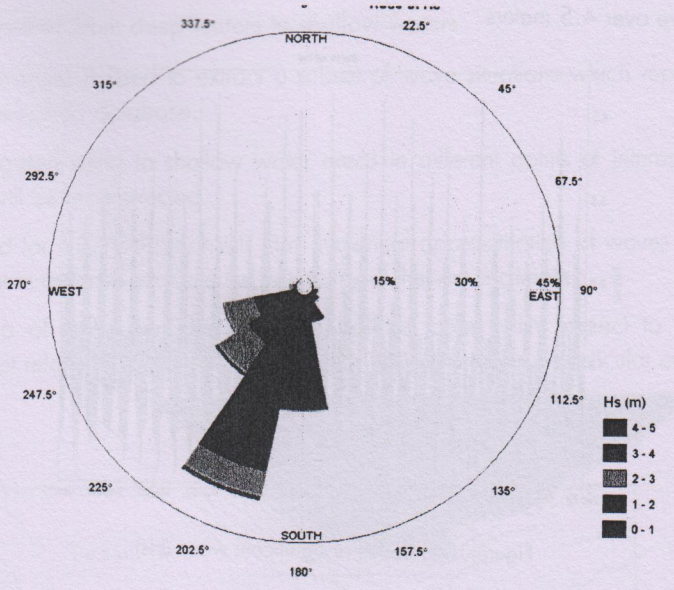


Figure 107: Wave Rose

Extreme regime

The Extreme regime is represented in this figure for one of the propagated points. For 200 years of return period a wave height of 5 meters is obtain, as is shown in the below picture:

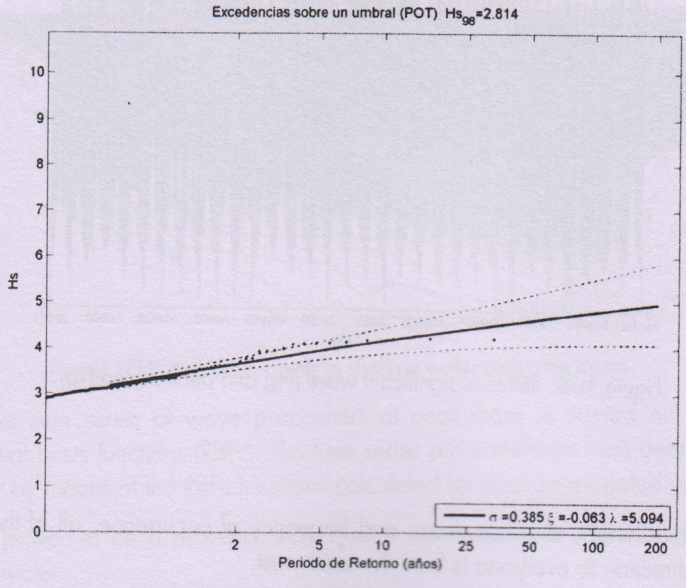


Figure 108: Wave heights and return periods

In conclusion, knowing the predominant wave direction, the wave height for 200 years of return period and the peak direction associated to this wave height is necessary for designing the port structures (rubble-mound breakwater and vertical breakwater).

To sum up, the dominant waves come from the south-south western direction, and for 200 years of return period, a. wave height of 5 meter with a peak period of 11,5 seconds have been taken for the preliminary design of port structures.

More detailed information of this study is enclosed in Annexure 3: Metocean analysis - Wave propagation.

7.2. BATHIMETRIC DATA

In order to have good bathymetric information of all the possible locations, a series of nautical charts -both in paper and electronic (ENC) - have been purchased through MaxSea TimeZero software.

Specifically, the following charts have been used:

- 2048-Kolachel Anchorage (1:30,000)
- 222-Quilion to Colachel (1:150,000)
- 223-Colachel to Manappad (1:150,000)
- 7365-Cape Comorin to Pamban (1:300,000)
- 7362-Cochin to Cape Comorin (1:300,000)

A complete bathymetric map has been developed combining all the charts, leading to a chart like the following (see drawing-01 for more detailed info).

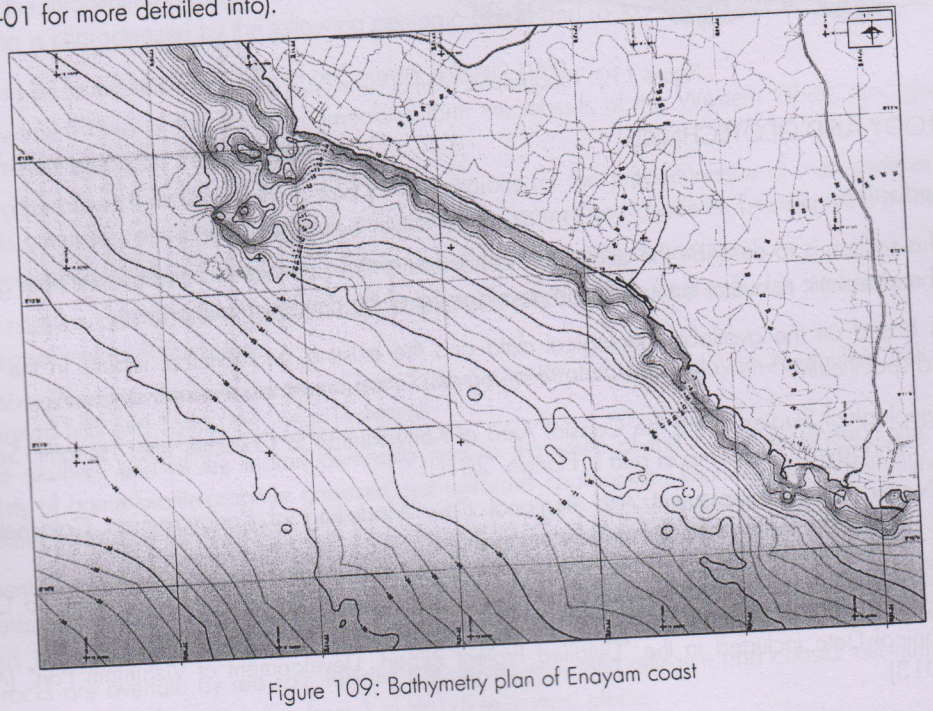


Figure 109: Bathymetry plan of Enayam coast

7.3. TOPOGRAPHIC DATA

Topographic information has been extracted from various sources like Google Earth through PlexEarth, specialized software which have been purchased by the Consultant for this purpose. This information has been

completed using the available land charts of the region. The following figure shows the result of the processing of information:

Figure 110: Topographic plan of the studied area

7.4. GEOLOGY AND GEOTECHNICS

7.4.1. Introduction

The aim of this section is to describe the geological conditions of the port location and evaluate the geological, geotechnical and seismic risks that may affect the development of the correspondent project.

The report is based on the available geological data and the existing geotechnical reports in the vicinity of Colachel, and specifically:

- Hydro-geological Studies along the Coastal Area of Kanyakumari to Colachel after Tsunami, South Tamil Nadu. S.Bhagavathi, P.Thamarai and L. Elango. 2010.
- Groundwater Quality assessment And Regional Flow Modelling of Kanayakumari Colachel Coastal Aquifer, Tamilnadu, India. S.Bhagavathi Perumal. 2008.
- "Geophysical Survey for Vizhinjam Deep Water International Transshipment Terminal Kerala Off-Shore, West Coast of India (Fugro, July 2011).
- Geotechnical Data included in the "Detailed Project Report. Development of Vizhinjam Port" (AECOM, May 2013).

7.4.2. Description of the regional geology

All the proposed locations are placed in the Tamil Nadu region, affected by intense metamorphism. Geologically, Tamil Nadu is divided into three zones: the northern region, the southern region and the central region. Colachel Port is located in the southern region.

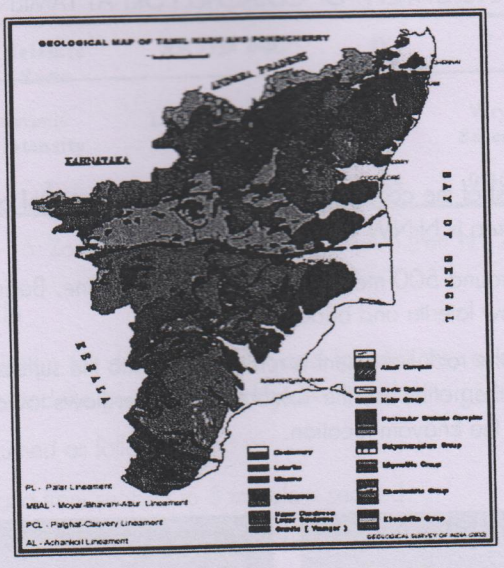


Figure 111: Geological map of Tamil Nadu (Source: *http://www.tnmine.tn.nic.in*).

According to the information provided by the Department of Geology and Mining of the local government, the **southern region** is characterized by the following geologic events and rocks:

- They can be found south of the Palghat-Cauvery tectonic zone.
- In the western area of this zone, charnockites form the massifs of the Western Ghats, and gneisses are predominant along the eastern part.
- This region differs from the northern and central regions for the predominance of meta-sedimentary rocks such as quartzites, sillimanite quartzites, calc-granulites, garnet and cordierite bearing meta-pelites.
- This zone is totally devoid of dolerite dykes and banded magnetite quartzites.
- In the northern part of this region, calc-silicates and crystalline limestone occur as thick sequences with a few tens of metres of thickness.
- Extensive limestone deposits are found from Palayam to Kiranur, Rajapalayam-Alangulam belt east of the Varshanad hills and Talaiyuthu, near Tirunelveli.
- At the southern end of the Indian peninsula and to the south of the Achankoil shear zone, the terrain consists of garnet-biotite-graphite gneisses, garnetiferous charnockite, khondalites (garnet-sillimanite-biotite-graphite) and cordierite gneiss.

The basement of the Kanyakumari District coastal belt, where the port area is located, consists of charnockite, granite gneiss, leptinite gneiss, peninsular gneiss, laterite and warkalai sandstone. There are several indications of numerous episodes of deformation, which caused repeated folds, faults, joints and fracture systems. The basement rocks are overlain by red soil, lateritic soil, Ilayey soil, river alluvium and coastal alluvium, black, red and red sandy soil of thickness ranging from 1 m to 1.5 m in most places.

7.4.3. Description of the site

This site is located to the northwest of the coastal belt. The basement consists of garnetiferous biotite gneiss. The general trend of the strike in this area is N-NW to S-SE.

Some rocky islets are observed around 500 meters away from the coastline. Besides, weathered rock has been identified close to the surface below laterite and beach sands.

These signs seem to indicate that the rock basement is relatively close to the surface and onshore soil thickness is small, although 3.5 kilometres to the northwest, the Tambraparna River flows towards the Indic Ocean, and the long-shore drift transports sands to the Enayam location.

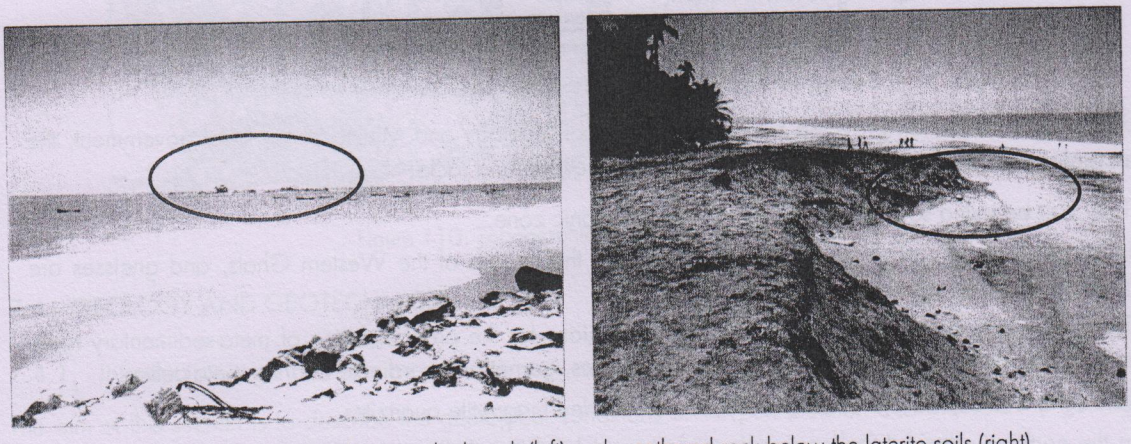


Figure 112: Rocky islets near the beach (left) and weathered rock below the laterite soils (right).

7.4.4. Seismic hazard

The proposed project falls under Seismic Zone III, according to the classification proposed at IS 1893 (Part I): Criteria for earthquake resistant design of structures. The zone factor Z which corresponds to Zone III is 0.16.

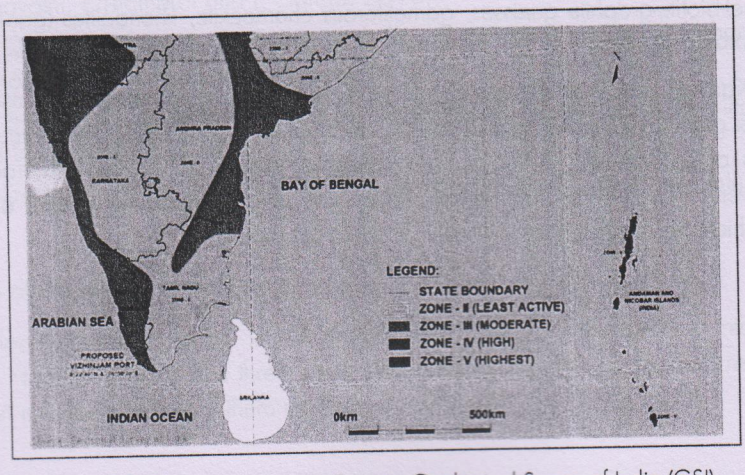


Figure 113: Seismic zone map. Source: Geological Survey of India (GSI).

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

Table 15: Zone factor Z value. Source: IS 1893 (Part 1) : 2002.

7.4.5. Estimated subsoil profile

In order to develop an initial design for dredging works and foundations, a preliminary soil profile has been estimated based on the site visits and the geological and geotechnical data given in 7.4.1.

The subsoil profile has been assumed as follows:

- Loose to medium dense sand from seabed to 5 m below seabed
- Medium to dense sand from 5 m to 15 m below seabed
- Moderately strong rock from 15 m below sea bed

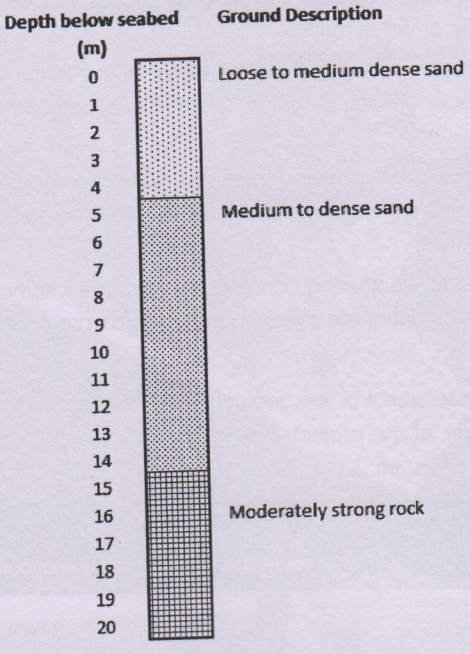


Figure 114: Preliminary soil profile assumed for the feasibility design

It is important to clarify that this soil profile is only a preliminary estimation, and must be reviewed by a proper geophysical and geotechnical study. Particularly, the field investigation shall include, at least, information from side scan sonar, sub-bottom profiler, boreholes, soil samples and laboratory tests.

It is also important to note that the bedrock surface is expected to be uneven, since the weathering of gneiss tends to create irregular profiles depending on the orientation and characteristics of the discontinuities. Among

others, this fact can influence the geotechnical design of pile foundations (the total pile length will vary with the specific location of the rock).

Thus, the proposed profile must be assumed just as a first approach of the average geotechnical conditions at the site, to be confirmed in further phases of the project.

7.4.6. Geotechnical risks

From a geotechnical point of view, the main risks to be considered in further stages of the project can be summarized as follows:

- Presence of rock or hard materials in the area to be dredged, which would involve an important impact on the cost and performance of the dredging works.
- Presence of soft or very loose materials in the locations of breakwaters, berths, or earthfills, which may require special foundations or ground treatments to guarantee the structural requirements.
- Steeply sloping seafloors and accompanying down-slope soil movements can cause additional lateral pile forces in the down-slope direction. Also, steep sloping makes the area more vulnerable to instability induced by the seismic activity of wave forces.
- Scouring of near-surface soils can occur and can be accentuated in the vicinity of piles. The extent of the scouring depends on the velocity of seafloor currents, the type of soil and the size and configuration of pile groups.
- Earthquake-related hazards should be assessed in seismically active areas. Earthquake motions may cause partial loss of strength or complete liquefaction in loose granular soil zones, essentially removing soil support developed in these zones.
- Gneisses are more susceptible to weathering compared to massive charnockites. Erosion in gneiss areas is higher than in charnockite areas, therefore rivers in gneiss areas are prone to transporting more sediments than those in charnockite areas.

The table below shows a general assessment of the geotechnical risks described above. More detailed analyses should be developed in further stages of the project, based on the results of the geotechnical field investigation (boreholes, trial pits, geophysical profiles, etc.).

	% rock near surface	Thick deposits of sediments	Steeply sloping seafloor	Type of rock (weather susceptibility)
Grade	Low	Low	Low	Moderate

Table 16: Geotechnical risks.

7.5. LAND AVAILABILITY

As the port is to be developed entirely on reclaimed land, no land acquisition is envisaged for the port development. However, the project shadow area can impact fishermen dwellings.

Coastal land from Colachel to Enayam would change to a port area. As a result of the Project development, this part of the sea coast and beaches would be permanently lost during the construction and operation of the Project.

However the port being an international facility with multitude of infrastructure planned, the port could also require backup areas in the immediate vicinity. Following images show the current land-use and population within the 2.5x3.00 Km square area close to port location.

- **Affected land and properties**

To carry out a description of the land use in areas near Enayam a rectangular area of 2 x 3 km surface was determined as the "scope area". Polygons with similar characteristics were grouped and classified. The scale of work to determine the polygons was 1: 2,500.

After the completion of this work, the land uses in the Enayam "scoping area" are:

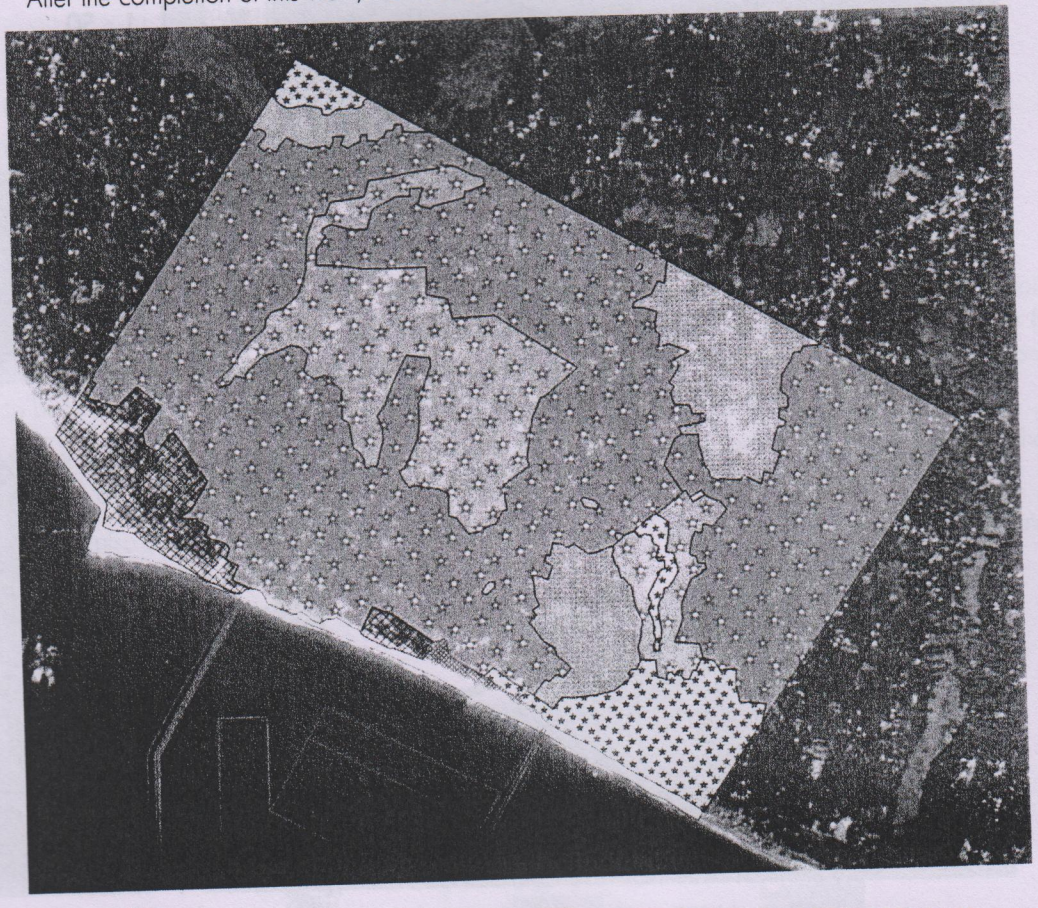


Figure 115: Enayam Port Area Land-Use Map

- **Population Affected**

The following image shows in-land population density close to the port area:

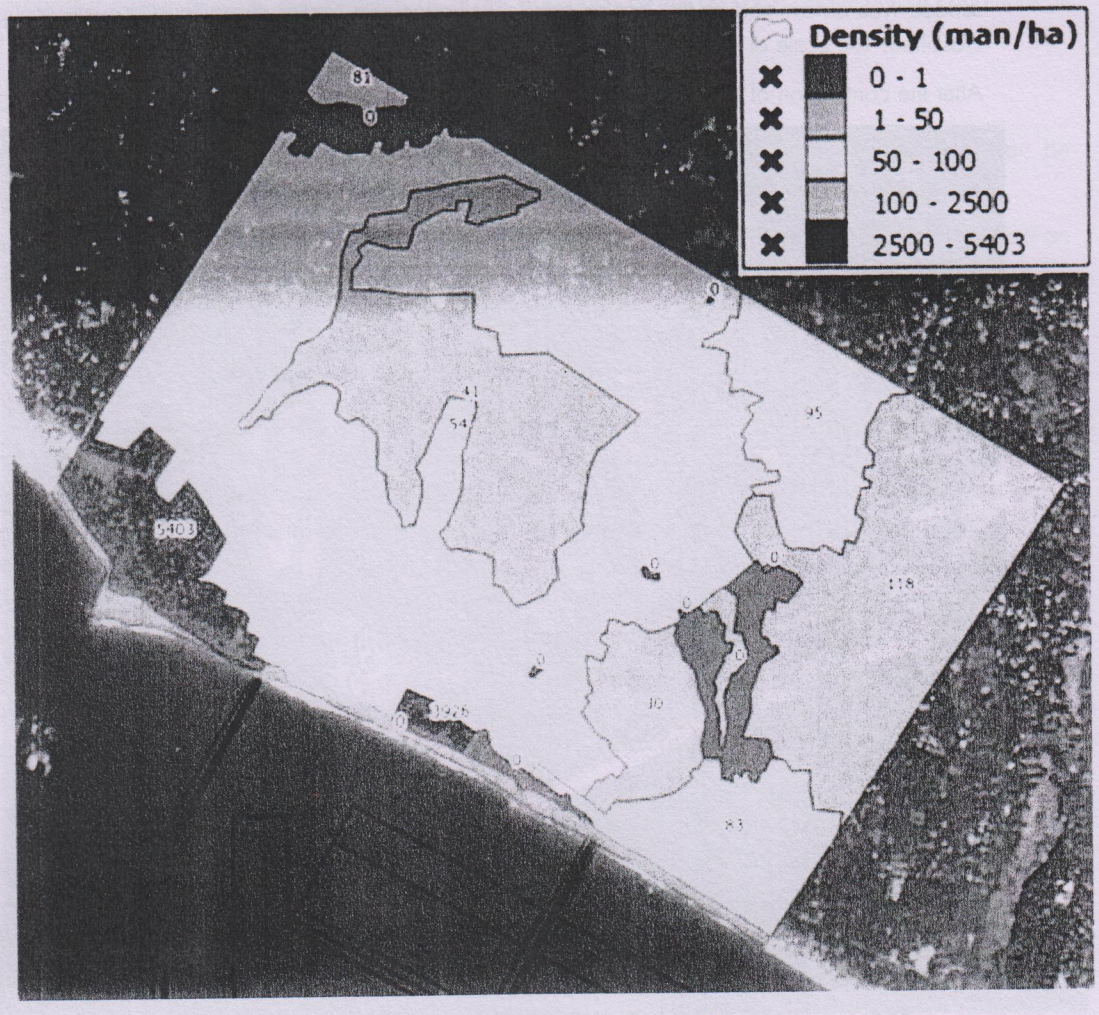


Figure 116: Enayam Port Area Population Density Map

- **Estimated land rates**

Land surface data and reference rates for the identified use, obtained from local real estate companies, field works and surveys (polls) and internet specialized websites, are the following.

Use	Lacs/acre
Beach and Shoreline	-
Sand Dune Vegetation	0.20
Dense Coconut Tree plantation	30
Dense Coconut - Fruit Trees	20
Sparse Coconut - Fruit Trees sparsely populated	10
Arable Crops	5
Sparse Fruit Trees	10
Altered, bare soil, disseminated trees	1
Pond	-
Urban area 1	8
Urban area 2	3

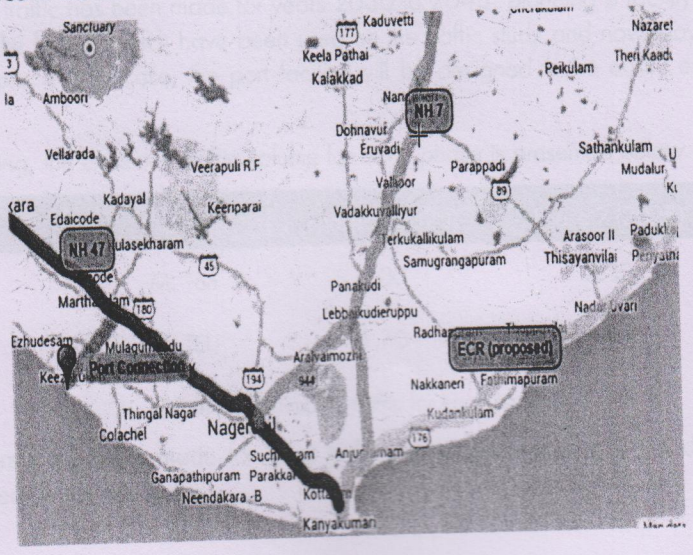
7.6. TRANSPORT LINKAGES

7.6.1. Road links

The closest main road to the port is the National Highway NH47, which connects Nagercoil and Thiruvananthapuram. It is about 10 km from the coastline as the crow flies. At present, it has two lanes (one in each direction) and it runs through numerous built-up areas, which means that traffic congestion is quite normal. A tender to build a new four-lane highway that will run parallel to this road is expected in the short term.

The National Highway NH7 is the road that connects by road the west coast of Tamil Nadu State –where the port is located- to the rest of the State of Tamil Nadu. The traffic on this four-lane highway runs smoothly.

A new road is also due to be built along the eastern coast of Tamil Nadu, which may well improve connectivity with the production centres in the hinterland.



As far as the zone closest to the port is concerned, in the stretch of land between this area and the NH47 there are many minor roads that connect the various towns that are found there. There are also numerous access roads to plantations and housings.

7.6.2. Rail links

The closest railway line is the one that connects Kanyakumari in the south to the State of Kerala in the north. This single broad gauge track runs approximately 9.5 km from the place in which the port is envisaged. This is the line the port will have to connect to, if cargo is to be brought in by rail.

There is also a single track that runs from Nagercoil towards the rest of the State of Tamil Nadu, which would facilitate the connection to the port's area of influence. It is expected that a second track will be added in the near future.

8. DESIGN CRITERIA

8.1. TRAFFIC AND PHASING

The Traffic and Market Study summarized in earlier provides an estimate of Colachel's trans-shipment and gateway traffic under multiple scenarios. It also explains in detail the factors that may substantially impact the traffic movements. Besides, the report provides traffic estimation for bulk (coal) traffic.

The conclusions drawn in the aforementioned study for the Base Case, which is the selected one to design the port facility, is shown in the table below:

Base Case	units	2018	2020	2025	2030	2035	2040	2045
Bulk Traffic	in Mn MT	-	-	3.3	6.6	9.9	9.9	9.9
Container - Gateway	in Mn TEU	0.6	1.0	2.1	2.9	3.9	5.0	6.2
Container - Trans-shipme	in Mn TEU	0.4	0.7	2.8	3.9	5.2	8.0	11.5
Total	in MN MT	15.4	26.2	79.4	111.1	151.2	210.6	284.1

Table 17: Traffic estimates for Base Case

Three phases have been defined to size the berths and operational area of the port, which lead to:

- Phase 1: From 2018 (beginning of operations) to 2020. The facilities will be defined to cater the forecasted traffic for 2020.
- Phase 2: From 2021 to 2025. The facilities will be defined to cater the forecasted traffic for 2025.
- Phase 3: From 2026 to 2030: The facilities will be defined to cater the forecasted traffic for 2030..

Although a forecast for traffic has been made for years 2030 to 2045, planning a facility for such a long period is very risky. Many of the factors which have been used on the traffic study and nowadays are considered valid may change in the future. In any case, the port facility will be designed to be easily expandable beyond the 2030 traffic forecast.

According to this phasing, the expected traffic volume for each phase is presented below.

	Units	Phase 1 (2020)	Phase 2 (2025)	Phase 3 (2030)
Bulk traffic (coal)	M. Ton	0.00	3.30	6.60
Container traffic (total)	M. TEU	1.70	4.90	6.80

Table 18: Estimated traffic for each phase

Although no estimations have been made for other traffic, some general cargo, liquid bulk or solid bulk are expected to be attracted by the new port.

8.2. TECHNICAL CRITERIA

8.2.1. Design Vessel

In order to design the berths, basin size and draft, two large vessels have been taken:

Vessel Type	Tonnage (DWT)	Displacement (t)	Length (m)	Beam (m)	Draft (m)
VLCS (Container ship)	18,000 TEU	260,000	400	59	16
Capesize (Bulk Carrier)	120,000	145,000	270	43	16
Capesize (Bulk Carrier) (1)	150,000	177,000	294	45.9	17.5

Table 19: Vessels main figures

(1) The 150.000 DWT Capesize bulk carrier will also be partially considered for the Phase 1 dredging because, although it is not expected in the near future, it could be expected to call the port in next phases of the port.

8.2.2. Wave heights

The wave height for planning will be:

- Mean regime Significant Wave Height (Hs): That is the set of sea states that have more probability of occurrence, and it is described by the highest third of the waves ($H_{1/3}$). For the project site, Hs is considered 2.0 m. More details from design criteria can be extracted from occurrence tables, for example predominant wave direction, peak period associated with different wave heights and their probability of occurrences, etc. All this information is shown in the below tables.

		Hs (m)										
		0.00 - 0.50	0.50 -1.00	1.00 - 1.50	1.50 - 2.00	2.00 - 2.50	2.50 - 3.00	3.00 - 3.50	3.50 - 4.00	4.00 - 4.50	4.50 - 5.00	Total
Tp (s)	2.00 - 3.90	0.21	0.12	0.02	0.01							0.35
	3.90 - 5.80	0.89	0.77	1.52	0.18	0.00	0.00					3.35
	5.80 - 7.70	0.16	0.60	0.95	1.55	0.21	0.02					3.50
	7.70 - 9.60	0.63	[illegible]	[illegible]	[illegible]	1.94	0.14	0.01				23.35
	9.60 - 11.50	0.70	[illegible]	[illegible]	[illegible]	[illegible]	1.06	0.03				30.05
	11.50 - 13.40	0.53	[illegible]	[illegible]	2.53	1.53	0.30	0.02				19.58
	13.40 - 15.30	0.17	4.62	5.38	2.77	1.76	0.51	0.14	0.02			15.33
	15.30 - 17.20	0.01	0.89	1.13	0.92	0.68	0.21	0.08	0.07	0.01		3.99
	17.20 -19.10		0.11	0.10	0.14	0.09	0.03	0.01	0.02			0.49
	19.10 - 21.00		0.01	0.01	0.00	0.00	0.00					0.03
Total		**3.29**	**30.68**	**29.52**	**21.60**	**12.23**	**2.28**	**0.29**	**0.11**	**0.01**	**0.00**	**100**

Table 20: Occurrence table (Hs(m)&Tp(s))

		Hs (m)										total
		0.00 - 0.50	0.50 -1.00	1.00 - 1.50	1.50 - 2.00	2.00 - 2.50	2.50 - 3.00	3.00 - 3.50	3.50 - 4.00	4.00 - 4.50	4.50 - 5.00	280506.00
DD (°)	0.00 - 35.80											0.00
	35.80 - 71.60	0.02										0.02
	71.60 - 107.40	0.20										0.20
	107.40 - 143.20	0.98	0.42	0.03	0.02							1.44
	143.20 - 179.00	0.33	4.39	2.98	0.32	0.02						8.02
	179.00 - 214.80	1.55	[illegible]	[illegible]	6.22	1.93	0.44	0.07	0.02			51.02
	214.80 - 250.60	0.18	3.31	7.63	13.32	6.85	1.30	0.22	0.09	0.01		32.89
	250.60 - 286.40	0.03	0.25	0.41	1.72	3.44	0.54	0.01				6.39
	286.40 - 322.20		0.01	0.00								0.01
	322.20 - 358.00											0.00
total	**280506.00**	**3.29**	**30.68**	**29.52**	**21.60**	**12.23**	**2.28**	**0.29**	**0.11**	**0.01**	**0.00**	**100.00**

Table 21 : Occurrence table (Hs(m)&DD(°))

		Tp (s)										total
		2.00 - 3.90	3.90 - 5.80	5.80 - 7.70	7.70 - 9.60	9.60 - 11.50	11.50 - 13.40	13.40 - 15.30	15.30 - 17.20	17.20 -19.10	19.10 - 21.00	280506.00
DD (°)	0.00 - 35.80											0.00
	35.80 - 71.60		0.01									0.02
	71.60 - 107.40	0.03	0.17									0.20
	107.40 - 143.20	0.25	1.07	0.02	0.10							1.44
	143.20 - 179.00	0.01	0.10	0.22	4.46	2.25	0.65	0.28	0.05			8.02
	179.00 - 214.80	0.01	0.09	0.33	[illegible]	[illegible]	[illegible]	[illegible]	2.22	0.23	0.02	51.02
	214.80 - 250.60	0.04	1.51	2.33	7.41	[illegible]	5.02	4.91	1.72	0.26	0.01	32.89
	250.60 - 286.40	0.01	0.39	0.59	2.16	3.07	0.16	0.02				6.39
	286.40 - 322.20	0.01	0.01									0.01
	322.20 - 358.00											0.00
total	**280506.00**	**0.35**	**3.35**	**3.50**	**23.35**	**30.05**	**19.58**	**15.33**	**3.99**	**0.49**	**0.03**	**100.00**

Table 22: Occurrence table (Tp(s)&DD(°))

- Extreme regime: For preliminary design of main defence structures, mainly breakwaters, a Return Period (Tr) of 200 years has been taken. That is the wave height that occurs, as a mean value, only once each 200 years.

The table summarizes the values for the shallow water control points near the breakwater:

	Mean regime Hs (m)	Extreme regime(200 years) Hs (m)
Enayam breakwater	2.0	5.0

Table 23: Hs Mean Regime and Extreme Regime

8.2.3. Sea level

The tide levels are shown in the table below:

Sea level	Description	Value
HAT:	Highest Astronomical Tide. The elevation of the highest predicted astronomical tide expected to uccur at least once a year	1.05 m
LAT	Lowest Astronomical Tide. All heights have been taken above the lowest astronomical tide	0.00m

Table 24: Tide levels

These tidal levels have been obtained from the Databases of astronomical tide, and others heights have been add over the Highest Astronomical Tide as:

- Meteorological tide :

  From the Journal of Coastal Research non-tidal sea level has been obtained. This Professional Paper based on the sea level data measured at three locations along the nearshore waters of Karnataka, west cost of India. In conclusion Correlation between alongshore component of wind and non-tidal sea level was 0.54 m at Malpe and 0.48 at Honnavar. A 0.54 m storm surge has been considered.

- Expected Sea Level Rise:

  For waterfront structures over the port design life the sea level rise for 50 years is 0.38m according to IPCC (*Intergovernmental Panel on Climate Change* , Climate Change 2014 Synthesis Report), the table below shows the projected change in global mean sea level rise for the mid-and late 21st century:

		2046–2065		2081–2100	
	Scenario	**Mean**	***Likely* range** [c]	**Mean**	***Likely* range** [c]
Global Mean Surface Temperature Change (°C) [a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	**Mean**	***Likely* range** [d]	**Mean**	***Likely* range** [d]
Global Mean Sea Level Rise (m) [b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Table 25: Climate Change 2014 Synthesis Report, IPCC

The **design water level** for the breakwater design is=HAT+ Storm Surge (meteorological tide) + Expected sea level Rise = 1.05+0.54+0.38=**+1.97m**

8.2.4. Operability

In order to limit the downtime on the berth caused by environmental factors, and more specifically, by waves, the defence structures must be capable to limit the wave height at berth.

The following maximum wave heights have been considered for container berths:

- Hs= 0.3 m for waves coming transverse to the vessel.
- Hs= 0.5 m for waves coming longitudinal to the vessel.

9. DETAILED PORT CONFIGURATION

9.1. GENERAL

The design of the port's facilities is the direct consequence of the traffic that it is expected to be able to attract in the future. In this sense, container cargo is obviously the primary activity, followed by, in a second phase and as a secondary activity, coal cargo. The fact that the port may attract small amounts of other types of general merchandise has been also taken into account.

Breakwaters have been defined to protect the facilities from the wave action following the criteria described in earlier sections. Besides, it is important to mention that, due to the fast growth expected for container traffic, berths will be expanded two or three years after finalizing the construction of Phase 1. Therefore, it has been decided not to prolong the south breakwater beyond the berth line in order to make Phase 2 expansions easier, faster and cheaper. Instead of that, the length of the main breakwater has been designed with the appropriate length to avoid downtimes for berth operations.

Then, the proposed layout is the result of bringing together the environmental and physical conditions of the site with traffic expected by 2020.

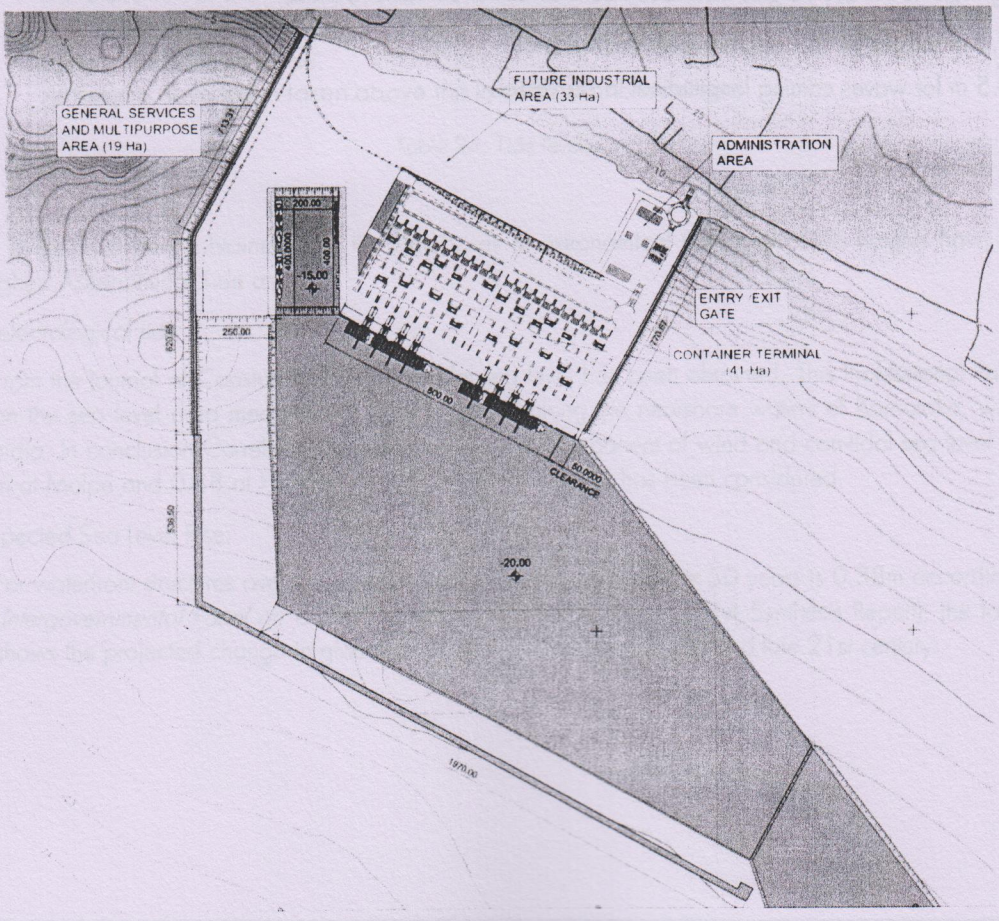


Figure 117: Port Layout for Phase 1

This layout is composed by the following main elements and figures:

Description	Units	Phase 1 (2018-2020)
Berths (total)	m	1,400
Container (2 berths)	m	800
General Cargo (1 berth)	m	400
Ancillary vessels (1 berth)	m	200
Terminals/Yards	Ha	93
Container	Ha	41
General services and multipurpose area	Ha	19
Industrial area	Ha	33
Breakwaters	m	4,630
Rubble mound	m	2,140
Vertical	m	2,490
Dredging and reclamation	Cu.m	10,123,273

Table 26: Main elements and figures of the port

The following chapters explain the criteria followed for planning of Phase 1 of the port's installations and its main characteristics. Also, the drawings included in Annexure 1 give more information about layout and details of the port.

9.2. BREAKWATERS

9.2.1. Introduction

Formulations to define the geometry of breakwaters have been obtained from the following codes, guidelines and manuals, among others:

- The Rock Manual (CIRIA)
- SPM (Shore Protection Manual, US)
- ROM (Recommendations for Maritime Works, Spain)
- PIANC Guidelines

The wave transformation from deep water to shallow water has been done for several points of interest near the breakwaters.

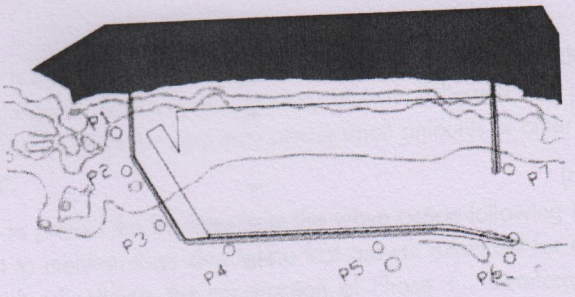


Figure 118: Location of points of interest

The result of this propagation is obtaining a wave height which has been taken as the first step for the preliminary design. So mean regime and extreme regime have been estimated in each point. All values are shown in the next table:

Shallow water Points	Mean Regime Hs (m)	Extreme Regime (200 years) Hs (m)
P1	1,78	4.00
P2	2,08	5.00
P3	2,00	4.80
P4	2,02	4.50
P5	2,02	5.00
P6	2,06	4.80
P7	1,99	4.90

Table 27: Wave heights in the points of interest

9.2.2. Rubble-Mound Breakwaters

This kind of breakwater is used in shallow waters, from the coast to a maximum depth of 15 m. Accropods for deeper sections and cubic blocks for nearshore sections, up to -6.0 m, have been considered for the armour units.

Hudson formula has been used for calculating the weight of armour unit:

$$W = \frac{\rho_r g H^3}{K_D \Delta^3 cot\alpha}$$

Where:
ρ_r=Mass density of Armour units

H=Design Wave Height

K_D=Stability Coefficient

$\Delta=(\frac{\rho_r}{\rho_w}-1)^3$

ρ_w=Mass density of Water

cot α=Armour Slope (H/V)

For randomly placed concrete armour units, Hudson formula has been rewritten by CIRIA as presented in the next equation:

$$(K_D cot\alpha)^{1/3}=\frac{H_s}{\Delta D_n}$$

Using the significant wave height, Hs(m) and the nominal diameter of the unit, Dn (m).

The value KD of the Stability Coefficient is KD=15 for accropods in the trunk of the breakwater portion and KD=6 for cubic blocks. Van der Meer formulas have been also considered for the design of the armour layer.

The main rubble-mound breakwater design is divided in three parts depending on the wave height. The east breakwater, which closes the container terminal, natural rock armour has been defined. Next paragraphs show each section main characteristics:

- First Section:

  It is the deepest part of the rubble-mound breakwater (around the depth of -15 m to -11m). The wave height has been taken from the point of interest P3 and P2, with Hs= 5 m. Accropods of 3 m^3 have been used for this section

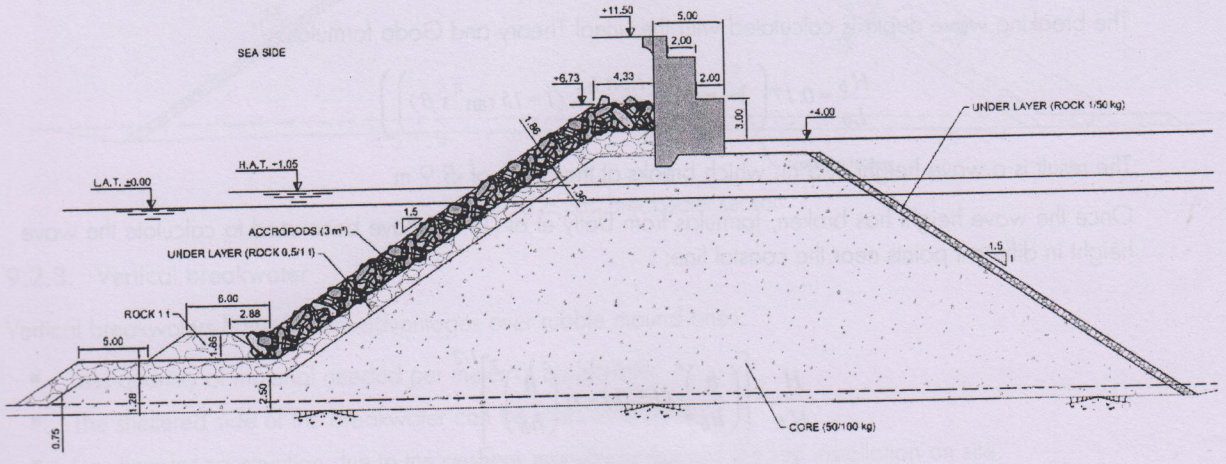


Figure 119: Rubble-mound section (3 m^3 accropods)

- Second section:

It runs between the depth from -11m to -6m, the wave height has been obtained from point of interest number 1 (P1) ,Hs=4 m . Accropods as armour units have been used, and the necessary volume has been 2 m^3.

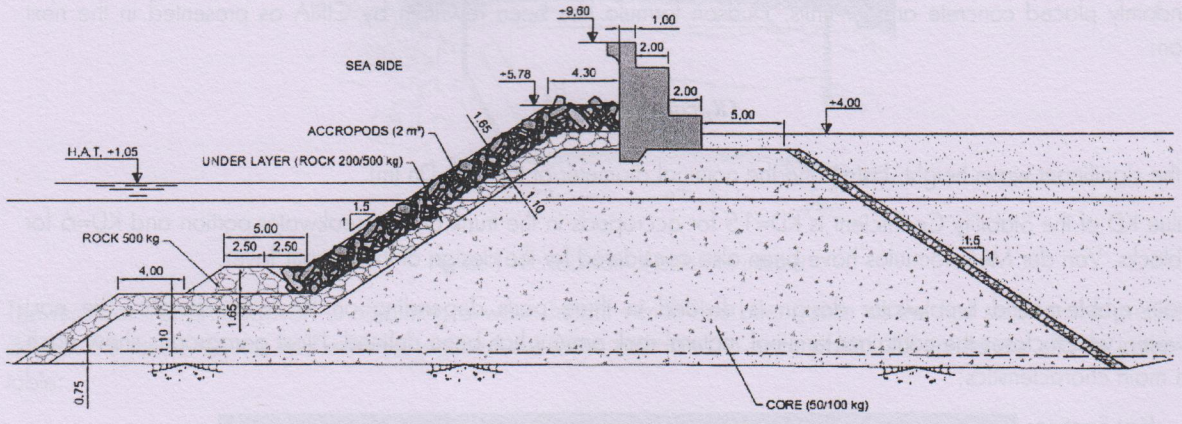


Figure 120: Rubble-mound section (2 m^3 accropods)

- Third section:

It runs between the -6 m contour line to the coastal line. Wave height has been obtained with an analytic method using different formulation for breaking wave:

The breaking wave depth is calculated with the Lineal Theory and Goda formulas:

$$\frac{Hb}{L0} = 0.17\left(1 - \exp\left(\frac{-1.5\pi\, hb}{L0}\,(1 + 15\tan^{4/3}\beta)\right)\right)$$

The result is a wave height of 5 m, which breaks at the depth of -5.9 m

Once the wave height has broken, formulas from Dally et al (1985) have been used to calculate the wave height in different points near the coastal line:

$$\frac{H}{Hb} = \left[\left(\frac{h}{hb}\right)^r (1+\alpha) - \alpha\left(\frac{h}{hb}\right)^2\right]^{1/2}$$

$$\alpha = \frac{K\gamma_s^2}{\tan\beta\left(\frac{5}{2} - \frac{K}{\tan\beta}\right)}\left(\frac{h}{H}\right)_b^2;\quad r = \frac{K}{\tan\beta} - \frac{1}{2}$$

The wave height is 3.3 m at the depth of -5 m. This has been taken for the rubble-mound breakwater design in the part near the coastal line using cubic blocks as armour units.

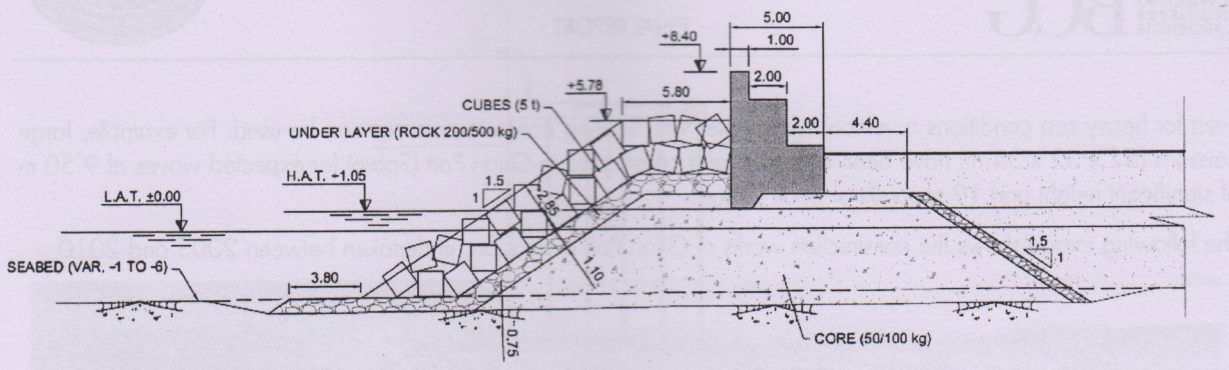


Figure 121: Rubble-mound section (cubic blocks)

- East breakwater:

  This structure closes the port on the east side of the container terminals. Calculations have been made following the same methodology as for the Third section of main breakwater. Given that this is a temporary breakwater until the works for next phase of the port begins, there is not a crown wall, but a rock protection on top of it. The typical cross section can be seen in the following figure.

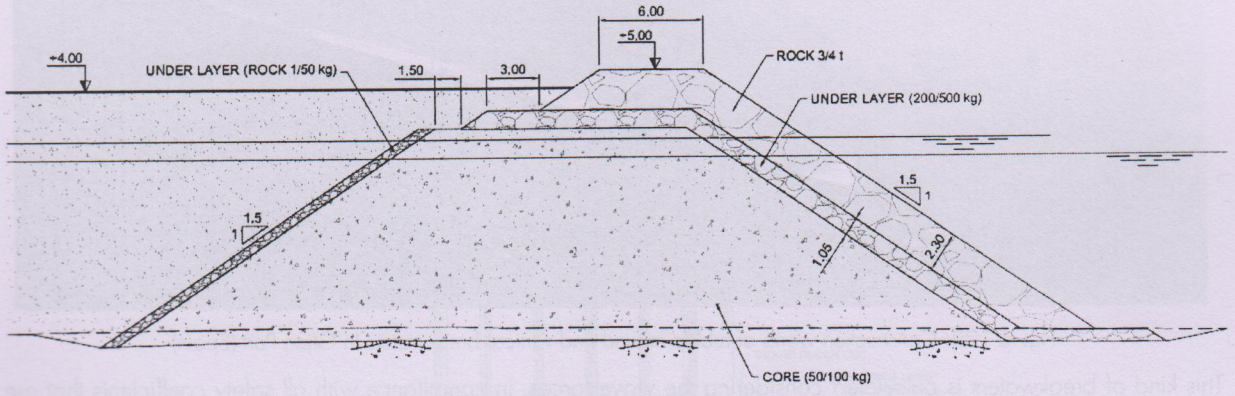


Figure 122: East breakwater section

9.2.3. Vertical breakwater

Vertical breakwaters have several advantages over rubble mound ones:

- Less quantity of material needed per meter of breakwater.
- The sheltered side of the breakwater can be used as a berth.
- Less time for construction due to the onshore manufacturing and the fast installation on site.
- Less environmental impact due to its lesser quantity of material and transportation.

This solution is widely used around the world. Many cases can be found in Japan (Mutsu-Ogarawa, Oga, Hoshiro...), Korea (Ulsan, Busan, Pohan...), Taiwan (Suao, Taipei...) or Qatar (Ras Laffan) in Asia; Italy (Genoa, Napoli...), Spain (Gijon, Algeciras, Valencia...), Greece (Piraeus) or France (Marseille) and Monaco in Europe, and Brazil (Porto de Açu) in South America.

Even for heavy sea conditions a vertical breakwater with floating concrete caissons can be used. For example, large caissons (52 x 32 x 34 m) have been designed and constructed in Gijon Port (Spain) for expected waves of 9.50 m of significant height and 19 seconds of peak period.

The following image shows the construction works of Gijon Port expansion, undertaken between 2005 and 2010.

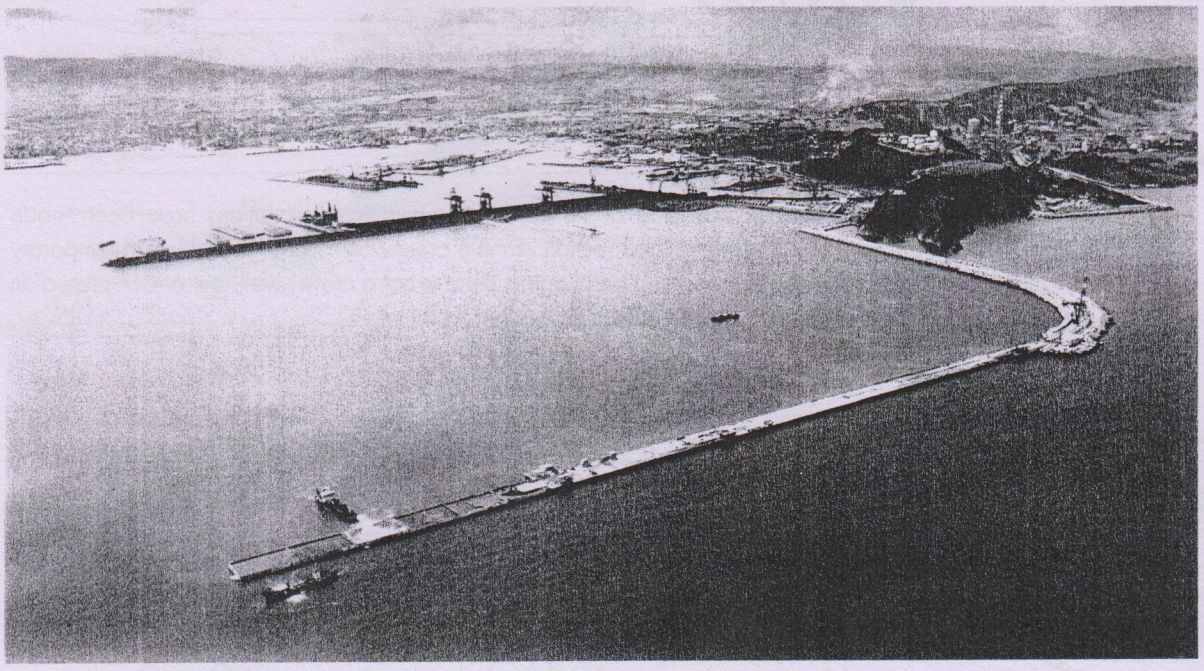


Figure 123: Construction works of rubble mound and vertical breakwaters in Gijon Port (Spain)

This kind of breakwaters is calculated considering the wave forces, in compliance with all safety coefficients that are explained in several international codes (Spanish ROM 0.5-05 code has been used for preliminary design).

Different heights of crest have been considered depending on the possibility of overtopping. No overtopping is allowed for vertical sections which in Phase 2 and phase 3 will be filled in the port side. However, a small overtopping is allowed for the rest of vertical sections which will have only water in the port side.

9.2.3.1. Wave Pressure Formulas

The pressures which hit the vertical breakwater due to the dynamic wave action are obtained using Takahashi and Goda formulas. These pressures are shown in the pressures diagram below. These are the forces -together with the uplift pressures and the own weight of the structure- which determine the geometry of the vertical breakwater. The geometry of vertical breakwaters has to meet the safety coefficients as sliding safety coefficient (SSC) and roll-over safety coefficient (RSC).

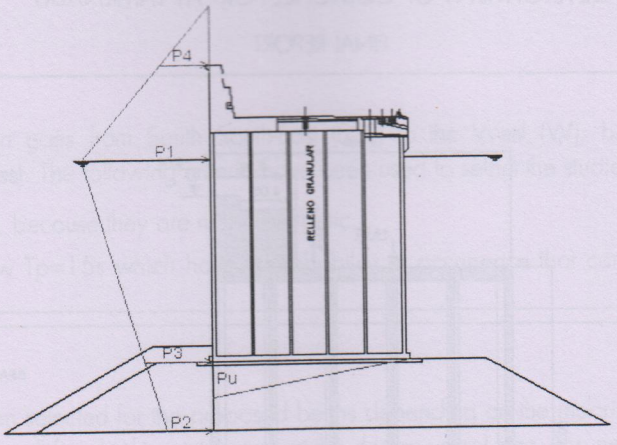


Figure 124: Pressure diagram.

9.2.3.2. Vertical Breakwater Section

The following figures show the vertical breakwater preliminary design:

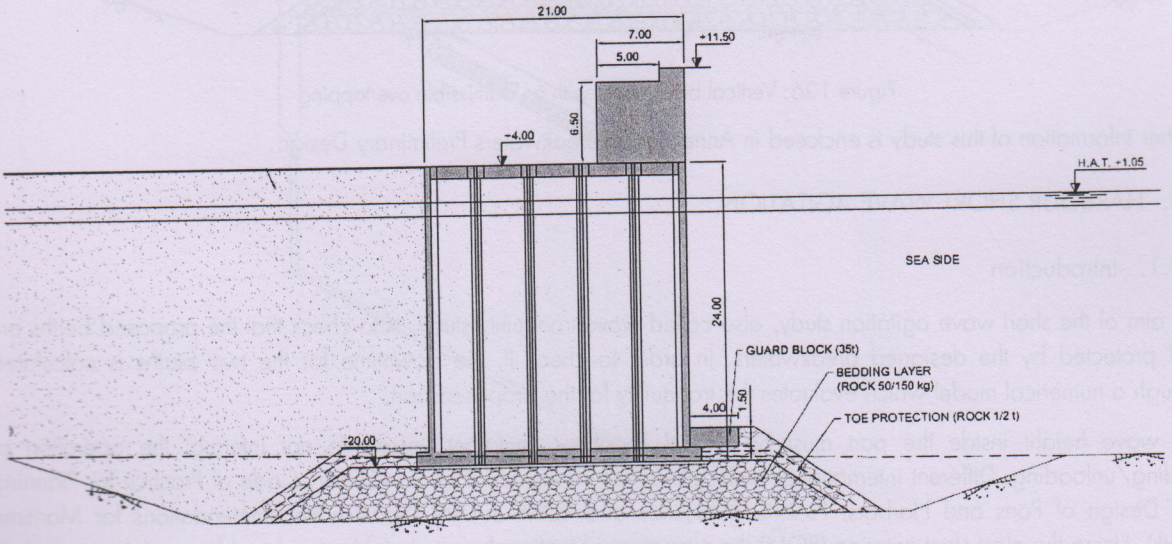


Figure 125: No overtopping vertical breakwater section

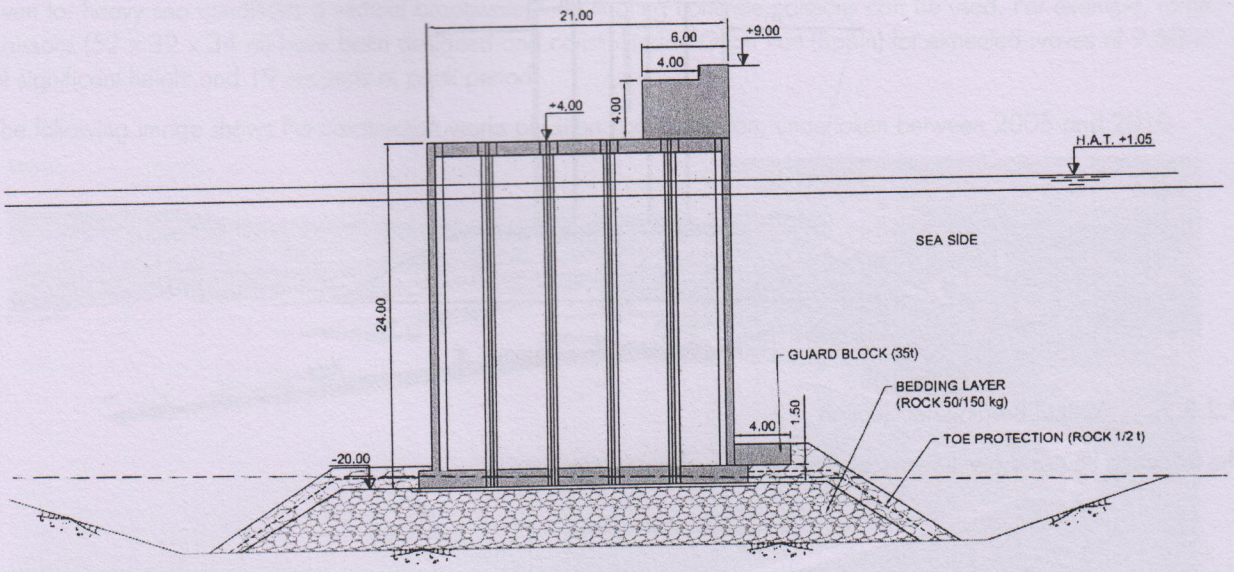


Figure 126: Vertical breakwater with an admissible overtopping

Further information of this study is enclosed in Annexure 5: Breakwaters Preliminary Design.

9.3. HARBOUR SHORT WAVE AGITATION

9.3.1. Introduction

The aim of the short wave agitation study, also called wave tranquility study, is to check that the proposed berths are well protected by the designed breakwaters. In order to check it, the downtime for the two berths is calculated through a numerical model which evaluates the tranquility for the proposed port.

The wave height inside the port must be limited to allow container vessels to not interrupt the operation of loading/unloading. Different international codes have been considered as IS 4651-V: Code of Practice for Planning and Design of Ports and Harbors, PIANC guidelines and ROM 3.1-99 (Spanish Recommendations for Maritime Work). Using the most strict criterion (ROM) the maximum operational wave height considered for container vessels is 0.5 m for waves forming an angle of +/- 45° over the fore and aft centerline of the vessel which is the case in this port.

9.3.2. Methodology

The methodology used is as follows:

- The Near shore wave climate has been analyzed in order to select the cases that have been propagated into the inner port with the agitation model.
- Six meshes have been defined for propagation. Depending on the peak period each case has been propagated in the appropriate mesh.
- Two areas have been selected for the proposed berths, and it has been also estimated the mean wave height in each area for each considered case.
- The downtime has been estimated for the proposed berths.

9.3.3. Selection of cases

The range of wave direction goes from South South-East (SSE) to the West (W), but the highest probability of occurrence is South South-West. The following criteria have been used to select the studied cases:

- Peak periods over 15s, because they are more energetic.
- The rest of cases below Tp=15s which have a probability of occurrence that can be relevant in the agitation study.

9.3.4. Areas of study

Two areas of study have been selected for the proposed berths depending on the mooring distribution for the vessels. The size of the areas has been defined taking into account the design vessel size. The next figure shows these areas:

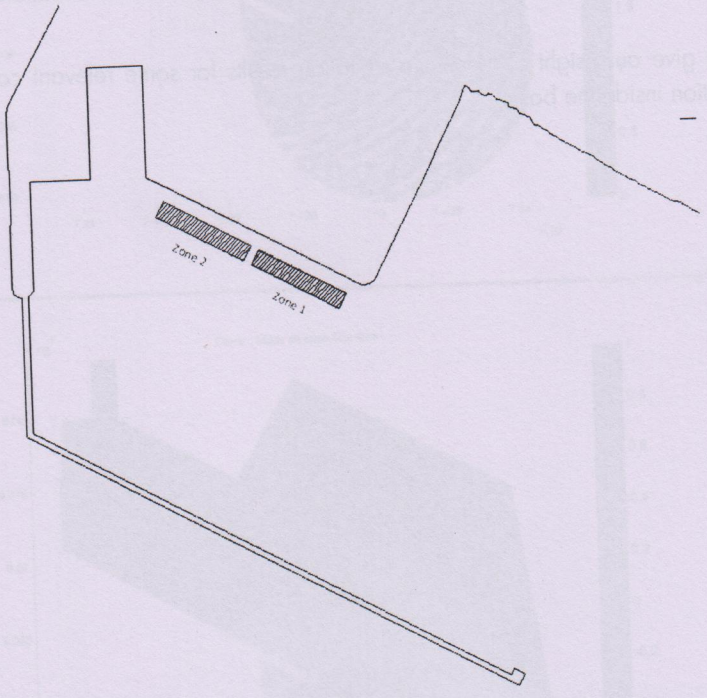


Figure 127: Areas of study (Berth line)

9.3.5. Downtime

Once the wave height has been calculated in each area for the cases under consideration, the next step is to estimate the downtime for the two proposed berths.

The table below shows the results of downtimes in days and hours for both options. These results show the inoperability of the different berths.

Description	Berth 1	Berth 2
Probability of occurrence (%)	0.49%	0.38%
Downtime (days)	1.57	1.40
Downtime (hours)	**38**	**34**

Table 28: Results of downtime in each berth

In conclusion, both berths have a very low downtime according to the recommendations for limit height by PIANC and ROM.

The following images give an insight of the wave agitation results for some relevant cases among all, which best shows the wave agitation inside the basin.

Hs	Tp		Direction
2.00	14	SSE	157.5

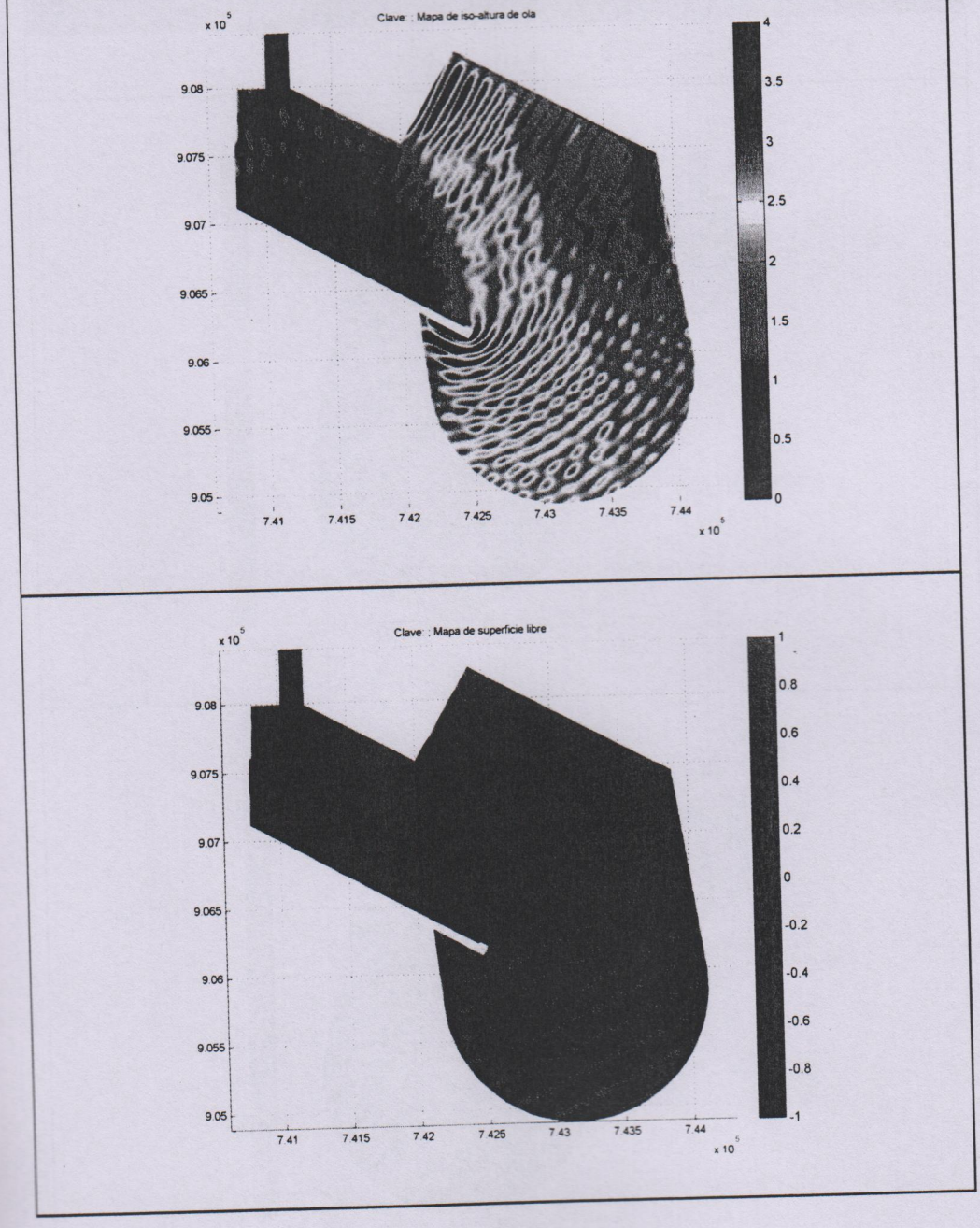


Figure 128: Option 1. wave height for Case 4

Hs	Tp	Direction	
1	18	SSE	157.5

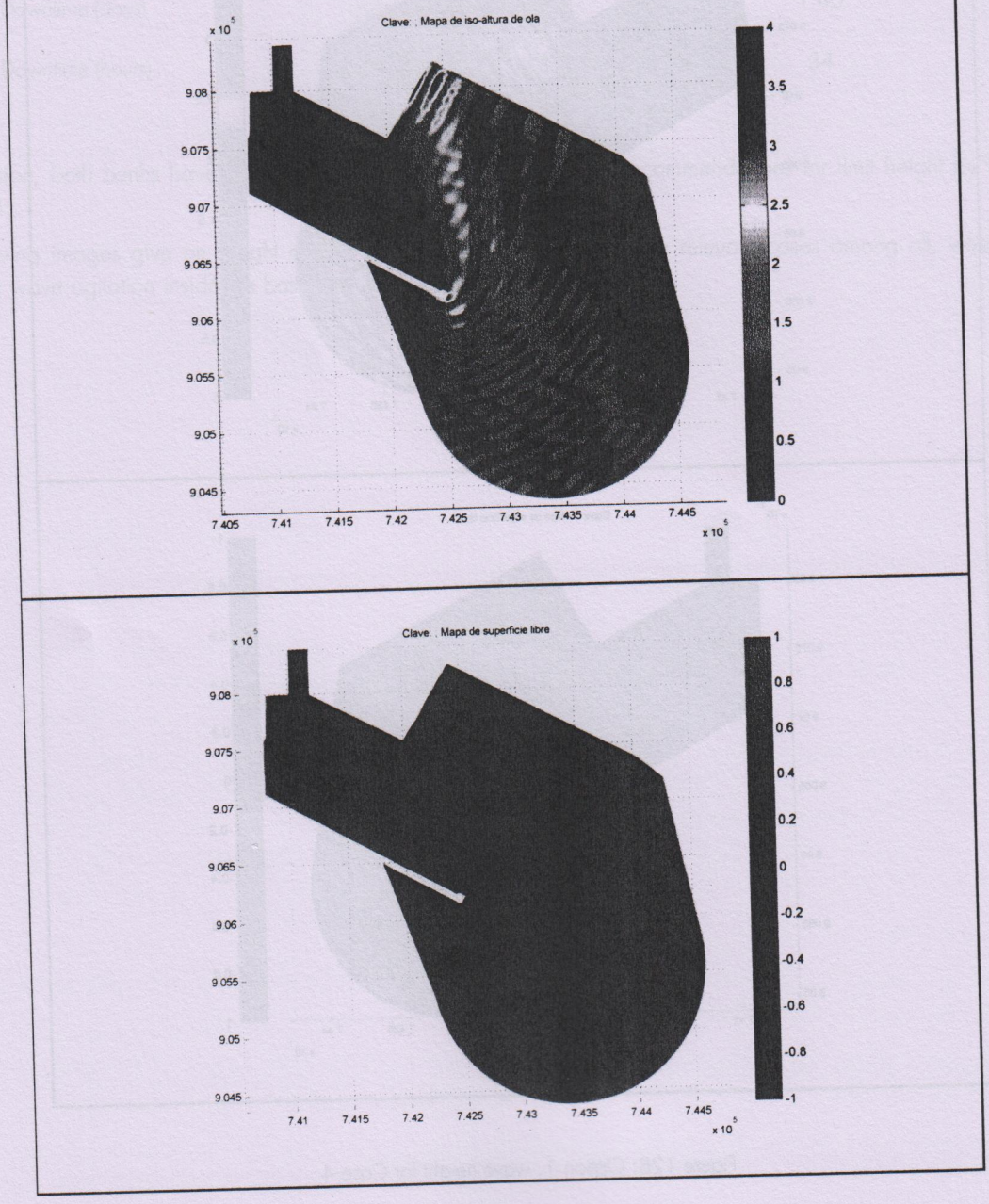


Figure 129: Option 1. Wave height for case 47

Further information of this study is enclosed in *Annexure 3: Harbour short wave agitation.*

9.4. NAVIGATION REQUIREMENTS

9.4.1. Vertical requirements

Both the outer channel and the inner channel (protected by breakwaters) must be designed to maintain a sufficient Under Keel Clearance (UKC) for the wind, waves and currents conditions for which a vessel can be moored and served on the berths. For this, ship related factors as ship squat, dynamic heel and wave response allowance, are the most important in vertical channel design.

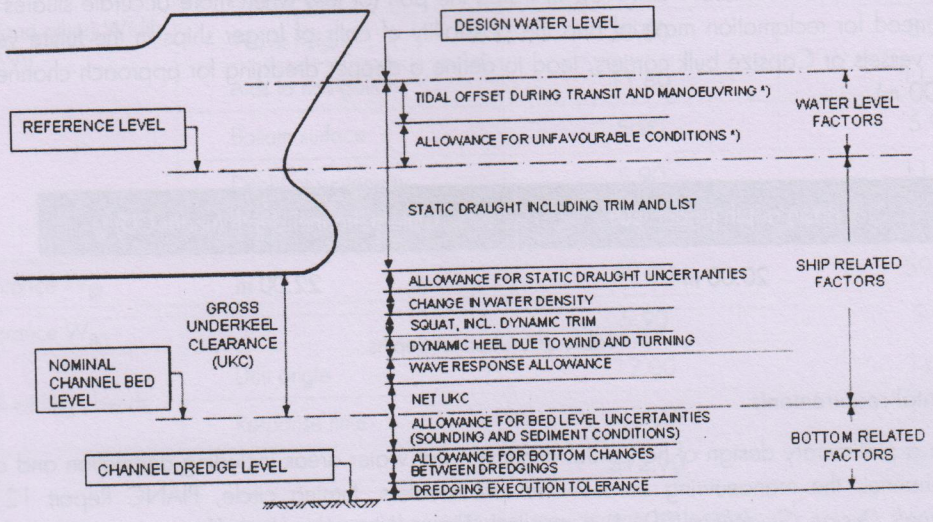


Figure 130: Channel depth factors (PIANC)

For concept design, the PIANC Report 121: *Harbour Approach Channels Design Guidelines* (2014) has been followed. In this document a ship related factor Fs which includes all of these ship effects is applied. This approximation depends on ship speed, intensity of wave effects on the design ship with its maximum draft T and type of channel.

For the design vessel (Maersk EEE type container vessel), with a 16 m draft (T) and 59 m wide (B), the results for inner and outer channel are as follows:

Factor	Inner Channel (m)	Outer Channel (m)
Ship Related factor (Fs)	17.92	20.80
Bottom tipe factor	0.40	0.50
Bilge keek factor (Sk)	0.70	0.70
TOTAL	**19.02**	**22.00**

Table 29: Channel depths for a 18.000 TEU container vessel.

The following components have been considered for calculations:

- Vessel speed: Moderate, 5-10 knots,
- Wave conditions: Heavy swell (Hs=2 m)
- Channel bottom type: Sandy

Although the needed depth for Phase 1 is 19.02 m inside the port (or less when more accurate studies and models are made), the need for reclamation material and the possibility of calls of larger ships in the future years such as larger container vessels or Capsize bulk carriers, lead to define a deeper dredging for approach channel (22.00 m) and basin (20.00 m).

Basin depth (under CD)	Outer Channel depth (under CD)
20.00 m	22.00 m

Table 30: Channel depths.

9.4.2. Horizontal requirements

In order to make a preliminary design of horizontal dimensions of water areas including orientation and alignment of the approach channel, the manoeuvring areas within breakwaters, turning circle, PIANC Report 121: *Harbour Approach Channels Design Guidelines* (2014) is applied. These dimensions are of great importance: first because they constitute a major part of the overall investment and second because they are difficult to modify once the port has been built.

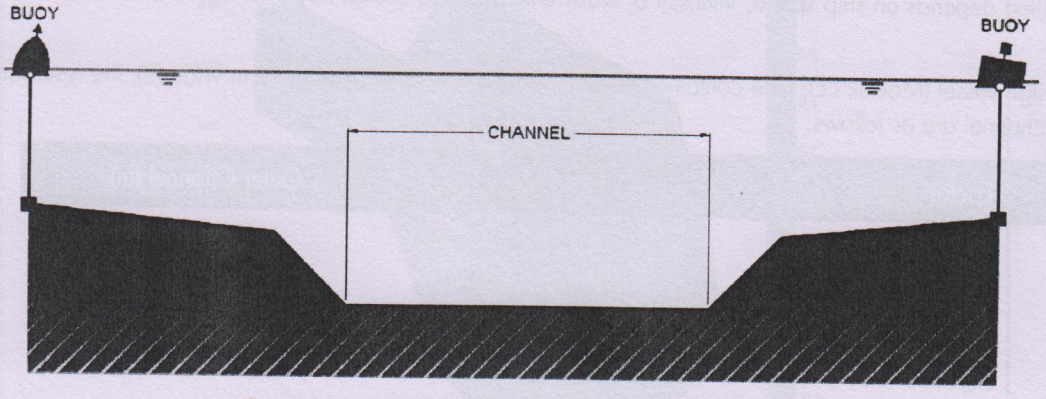


Figure 131: Basin and channel width definitions (PIANC)

The overall bottom width (W) of a straight channel is given by:

$$W = W_{BM} + \sum W_i + W_{BR} + W_{BG}$$

Where W_{BM} is the basic width, Wi is the additional width due to environmental actions, and W_{BR} and W_{BG} are the additional width due to side banks on each side of the channel.

For the case of Colachel-Enayam, those widths are shown in the table below:

Factor		Outer Channel (m)	Basin (m)
Basic Width (W_{BM})		88.50	88.50
Environmental (and other) Width (Wi)	Vessel speed	0.00	0.00
	Cross wind	23.60	23.60
	Cross current	41.30	35.40
	Long. Current	5.90	5.90
	Wave height	29.50	0.00
	Aids to navigation	11.80	11.80
	Bottom surface	5.90	5.90
	Depht of waterway	5.90	11.80
	Cargo hazards	0.00	0.00
Bank Clearance W_{BR}		59.00	59.00
Bank Clearance W_{BG}		5.90	5.90
Additional width in bends	Drift angle	12.00	12.00
	Response time	23.60	23.60
TOTAL		312.90	283.40

Table 31: Horizontal navigational requirements by factors

The entire basin will work as a turning circle, so there will be no inner approach channel properly.

Taking the former numbers as a minimum, and given the need of sand for reclamation, the preliminary dimensions for the channel are as follows:

Straight Outer Channel	Bend Outer Channel
400.00 m	>450.00 m

Table 32: Channel widths.

Regarding stopping distance and turning circle, PIANC states that stopping distance is $3 \cdot L_{oa} - 1 \cdot L_{oa}$ for tugs to go near the vessel and 2 L_{oa} for the actual stopping distance-, given the vessel enter the inner channel (or the basin) with an initial speed of 4 Knots.

The turning circle is the area where vessels are often assisted by tugs to their berths and may be turned beforehand. For a preliminary design, the nominal diameter for this circle is $2 \cdot L_{oa}$, which in this case is 2 x 400 m. Then:

Stopping distance (m)	Turning circle diameter (m)
1,200.00 m	800.00 m

Table 33. Stopping distance and turning circle diameter

This conceptual design for vertical and horizontal navigation requirements should be optimised or assessed in greater detail by using ship manoeuvring simulation in the next steps of the design process. These simulations can also be used to assess the requirements for manoeuvring in difficult situations, such as the usual south-west monsoon conditions, with heavy cross winds, heavy swell or a combination of both.

9.4.3. Aids to navigation

For this first approach to determine the navigational marks and aids, IALA (The International Association of Marine Aids to Navigation and Lighthouse Authorities) recommendations have been considered to design it. Also, opinions from navigational and Port Authority experts have been collected.

The following navigational marks have been defined:

- Starboard and port marks to be used in the entrance to the port.
- Special buoys set near south breakwater and south west breakwater to signal the area is not planned for dredging in Phase 1.
- Leading lights to indicate the navigation course.
- Cardinal marks to indicate depth limitation in approach channel.

Further information on navigational marks is included in Drawing-05.

Vessel Traffic Management System (VTMS) is also expected to be necessary for a proper operation of the port. This system should include at least a Radar, an Automated Identification System (AIS) base station, a VHF radio system, and a control station to integrate all components of the system.

9.5. DREDGING AND RECLAMATION

9.5.1. Introduction

In order to select suitable dredging equipment, it is necessary to take into account considerations about soil, dredging depth, environmental conditions, logistic factors, etc. This proposed methodology and equipment is prepared based on the information available at this stage but the final approach has to be developed by the contractors who are experienced and innovative in the field of marine dredging operation.

9.5.2. Dredging works

The total quantity of material to be dredged has been obtained by comparing the current bathymetry to the final geometry of the sea bottom as shown in Drawing-05: Dredging Plan:

DREDGING	
AREA (m^2)	QUANTITY (Cu.m)
2,739,862	6,819,280

Table 34. Dredging quantity and affected area

According to geological information available at this moment, the material to be dredged consists of loose to medium dense sand. All sand will be placed in the reclamation area. Considering dredging depth, environmental conditions and the amount of material to be dredged, the work method considers a Cutter Suction Dredger (CSD) in sheltered waters (inside port) and a Trailing Suction Hopper Dredger (TSHD) to carry out dredging of vertical breakwater trench (if needed) and approach channel. This combination of two equipments gives the dredging works enough flexibility to be finished in a short period of time, which is a requirement to commission the port before 2018 is finished.

Cutter Suction Dredger (CSD)

CSD is a stationary or self-propelled vessel that uses a rotating cutter head to loosen the material in the bed ('cutting'), which is extracted by a suction inlet located beneath the cutter head. CSD discharges the dredged material directly to shore via a floating pipeline or into a barge with a special loading system.

Figure 132: Cutter Suction Dredger

Main features of this kind of dredgers are listed below:

- Dredging depth up to 30 m
- Draught around 3 m, suitable to dredge an emerged terrain opening a channel.
- Suitable for dredging inner harbour (basin) and filling reclamation area.
- Wave height < 1m

- Discharging pipelines can be floating or submerged.
- Versatility related to dredging material: clay, loose materials and soft rock.
- Large number and variety of CSD are presented in the market.
- Dredging ratio in the range of 500-100,000 m^3/day

A medium-size CSD which can reach an average ratio of 20,000 m^3/day is suggested for this works, as it can fulfil the time requirements explained above.

Trailing Suction Hopper Dredger (TSHD)

TSHD is a self-propelled vessel that can dredge using suction tubes equipped with a drag head that is trailed over the ground. This vessel stores the dredging material inside the hopper.

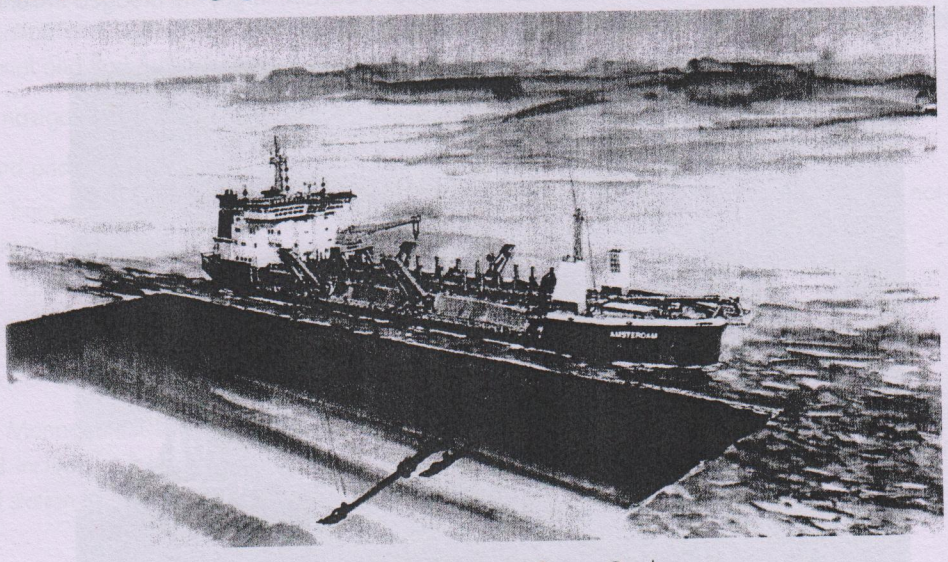


Figure 133: Trailing Hopper Suction Dredger

Main features of this kind of dredgers are listed below:

- Dredging depth up to 100 m.
- Minimum draught around 5 m.
- Wave height < 3 m.
- Sailing speed around 2 knots while dredging, and up to 12 knots during transport.
- Hopper capacity in the range of 1,500 (small ones) and 38,000 m^3 (large ones).
- Discharging can be carried out by opening the hopper bottom doors, pumping the material by means of a pipeline, or throwing dredged material though a cannon (rainbow)

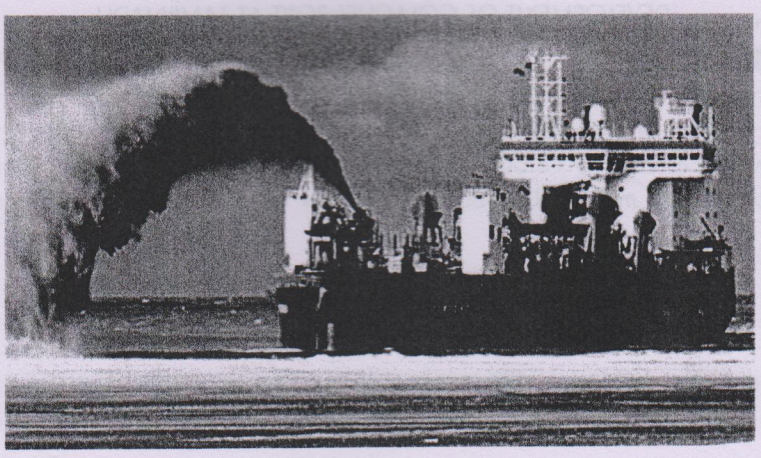


Figure 134: TSHD discharging by rainbow

Operation time required to discharge through the pipeline or cannon is about 1 hour. However, few minutes are required to discharge by means of opening the bottom. They are really efficient to dredge loose material and they have positioning and sailing advanced systems to guarantee the depth accuracy.

A small-size TSHD (2,000 m^3 of hopper capacity) is suggested to dredge both at the first stage of the works

9.5.3. Reclamation Works

Around 10.1 million cubic meters will be required for reclamation in Phase 1, broken down as shown in the following table:

ZONE	AREA (Ha)	QUANTITY (up to +2.00m) (Cu.m)
Container terminal	41.1	6,021,505
General services and multipurpose area	19.1	2,618,344
Entry/exit gate	3.5	220,337
Administration area	3.2	209,178
Future industrial area	30.8	2,562,986
Reclamation bunds	-	-1,509,077
TOTAL	**97.7**	**10,123,273**

Table 35. Breakdown of land reclamation quantities.

By contrast, a total dredging of around 6.8 million cubic meters will be required on Phase 1, so the rest of required material for reclamation (around 3.3 million cubic meters) must be obtained from other sources. It can be transported from quarries near Colachel, but the easiest and cheapest way to obtain that material is using the same dredging equipment and by dredging the basin of future Phases 2 and 3. This way dredging costs on Phase 2 and 3 is reduced.

The reclamation area will be filled up to +2.00 LAT. Then, a suitable capping layer and pavement will be used on top of the fill level around 2.00 m thick. Land-based equipment will be used to spread and level the delivered materials.

Bunds

In order to retain the dredging material in the reclamation area, bunds will be constructed around each of the reclamation areas prior to start filling.

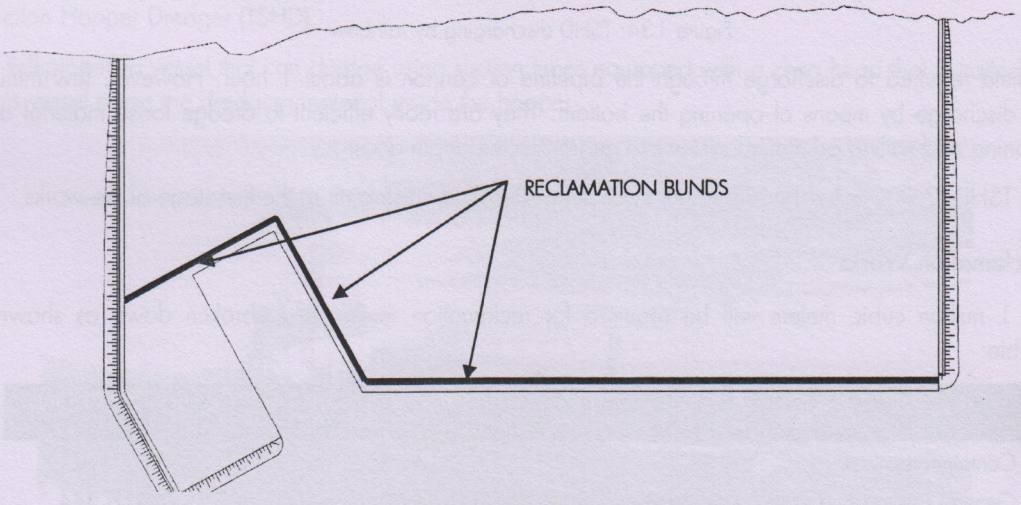


Figure 135: Proposed reclamation bunds

The proposed work sequence is the following:

- Rubble mound will start from the landside and will provide a permanent limit for the reclamation area at the west end.
- TSHD will be used to dredge the trench if necessary, in order to start construction of the vertical breakwater which will help to CSD to work in adverse weather conditions within the basin.
- Permanent reclamation bunds are to be constructed as shown in the figure, parallel to the berth alignment (west to east) and perpendicular to the shoreline at the east end.
- Dredging will be carried out at the basin and turning circle area, and material will be pumped to reclamation area.

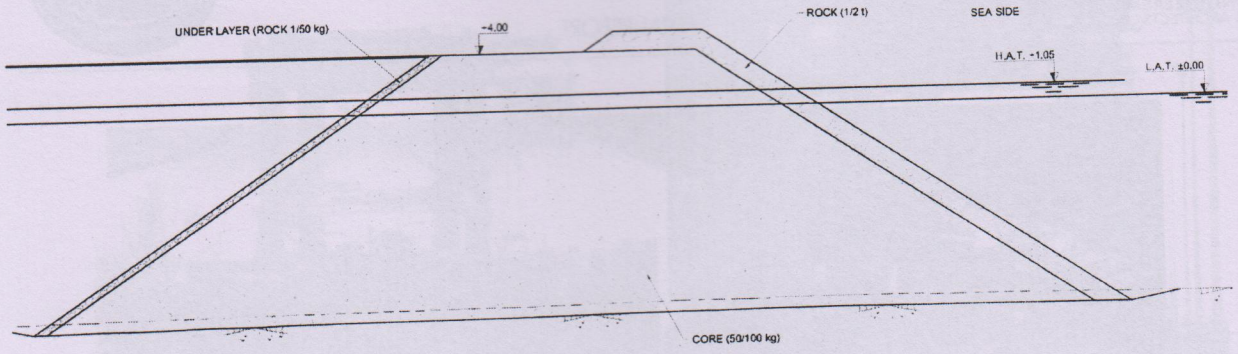


Figure 136: Cross section of reclamation bund

9.6. FACILITIES

9.6.1. Container terminal

A container terminal is an intermodal facility at which cargo is transferred from sea to land (both road and rail) and vice versa. It must be able to transfer cargo between the two quickly, efficiently and safely. It comprises three sub-systems:

- Dock: This is where merchandise is loaded onto or unloaded from the ship. It comprises the infrastructure of the dock itself and the equipment used to load and unload the containers.
- Container storage area: Every container has to pass through a storage facility before entering or leaving the port. There are various types and systems of storage depending on the layout of the containers, the equipment used or the degree of automation or the available spaces, among other aspects.
- Land entry and exit point: this comprises gates for trucks (which feature control and distribution elements) and for trains (with an area dedicated to train composition).

9.6.1.1. Handling system

In the case of this port, a semi-automated terminal is proposed, in which the container yard is laid out with stacks running perpendicular to the dock. This system allows for high storage capacity per square meter and high productivity, as it enables the movements of the dock to be independent of those of the yard itself.

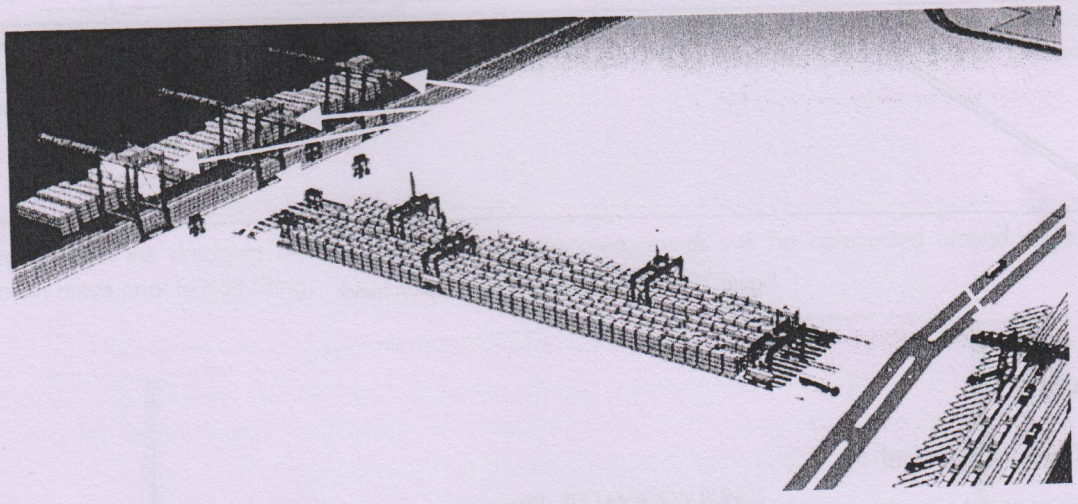


Figure 137: Scheme for container terminal operations

The main features of this kind of terminal are:

- Berth-yard transfer: Handling of containers between the quay cranes and the yard cranes is made by shuttle carriers (SC). The Ship-to-Shore cranes (STS) leave the container on the pavement and a shuttle carrier takes it to the water-side transfer area of the yard, or vice versa. Super Post Panamax cranes, with a minimum outreach of 65 m, must be used to attend 18,000 TEU vessels.

Figure 138: STS Crane (Liebherr)

The SC is a small straddle carrier whose only purpose is to transport containers from quay to yard and vice versa. Its main advantage is that it allows a complete separation of transport operations and loading/unloading of quay cranes and yard (decoupling). Thus, the STS cranes can unload containers directly on the floor independently of the presence of the SC, which can take or leave them independently of the cranes.

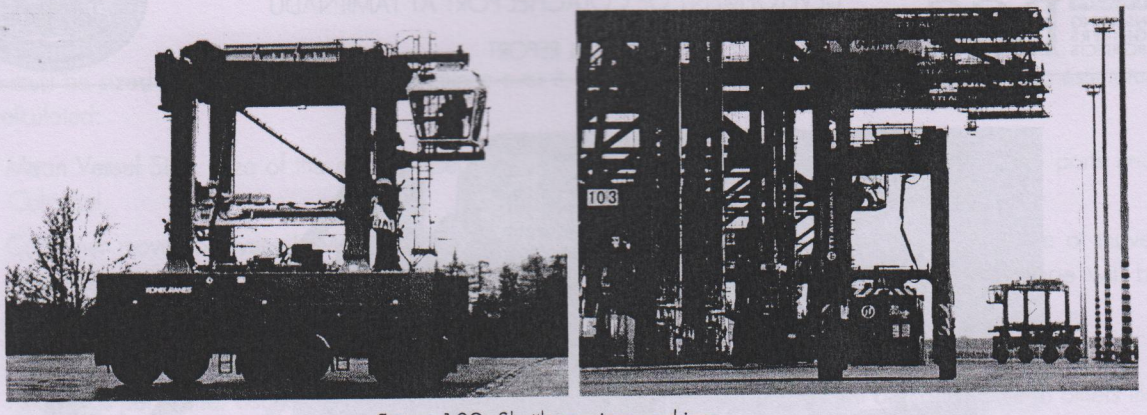


Figure 139: Shuttle carriers working

- Container yard. An Automated Rail-Mounted Gantry container crane (A-RMG) takes the container from the water-side transfer area and stocks it in the yard. Whenever is needed, the crane takes it and leave it on the land-side transfer area, where a truck is waiting to be loaded.

  This can occur to the other direction- a truck leaves the container and the ARMG stocks it in the yard and whenever is needed the crane leaves the container o the sea-side of the yard to be loaded into a ship. Usually, every block is covered by two ARMG, one for the sea side and the other for the land side.

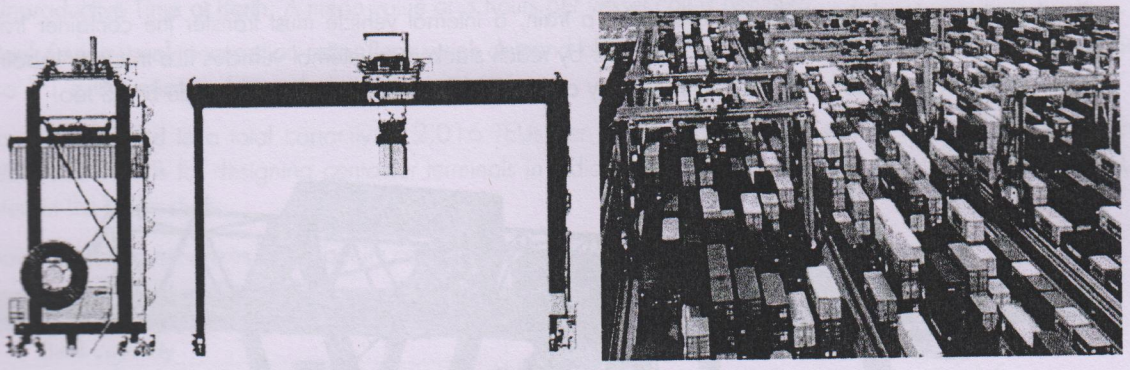


Figure 140: Scheme and twin A-RMGs in an automated container yard

Apart from the automated yard, there are other stacking areas for empty containers or rail yard. Other equipment such as Reach Stackers (RS) or

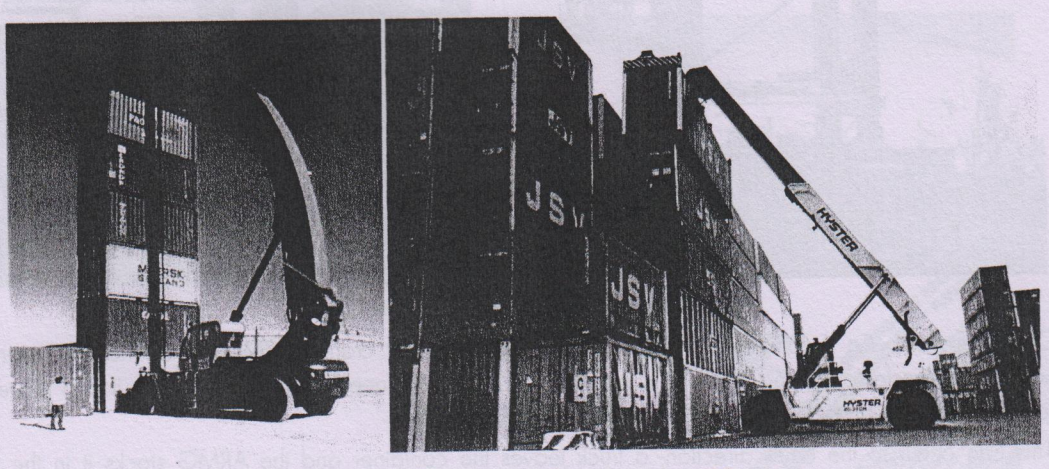


Figure 141: Two different types of reach stackers (RS)

The connectivity from the yard to outside the container terminal can be done by two ways, by road or by railway. If the container enters or leaves the terminal by road, a normal truck is used.

On the other side, if the mode of transport is a train, a internal vehicle must transfer the container from the stacking yard to the rail yard. This can be made by reach stackers or internal vehicles like tractors. Loading the train car is usually made by Rail Mounted Gantry cranes (RMG), although it can be made by RS too.

Figure 142: Rail yard with Rail Mounted Gantry cranes

A total of 9 STS cranes, 44 A-RMG cranes, 16 SC, 2 RMG cranes for the rail yard, 2 RS and 4 tractors have been estimated to be needed for terminal operations.

9.6.1.2. Berths

Berths must be sized to cater the estimated handlings over it. With this aim, some parameters must be also estimated and calculated:

- **Mean Vessel Size**: Size of the mean vessel obtained from the studies carried out analyzing similar ports near Colachel.
- **Container moves per vessel.** Market data and container terminal studies give the usual percentage of moves over the total capacity of the vessel is between 30 and 50%. It is expected that this percentage will be growing from 2018 to 2030. For capacity calculations, 1750 movements per vessel call are used.
- **Cranes per vessel.** 9 cranes are planned for two berths. This means each berth will have 4.5 cranes.
- **Handlings per crane.** Usually this variable goes from 25 to 35. Since this port must be competitive to others like Colombo, 30 moves have been estimated for capacity calculation. This productivity could grow over time as crane operators improve their skills.
- **Peak berth utilization:** 70% is used for berth capacity calculations. While 60 % is a usual factor for normal operation, a terminal is able to afford up to 70% with some congestion. This congestion will only occur when the terminal is reaching its maximum capacity and will be expanded soon.
- **Operational Time:** Three shifts of eight hours each with one hour break can be expected. 21 hours a day, 7 days a week, 52 weeks a year is use for capacity analysis.
- **Unproductive Time at Berth**: A mean value of 3 hours per vessel call is assumed.
- **Peak/mean week occupation ratio**: Peak week demand of the terminal is usually 10% higher than the average, so 1.1 is the ratio used for calculations.

These parameters lead to a total capacity of 2,016 TEUs per meter of berth and per year. This is in line with the latest recommendations for designing container terminals in India. The terminal total capacity is close to 1.7 M TEUs forecasted in the traffic study.

The following table summarizes the capacity calculations:

Description	Unit	Value
Berth capacity		
Handling/TEU ratio		1.5
Mean vessel size	TEU	6,540
Container handlings per vessel (35%)	No	1,750
Container handlings per crane	No	30
Unproductive time at berth per vessel	hr	3
Mean number of cranes per vessel	No	4.5
Crane work hours per day	hr/day	21
Peak berth utilization	%	70
Peak/mean season occupation ratio		1.1
Total capacity per berth	**TEU/yr**	**803,295**
Number of berths		2
Terminal capacity	**TEU/yr**	**1,604,208**
Capacity per linear meter of berth	TEU/m/yr	2,005

Table 36: Berth capacity calculations

9.6.1.3. Container yard

The capacity of a container yard is governed by the following parameters:

- **Mean Dwell Time**: Time a container stays inside in the yard. 4.5 days for loaded containers (a mean value of 3 for trans-shipped and 6 for gateway) and 8 days for empty ones is used for calculations. These numbers are usual in other container terminals around the world.
- **Slots:** This is the total number of twenty - foot ground slots of the container yard. The planned terminal is composed by:
  - 5,112 loaded container slots
  - 432 reefer container slots
  - 600 empty container slots
- **Mean Storage Height**: In an automated yard this height can be around 75 % of the maximum storage height -5 for normal containers, 4 for reefers and 7 for empty containers. 70 % is used taking into account some other factors like peaks and re-organization activities.

The total capacity of the container yard is almost 1.8 M TEU. Given the variability of the dwell time, this allowance from the 1.7 M TEU traffic forecasts seems appropriate.

The following table summarizes the capacity calculations:

Description	Unit	Value
Yard Capacity for loaded containers		
Slots (9 lines, 30 rows blocks)	No	5,544
Mean dwell time	days	4.5
Maximum storage height	No	5.00
Mean storage height (70%)	No	3.5
Total Capacity for loaded containers	**No/yr**	**1,573,880**
Yard Capacity for empty containers		
Slots (20 feet)	No	600
Dwell time	days	8
Maximum storage height	No	7
Mean storage height	No	4
Total Capacity for loaded containers	**No/yr**	**109,500**
Total slots	No	9,316
Mean dwell time (loaded+empty)	days	4.9
Mean storage height (loaded+empty)	No	3.6
Total Yard Capacity	**No/yr**	**1,790,143**

Table 37: Yard capacity calculations

9.6.1.4. Gates

Gates are the exit and entry point for all truck traffic. It is expected that 75-80% of total gateway traffic will be by truck -and the other 20-25% will be by train. These shares lead to around 0.53 million trucks for 2020.

Based on other projects developed by TYPSA-BCG, an initial estimation of 9 reversible lines -plus 2 more lines for other traffic as maintenance, staff, rejected trucks, etc.- has been made. Further calculations in next stages of the design for capacity assessment should be performed to better assess the capacity of the gates. These calculations should take into account parameters like working hours, type of gates and pre-gates, and peak factors.

9.6.1.5. Rail yard

The rail yard will handle all containers entering or exiting by train. As explained above, around 20-25% of gateway traffic will be by train. These shares lead to around 0.17 million containers for 2020.

An initial estimation of 4 spurs -plus other 2 lanes for manoeuvres and connection to next phases of the port- and three RMG cranes have been provided.

In order to assess accurately the capacity of the yard, the necessary calculations in next stages of the design should be performed, taking into account parameters like working hours, crane performance or dwell time, and peak factors.

9.6.2. Multipurpose and ancillary berths and terminals

Although there is no forecast for general cargo, a 400 m general cargo and multipurpose berth is included in the port layout. This berth will allow the container terminal to be very specialized and avoid interruptions in operations. Cruisers are also able to berth in this terminal.

Besides, a 200 m berth for ancillary vessels such as tugs, pilots and mooring launches is included in the facilities.

9.6.3. Solid bulk terminal

Coal traffic is expected to begin in 2022. A solid bulk terminal is included in Phase 2 development to cater this cargo.

This terminal consists of a 400 m long and 20 m deep berth. To assess the berth capacity, the following table shows the parameters and values taken into consideration:

Description	Units	Value
Quay crane productivity	T/hr	2,000
Annual working days	Days/yr	365
Daily working hours (3 shifts)	h/day	21
Berth capacity (occupation)	%	75
Yard Capacity for loaded containers	**T/yr**	**11,497,500**

Table 38: Coal berth performance assumptions.

This calculation means the berth could cater all coal traffic with only one crane, although having only one might cause difficulties to serve ships in case of malfunction.

The stockyard is equipped with conveyors and stackers/reclaimers, standard equipment for this kind of terminals.

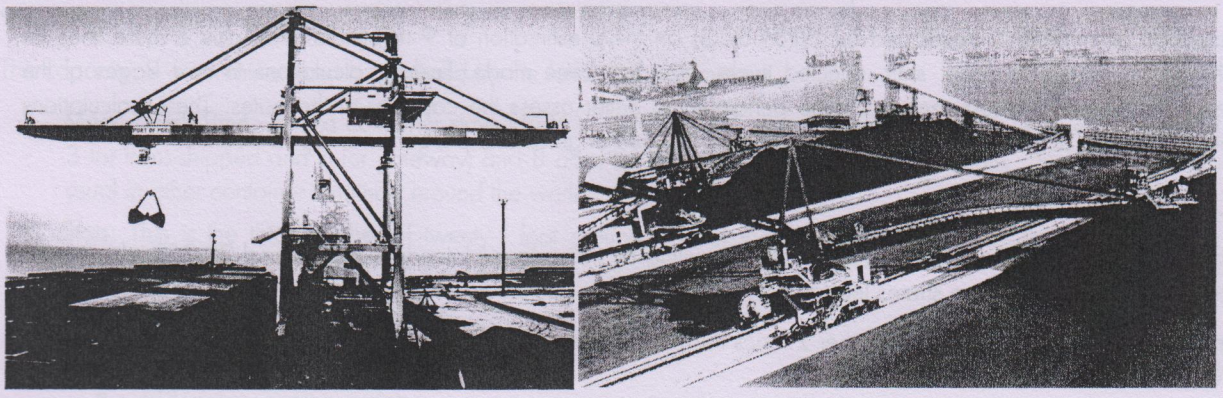


Figure 143: Some examples of coal terminal equipment. Gantry crane (left) and stacker/reclaimer (right)

The following figure shows the layout of the terminal on Phase 2, whit a total area of 9 Ha, while in Phase 3 the terminal will be duplicated to 18 Ha to be able to cater the expected coal traffic.

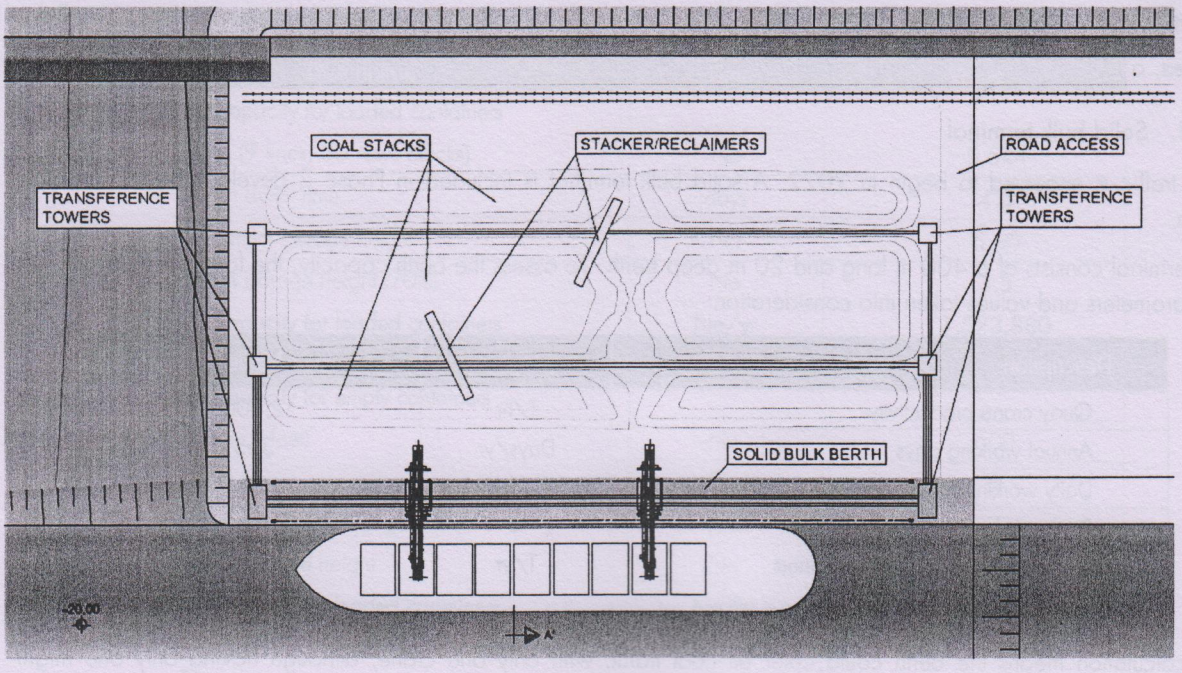


Figure 144: Coal terminal layout on Phase 2

9.6.4. Buildings

Some administration and control buildings will be required for the new port. The following list includes the most important ones –which have been foot printed on the drawings:

- Port administration building

- Police station
- Fire station
- Customs

The container terminal includes:

- Maintenance workshop
- Marine operations building
- Administration building
- Entry/Exit gates

Some other buildings might be added in future stages of the design process.

9.7. PORT PLANNING FOR PHASES 2, 3 AND FUTURE EXTENSION

When traffic is near Phase 1 capacity, Phase 2 expansion must be developed to service the new traffic.

Phase 2, planned from 2021 to 2025, consists of a 2,000 m extension of the container berth and another 92 Ha for container terminals, and a new 400 m berth and 9 Ha for a new coal terminal on the west side of the port.

Container terminal capacity in this phase is around 5.6 million TEUs per year and more than 10 M tonnes of solid bulk (coal).

Phase 3, planned from 2026 to 2030 consist on extending the container terminal by 1,200 m of berth and 95 Ha of yard. This will mean 4,000 m of total berth line which gives a total capacity of 8 million TEUs per year. Regarding solid bulk terminal, it will be duplicated to a total berth of 800 m and a total stockyard of 18 Ha.

Both the Phase 2 and Phase 3 coal berths have been planned to be built with the possibility to be converted into a container berth in case of the container traffic raises beyond expected rates and coal traffic below expected.

The following table shows the main figures and characteristics for the three analyzed phases of the port (cumulative figures):

Description	Units	Phase 1 (2018-2020)	Phase 2 (2021-2025)	Phase 3 (2026-2030)
Container Terminal Capacity	TEU	1,606,590	5,623,064	8,032,949
Bulk Capacity (coal)	M. Ton	0.00	3.30	6.60
Berths (total)	**m**	**1,400**	**3,800**	**5,400**
Container	m	800	2,800	4,000
Multipurpose	m	400	400	400

Ancillary vessels	m	200	200	200
Solid bulk	m	0	400	800
Terminals/Yards/Areas	**Ha**	**93**	**249**	**379**
Container	Ha	41	133	228
General services & multi- purpose	Ha	19	19	19
Solid bulk terminal	Ha	0	9	20
Industrial area	Ha	33	88	112
Breakwaters	**m**	**4,639**	**7,237**	**8,904**
Rubble mound	m	2,133	2,842	3,402
Vertical	m	2,506	4,395	5,502
Dredging and reclamation				
Dredging	Cu.m	6,819,280	13,151,903	14,973,161
Reclamation	Cu.m	3,303,993	12,866,152	19,261,679

Table 39: Main figures for Phase 1, 2 and 3 (cumulative figures)

A future extension beyond Phase 3 is possible in order to increase the port capacity to 16 million TEU. This extension can be made converting the vertical breakwater into a berth line and a new landfill area shall be developed seawards.

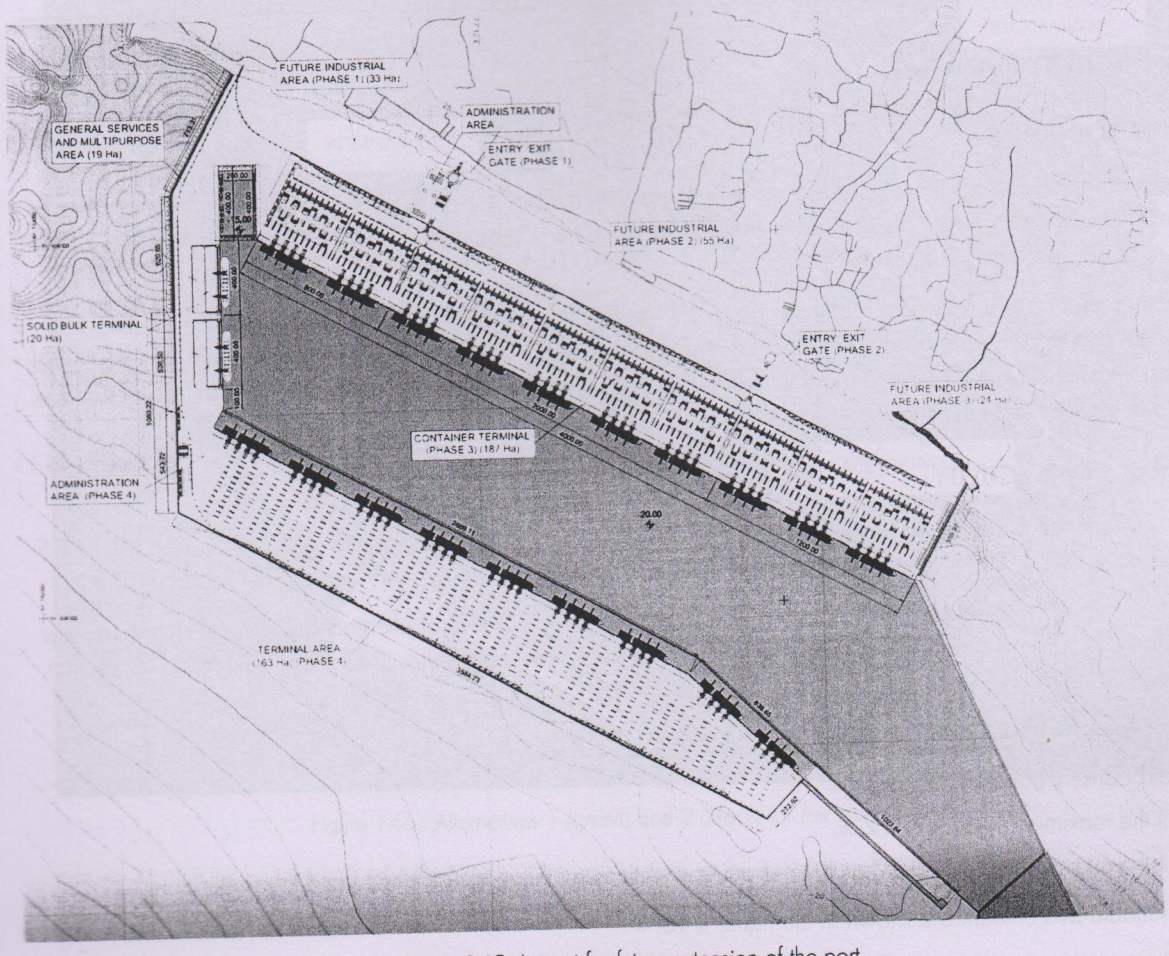


Figure 145: Layout for future extension of the port

Further information regarding Phase 2, 3 and future extension (Phase 4) are included in Drawing-02, Sheets 1 to 4.

10. CONNECTIVITY PLANNING

10.1. INTRODUCTION

As stated in chapter on Key imperatives, transport linkages with the port hinterland are a key factor for the success of the project. One million TEUs are expected to travel from or to the port hinterland, and suitable connections by road and rail must be developed to facilitate this traffic.

Next sections show a first approach of these linkages to assess their feasibility, preliminary calculation of costs, land requirements and to allow an initial environmental and social impact evaluation. Further studies should be developed to optimize this preliminary design in order to reduce the impact on housing and properties. These studies are explained in section 15 of this report.

10.2. RAIL CONNECTIVITY

A 20 or 25% of the gateway traffic is expected to travel by train. That means around 0.25 Million TEU or 3.85 million tonnes in 2020.

A single lane broad gauge track runs parallel to the west coast of India. Several alternative layouts of a new railway which connects to the existing one have been analyzed to know which is better in terms of environmental impact, length, slopes, and earthworks.

All alternatives have been chosen according to the following criteria:

- Avoid densely populated areas.
- Limit the maximum slope to 0.12 %.
- Limit the minimum radius to 500 m, apart from connections on the existing railway and the port.

The most suitable two of them are shown in the figure 146.

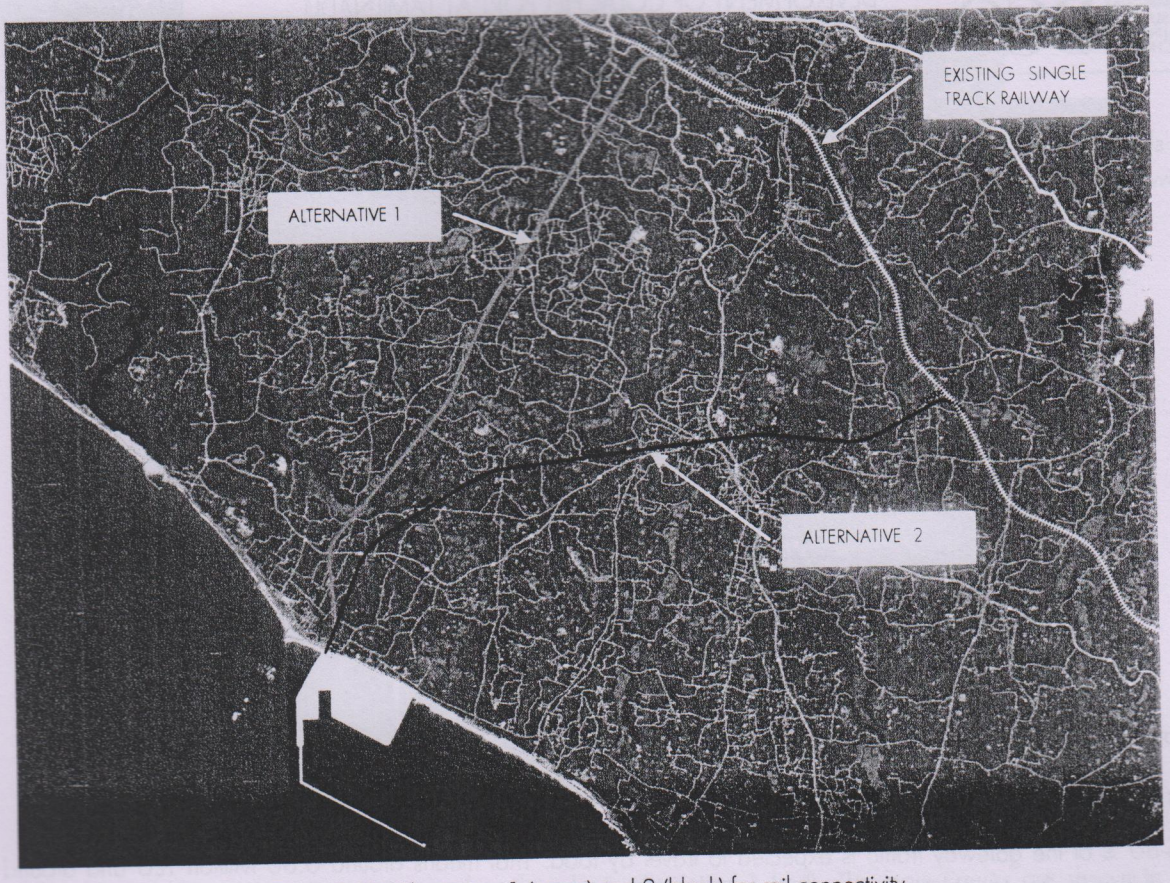


Figure 146: Alternatives 1 (green) and 2 (black) for rail connectivity

A double broad gauge track has been considered for linking the port and the main track. The typical cross section is:

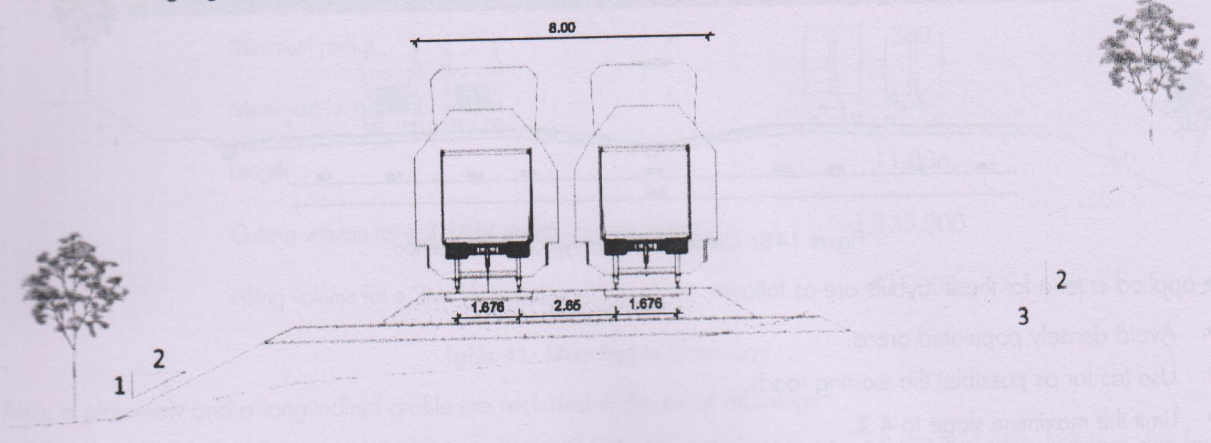


Figure 147: Connecting railway typical cross section

The shortest and less costly option in terms of earthworks is alternative 1 (green). Its main figures are shown in the following table:

Description	Unit	Value
Minimum radius	m	500
Maximum longitudinal slope	%	1.20
Length	m	9,985
Cutting volume (at a 3H/2V slope)	Cum	756,500
Filling volume (at a 2H/1V slope)	Cum	348,000

Table 40: Main figures of the rail connection.

A plan view and a longitudinal profile are included in the set of drawings.

10.3. ROAD CONNECTIVITY

A 75-80 % of the gateway traffic is expected to travel by road. That means around 0.80 Million TEU and around 0.53 million trucks –in addition to the cars- travelling to and from the port can be expected in 2020.

In the same way as the rail linkage, several alternative layouts of the four lane connecting road have been analyzed.

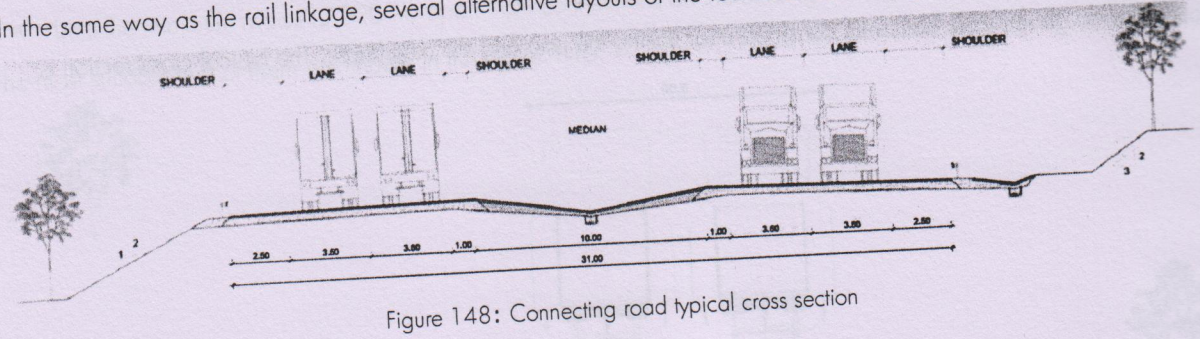


Figure 148: Connecting road typical cross section

The applied criteria for these layouts are as follows:

- Avoid densely populated areas.
- Use (as far as possible) the existing roads.
- Limit the maximum slope to 4 %.
- Limit the minimum radius to 300 m.

The most suitable two of them are shown in the figure.

Figure 149: Alternatives 1 (blue) and 2 (red) for road connectivity

The shortest and less costly option in terms of earthworks is alternative 1 (red). The main figures are shown in the following table:

Description	Unit	Value
Minimum radius	m	300
Maximum longitudinal slope	%	4.00
Length	m	11,806
Cutting volume (at a 3H/2V slope)	Cum	1,135,000
Filling volume (at a 2H/1V slope)	Cum	831,000

Table 41: Main figures of the road.

Also, a plan view and a longitudinal profile are included in the set of drawings.

NHAI is currently undertaking a project to expand NH 47. The project is under NHDP-Phase-III and includes four laning of NH 47 from Villukuri to Kanyakumari and four laning of NH 47B from Nagercoil to Kavalkinaru. Currently land acquisition for the project is ongoing. The stretch of NH 47 & NH 47 B from Villukuri to Nagercoil to

Kavalkinaru is expected to be the principal evacuation route for the Colachel port. This stretch would connect NH 47 to NH 7 which then would further connect to the key hinterland areas of the port. This stretch is expected to handle approximately ~1 Mn trailers annually (import, export and empty trailers) by 2025 for the Colachel port. To ensure that the road has the capacity to handle the trailer volumes generated by the container traffic in the Colachel port without congestion, the planned road from Villukuri to Nagercoil to Kavalkinaru can be developed as a six lane road under the current road expansion project. This project can further cover the extension of the six lane road till the location of the Enayam port. Requisite land acquisition can be commenced along with the current land acquisition for the broadening of NH 47.

10.4. IMPLICATIONS ON LAND RECLAMATION

These linkages run almost perpendicular to the shore, within the Vilavancode Taluk of Kanyakumari District and, as is shown in the annexed drawing, they cross several villages of that taluk.

Specifically, the following villages will be affected:

- Karungal (TP) Midalam
- Keezhkulam
- Paloor
- Kylliyoor
- Nattalam

The table shows the initial rough estimates of the impacts of land acquisition for the railway and road links at each of the affected villages, as shown in Drawing No 7, sheet 2 of 2. The areas have been calculated assuming a 60 m wide corridor for road and a 40 m wide corridor for railway, as stated in previous sections.

VILLAGES	ROAD LINKAGE		RAILWAY LINKAGE	
	Length (m)	Area (Sq.m)	Length (m)	Area (Sq.m)
Karungal (TP) Midalam	390	23,400	-	-
Keezhkulam	2,765	165,900	3,813	152,500
Paloor	3,084	185,000	3,136	125,400
Kylliyoor	1,711	102,700	795	31,800
Nattalam	3,843	230,600	2,242	89,700
TOTAL	**11,793**	**707,600**	**9,986**	**399,400**

Table 42: Rough impact estimates on land acquisition.

The boundaries used to calculate affected distances and areas of each village have been taken from the Coastal Zone Management Plan (CZMP) of Tamil Nadu, developed by Department of Environment of the Government of Tamil Nadu. In turn, the CZMP has used the Cadastral Map of scale 1:5000, and other complementary sources.

As stated before, the layout and, in turn, the affected villages, lengths and areas can be modified in latter phases of the project, when the design will be optimized.

11. INITIAL ENVIRONMENTAL EXAMINATION

The Initial Environmental Examination (IEE) Report (included as Annexure 5) deals with the Environmental issues related to the Project in order to assess the likely impact. The IEE has been conducted within the short time available. The study mainly depends on secondary data on physiological condition of the area. Some field verifications have been undertaken by the study team for updating the secondary data when it was necessary.

IEE has been carried out as part of this TEFR, in order to determine whether the Project will be environmentally feasible. The general objectives of IEE study have covered the following:

- *To provide information about the general environmental settings of the project area as baseline data.*
- *To provide information on potential impacts of the project and the characteristic of the impacts, magnitude, distribution and their duration.*
- *To provide information on potential mitigation measures to minimize the impact including mitigation costs.*
- *To provide basic information for formulating management and monitoring plan.*

The indicative outline of the IEE report is as follows:

- A. Introduction.
- B. Description of the Project.
- C. Description of the Environment.
- D. Screening of Potential Environmental Impacts and Mitigation Measures.
- E. Institutional Requirements and Environmental Management Plan.
- F Conclusions.

The development of proposed Colachel Port at Tamil Nadu offers an efficient and cost effective supply chain/value proposition to the local importers and exporters. This could trigger a new set of opportunities as induced developments.

11.1. ALTERNATIVE ASSESSMENT

Initially, 4 alternatives were considered for the location of the port infrastructure. After a multicriteria analysis where the environmental and social factors played a key role together with the rest of the project components **Enayam**, was considered as the **best rated alternative location, with the lowest impact, while** the worst rated one, with the highest impact, was Colachel. Kanyakumari and Manavalakurichi obtained similar intermediate ratings.

The Enayam location has lower environmental impacts than the others with respect to dredging, cultural sites and its low impact on property due to its low population. Port expansion will not need a wide extra inland area since the land reclamation area will provide room for port facilities and industries.

11.2. PROJECT BENEFITS AND LAND ISSUES

Dedicated roadway and railway connectivity proposed for the Colachel-Enayam port would provide access to the major existing road and railway network which offers an efficient and cost effective supply chain/value proposition to the local importers and exporters in the State of Tamil Nadu. Employment opportunities to the local people would rise for skilled, semi-skilled and unskilled work force during the construction and operation phases

This will accomplish one of the main objectives of the proposed port project, bringing significant benefits to local people and to the region as a whole and positive impact on the socioeconomic conditions of the project region and the whole Tamil Nadu State.

However, the activities during the construction phase might have some other potential impacts on the socio-economic environment which includes dredging, reclamation, transportation of quarrying materials, construction of terminals and breakwater as well as establishment of labour camps. During the operation phase, the operation of terminals, marine traffic, road & rail traffic and establishment of labour/employee colony might have potential impact on the socio-economic environment of that region. However, as the port is planned to be developed entirely on the reclaimed land, **no land acquisition is envisaged for the port development**.

However, a total number of **427 properties would be directly affected** by the implementation of the railway line and road connections. Apart from that, being an international harbour, the port would require additional basic infrastructure facilities, administrative buildings cruise and navy operations facilities, warehouses, residential areas, truck parking areas. Hence, backup areas in the immediate vicinity will be required in the future for developing other further facilities.

11.3. ENVIRONMENTAL IMPACTS, MITIGATION MEASURES AND EMP

As for the impact onto the current environmental conditions, the port activities and their impacts on the environmental and social attributes during the development and operation phase have been discussed in detail.

It was concluded that most of the negative effects that may take place with the implementation of the project could be mitigated with the adoption of appropriate mitigation measures, both in construction and operational phase and the effective implementation of the proposed environmental management and monitoring programmes.

11.4. PRELIMINARY BUDGET FOR ENVIRONMENTAL AND CSR MEASURES

A preliminary environmental budget plan to address all environmental management requirements has been prepared. Some of the key areas identified are the following:

- Environmental (terrestrial and marine) monitoring in both construction and operation phase: monitoring of Shoreline changes in Colachel-Enayam coast in both construction and operation phase
- Water & wastewater management; Solid waste management
- Groundwater development at Project Area:; Focused water supply augmentation study in the **5 km** study area; Storm water management and rainwater harvesting is also planned
- Employment for solid waste management using Women Self Help Groups (SHG)
- Fishermen who lost livelihood opportunities will be given preference in providing employment, scavenger boat operations. STP operators for the streams will be from those groups who lost livelihood opportunities
- Rainwater harvesting, desiltation using silt traps, solid waste removal using waste trap, flow tank for spill over, collection tank, sump from where the water will be pumped to the various locations and also for the excess water to be drained to the sea by a naturally controlled mechanism.
- Sanitation facility at new fishing harbour for the entire fishing village of Enayam. Bathing rooms.

The budgetary preliminary estimate for Environmental Management for proposed port, road and railway alignment during construction phase is **Rs 292 Million (29 Crores)** and the annual budgetary estimate during operational phase is **Rs 20 Million**

As for the **social compensation** and measures, the future Port Authority is encouraged to initiate many CSR activities for improving the way of living of people of Colachel-Enayam and other nearby villages in 2.0 km radii area in sectors like fisheries, agriculture, tourism, common infrastructure facilities, educational & medical facilities, sanitation & wastewater treatment, solid waste management, etc. **CSR activities** are also planned to achieve environmental standards:

A **preliminary budget** is included for the social measures proposed, **excluding land acquisition cost**, for port construction (reclamation) and implementation of the access road and railway corridors. The budgetary preliminary estimate for CSR measures for proposed port, road and railway alignment is **Rs 950 Million (95 Crores).**

Cost of CSR activities that include:

- Water Supply Scheme for Enayam fishing Village
- Rehabilitation of livelihood loses. Creation of a skill development centre in Enayam
- Implementation of a new fishing harbour in Enayam (equipped with cold store, sanitation and loading and unloading and distribution facilities and integration with new fishing harbour (rehabilitation of the existing fishing harbour) in Colachel
- General CSR activities, as compensation measures, in sectors like fisheries, agriculture, tourism, common infrastructure facilities, educational & medical facilities, sanitation & wastewater treatment, etc (provision of funds for social enhancing measures)

11.5. ENVIRONMENTAL AND SOCIAL FEASIBILITY

Also to ensure the social feasibility of the project and to ensure the quality of the population livelihood in the project area, this preliminary Environmental Examination states that **important studies and plans should be finished and approved before the project was operational**. Final ESIA Report should address these important issues, and the conclusions of these studies and plans should be translated into conditions into the final Project Design. It is then recommended that a set of Studies and Plans should be carried out before project implementation

- Risk Analysis

Addressing proposed project actions related risks associated with explosion, fire, or release of hazardous materials in the event of accident or a natural disaster with the construction and operation of the proposed port in terms of identifying the hazards and suggesting the suitable mitigation measures.

- Disaster Management Plan

A framework for Disaster Management Plan should be prepared to minimise damages in the event of a disaster. An On-Site Emergency Preparedness Plan and Off-Site Emergency Preparedness Plan must be broadly prepared to deal with emergencies and prevent disasters including an institutional framework with clear assignment of roles and responsibilities was broadly prepared with which location of Emergency Control Centre and Assembly Points to be identified.

- Spill Contingency Plan

An oil spill contingency plan for shall be prepared and approved by the Indian Coastguard. It would describe about the different organisation/ teams required and their responsibilities. It also covered training, inspection and drill schedule and equipment, etc. required effect function of contingency plan.

11.6. ENVIRONMENTAL MOEF CLEARENCE

Finally, the proposed Port Project is a Category A Project as the proposed cargo handling capacity is ≥ 5 million tonnes per annum (TPA). Hence, Environmental Clearance from the Ministry of Environment and Forest (MoEF), Government of India will be required as given in rule 2(II) of Annex I of the "EIA Notification" of The Environment (Protection) Act, 1986.

In further project development stages, a full comprehensive Environmental Social Impact Assessment Study should be carried out as per the MoEF's EIA Guidance Manual for Ports and Harbour along with the International Finance Corporation's (IFC) Performance Standards 2006, Environmental, Health and Safety (EHS) Guidelines for Ports, Harbour and Terminals, and EHS Guidelines for Construction Materials Extraction for obtaining the **Clearance from MoEF**.

12. ESTIMATION OF PROJECT CAPITAL COST

12.1. PRINCIPLES FOR COST ESTIMATION

This cost estimates are calculated in order to have an input on the CAPEX of the project and to be able to calculate its financial feasibility.

The following assumptions have been used:

- All costs are presented Rupees.
- Mobilization and demobilization costs are included in respective entities.
- Land costs have been obtained by requesting information from authorities and private companies. A deeper analysis must be developed to confirm these costs.
- Engineering and project management is added as 7.5 % of the project costs.
- Besides, 15% of the project costs have been included for contingencies.

Costs and rates are based on similar projects developed by TYPSA and BCG, and marine projects of south India, like Colachel fishing harbour, currently in progress. Some of the rates are "macro-rates", which means a rough estimate of a major unity.

Cost estimates have been broken down in the following sections:

- Preliminaries

This section includes all the preliminary studies and surveys (e.g. bathymetric or topographic surveys previous to the beginning of the construction), and some other works required before the main works begin. One important preliminary work is the temporary berthing facility which will allow the construction of the breakwater by maritime means.

- Breakwaters

As explained earlier, both rubble mound and vertical breakwaters have been proposed following a cost saving criteria. The following considerations have been assumed for rubble mound breakwaters:

- Rock layers porosity: 0.370
- Concrete cubes layer porosity: 0.470
- Accropods layers porosity: 0.491

Regarding vertical breakwaters, the following assumptions have been taken for caisson construction and installation:

- 20% of total volume of caisson is reinforced concrete and 80% is sand fill.
- Reinforcement steel rate is 100 kg/m^3 of concrete.

Berths

The cost estimates have been made considering the basic design of an open pile berthing structure, assuming a 9 m x 9 m grid and mean length of 35 m for piles, with stone pitching as slope protection underneath the berth. Also, a mean thickness of 1.0 m for reinforced concrete superstructure has been considered, with a reinforcement steel rate of 120 kg/m^3.

Berth equipment such fenders, bollards, ladders or mooring rings have been considered. Both fenders and bollards have been assumed to be located every15 m.

STS rails (A150) and fixtures (pads, clips, plates, bolts, etc) have been considered along the container berth as well.

Dredging and reclamation

This section includes the dredging costs to obtain the required drafts for the basin, the berth pocket and the approach channel. It also includes the costs for land reclamation, which is assumed to be done through dredging from surrounding areas of Phase 2 and 3 of the port. Finally, the ground improvement of reclaimed areas has been included too.

Reclamation for port related industrial areas has been included but no ground improvement or pavement has been considered. Instead of it, ground improvement costs are only estimated over the yard areas of the port.

A breakdown of quantities on dredging and reclamation is included in clause 9.5.

Rates for dredging include equipment mobilization, demobilization and service tax (14.42%).

Yards

Pavement design has been estimated in different areas. Three zones have been studied:

- Container yard-Stacking area:
  80 mm thickness concrete block paving + 30 mm laying course material + 470 mm cement bound granular mixture C8/10 + 450 mm aggregate sub-base + 900 mm capping layer
- Container yard-Operation area:
  80 mm thickness concrete block paving + 30 mm laying course material + 560 mm cement bound granular mixture C8/10 + 450 mm aggregate sub-base + 900 mm capping layer
- Multipurpose area:
  240 mm concrete C32/40+ 150 mm aggregate sub-base + 900 mm capping layer

The design has been performed in accordance to "The Structural Design of Heavy Duty Pavements for Ports and Other Industries" (NTERPAVE -4th Edition: 2007), based on British Standards and broadly used for this kind of ports.

ARMG concrete beams, rails (MRS 87A) and fixtures have been considered in container yard too.

Equipment

The quantities included in this section are the required so that the terminal is working at full capacity in 2020.

Buildings

A rough estimate of buildings has been made in this section. Four entities are included, depending on the type of building.

- Administrative and operation buildings: Port administrative building, private operator administrative building, port and yard operations buildings.
- Maintenance buildings: Cranes maintenance and others repair buildings,
- Utility Buildings: Fire station, electrical sub stations, fuel station, reefer shop and other utility buildings.
- Miscellaneous buildings: Canteen, quay workers restrooms, security booths, and others.

A rate per square meter has been assigned to each type of building, as can be seen in the cost estimates table.

Networks and utilities

Networks include not only roads and railways inside the port area, but gates and parking areas. The main utilities, such us power and water supply, water drainage and sewage, or communications are included too.

Regarding Aids to Navigation and VTMS, cost estimates have been calculated following clause 9.4.

Connectivity

Infrastructures to link the port to the main transport networks are included here. Macro-rates per each kilometre are used to estimate the cost for them. These rates take into account the land relief and the expected amount of structures (bridges, viaducts or tunnels). The total lengths for road and railway links are obtained from the drawings.

Land acquisition

Taking into account their typical cross sections, a corridor of 60 m for the new 4-lane road and 40 m for the new 2-track railway is assumed to estimate land acquisition costs. The mean value of land cost has been calculated based on the specific rates given in section 7.5.

A specific feasibility study for connectivity should be made to assess accurately these costs.

12.2. TOTAL COST ESTIMATES

As a result of multiplying the obtained rates by the estimated quantities of each entity, the partial, section and total amount is obtained.

The following table shows the total cost estimates.

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
1	PRELIMINARIES								
1.1	Surveys and studies	L.S.	25,200,000.00	1	2.52	0.25	0.63	0.25	0.63
1.2	Site Clearance, site offices, fencing	L.S.	22,050,000.00	1	2.21	1	2.2	1	2.21
1.3	Temporary berthing facilities	L.S.	189,000,000.00	1	18.9	0	0	0	0
	Total				23.63		2.84		2.84
2	BREAKWATERS								
2.1	Rubble mound breakwater								
2.1.1	Core material (50-100 kg)	Cu.m	1,890.00	704,839.10	133.21	134,967.32	25.51	134,967.32	25.51
2.1.2	Rock (1-50 kg)	Cu.m	1,890.00	16,922.31	3.2	3,933.97	0.74	3,933.97	0.74
2.1.3	Rock (0.2-0.5 t)	Cu.m	2,835.00	22,785.08	6.46				
2.1.4	Rock (0.5-1 t)	Cu.m	3,465.00	49,932.29	17.3	0	0	0	0
2.1.5	Rock (3-4 t)	Cu.m	5,040.00	24,924.16	12.56	24,924.16	12.56	24,924.16	12.56
2.1.8	Concrete cubes (5 t)	Cu.m	8,820.00	3,865.17	3.41	0	0	0	0
2.1.9	Accropods (2 m^3)	Cu.m	10,710.00	3,751.84	4.02	0	0	0	0
2.1.10	Accropods (3 m^3)	Cu.m	11,340.00	33,123.28	37.56	0	0	0	0
2.1.11	Superstructure *(Crown wall)*	Cu.m	12,600.00	40,232.64	50.69	0	0	0	0

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
2.2	Vertical Breakwater								
2.2.1	Bedding layer (50-150 kg)	Cu.m	1,890.00	269,185.01	50.88	274,386.44	51.86	191,237.21	36.14
2.2.2	Rock protection (1-2 t)	Cu.m	3,465.00	72,115.94	24.99	71,731.07	24.85	49,993.90	17.32
2.2.4	Guard blocks (36 t)	Cu.m	11,970.00	15,036.00	18	0.63	0	0.44	0
2.2.5	Caissons								
2.2.5.1	Structure (reinforced concrete)	Cu.m	23,940.00	240,643.52	576.1	160,942.02	385.3	112,170.64	268.54
2.2.5.2	Sinking on site	L.S.	220,500,000.00	1	22.05	0.63	13.98	0.44	9.74
2.2.5.3	Sand fill	Cu.m	630	962,574.08	60.64	643,768.09	40.56	448,682.55	28.27
2.2.6	Superstructure *(Crown wall)*	Cu.m	12,600.00	81,967.50	103.28	41,316.08	52.06	28,795.78	36.28
	Total				1,124.35		611.46		439.15
3	BERTHS								
3.1	Container berth (35 m wide)								
3.1.1	Concrete Piles (1500 mm)	m	113,400.00	16,520.00	187.34	41,300.00	468.34	24,780.00	281.01
3.1.2	Superstructure	Sq.m	26,775.00	29,750.00	79.66	74,375.00	199.14	44,625.00	119.48
3.1.3	Berth equipment								
3.1.3.1	Fenders	Un	2,835,000.00	57	16.16	143	40.54	86	24.38

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
3.1.3.2	Bollards and misc.	L.S.	18,900,000.00	1	1.89	2.5	4.73	1.5	2.84
3.1.3.3	STS Rails and fixtures	m	63,000.00	1,600.00	10.08	4,000.00	25.2	2,400.00	15.12
3.1.4	Slope protection under berth								
3.1.4.1	Filter (1-50 kg)	Cu.m	1,890.00	14,029.08	2.65	35,072.70	6.63	21,043.62	3.98
3.1.4.2	Armourstone (0.5-1 t)	Cu.m	3,465.00	43,591.63	15.1	108,979.08	37.76	65,387.45	22.66
3.2	Multipurpose berth (20 m wide)								
3.2.1	Concrete Piles (1200 mm)	m	94,500.00	4,655.00	43.99	0	0	0	0
3.2.2	Superstructure	Sq.m	26,775.00	8,000.00	21.42	0	0	0	0
3.2.3	Berth equipment						0		
3.2.3.1	Fenders	Un	2,520,000.00	27	6.8	0	0	0	0
3.2.3.2	Bollards and misc.	L.S.	6,300,000.00	1	0.63	0	0	0	0
3.2.4	Slope protection under berth								
3.2.4.1	Filter (1-50 kg)	Cu.m	1,890.00	5,078.22	0.96	0	0	0	0
3.2.4.2	Armourstone (0.5-1 t)	Cu.m	3,465.00	15,779.21	5.47	0	0	0	0

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
3.3	Ancillary berth (20 m wide)							0	0
3.3.1	Concrete Piles (1200 mm)	m	94,500.00	2,345.00	22.16	0	0	0	0
3.3.2	Superstructure	Sq.m	26,775.00	4,000.00	10.71	0	0	0	0
3.3.3	Berth equipment						0		
3.3.3.1	Fenders	Un	315,000.00	20	0.63	0	0	0	0
3.3.3.2	Bollards and misc.	L.S.	3,150,000.00	1	0.32	0	0	0	0
3.3.4	Slope protection under berth								
3.3.4.1	Filter (1-50 kg)	Cu.m	1,890.00	2,539.11	0.48	0	0	0	0
3.3.4.2	Armourstone (0.5-1 t)	Cu.m	3,465.00	7,889.61	2.73	0	0	0	0
3.4	Solid bulk berth (35 m wide)								
3.4.1	Concrete Piles	m	94,500.00	0	0	16,520.00	156.11	20,650.00	195.14
3.4.2	Superestructure	Sq.m	50,400.00	0	0	29,750.00	149.94	37,187.50	187.43
3.4.3	Berth equipment								
3.4.3.1	Fenders	Un	2,835,000.00	0	0	57	16.16	71	20.13
3.4.3.2	Bollards and misc.	L.S.	9,450,000.00	0	0	1	0.95	1.25	1.18

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
3.4.4	Slope protection under berth								
3.4.4.1	Filter (1-50 kg)	Cu.m	1,890.00	0	0	14,029.08	2.65	17,536.35	3.31
3.4.4.2	Armourstone (0.5-1 t)	Cu.m	3,465.00	0	0	43,591.63	15.1	54,489.54	18.88
	Total				429.18		1,123.25		895.53
4	DREDGING AND RECLAMATION								
4.1	Reclamation bunds								
4.1.1	Core material (50-100 kg)	Cu.m	1,890.00	1,384,731.15	261.71	1,736,340.00	328.17	1,041,804.00	196.9
4.1.2	Filter (1-50 kg)	Cu.m	1,890.00	29,013.05	5.48	36,380.00	6.88	21,828.00	4.13
4.1.3	Armourstone (1-2 t)	Cu.m	3,780.00	95,333.15	36.04	119,540.00	45.19	71,724.00	27.11
4.2	Dredging of sand and pumping into reclaim. area	Cu.m	491.4	6,819,280.00	335.1	6,332,623.00	311.19	1,821,258.00	89.5
4.3	Dredging of sandbank and pumping into reclaim. area	Cu.m	491.4	3,303,992.65	162.36	9,562,159.00	469.88	6,395,527.00	314.28
4.4	Ground improvement	Sq.m	126	668,766.00	8.43	954,109.00	12.02	530,395.00	6.68
	Total				809.12		1,173.32		638.59
5	YARDS								
5.1	Container Yard-Stacking & Operation area								
5.1.1	Concrete block paving + laying course material	Sq.m	882	410,769.00	36.23	922,426.00	81.36	530,395.00	46.78

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
5.1.2	Cement Bound Granular Mixture $C_{8/10}$	Cu.m	5,166.00	213,599.88	110.35	479,661.52	247.79	275,805.40	142.48
5.1.3	Aggregate sub-base	Cu.m	1,575.00	184,846.05	29.11	415,091.70	65.38	238,677.75	37.59
5.1.4	Capping layer	Cu.m	945	369,692.10	34.94	830,183.40	78.45	477,355.50	45.11
5.1.5	ARMG Rail and fixtures	m	44,100.00	11,748.00	51.81	26,381.00	116.34	15,169.00	66.9
5.1.6	ARMG beams (Reinf. Concr.)	Cu.m	23,940.00	6,408.00	15.34	14,390.00	34.45	8,274.00	19.81
5.2	Multi-purpose Area			257,997.00		31,683.00		0	
5.2.1	Concrete $C_{32/40}$	Cu.m	7,875.00	61,919.28	48.76	7,603.92	5.99	0	0
5.2.2	Aggregate sub-base	Cu.m	1,575.00	28,650.00	4.51	4,752.45	0.75	0	0
5.2.3	Capping layer	Cu.m	945	171,900.00	16.24	28,514.70	2.69	0	0
	Total				347.29		633.2		358.67
6	EQUIPMENT								
6.1	Container Terminal								
6.1.1	STS Cranes (Quay)	Un	630,000,000.00	9	567	22	1,386.00	14	882
6.1.2	A-RMG Cranes (Yard)	Un	126,000,000.00	44	554.4	110	1,386.00	66	831.6
6.1.3	RMG Cranes (Rail yard)	Un	157,500,000.00	2	31.5	4	63	2	31.5

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
6.1.4	Shuttle Carriers	Un	53,550,000.00	16	85.68	40	214.2	24	128.52
6.1.5	Reach Stackers	Un	31,500,000.00	2	6.3	5	15.75	3	9.45
6.1.6	Terminal tractors	Un	6,300,000.00	4	2.52	10	6.3	6	3.78
6.2	Coal Yard								
6.2.1	Gantry Cranes (Quay)	Un	630,000,000.00	0	0	2	126	2	126
6.2.2	Stackers, reclaimers, conveyors	L.S.	126,000,000.00	0	0	1	12.6	1	12.6
	Total				1,247.40		3,209.85		2,025.45
7	BUILDINGS								
7.1	Admin. and Operation Buildings	Sq.m	35,280.00	2,600.00	9.17	1,300.00	4.59	650	2.29
7.2	Maintenance Buildings	Sq.m	28,980.00	4,500.00	13.04	4,500.00	13.04	2,250.00	6.52
7.3	Utility Buildings	Sq.m	34,650.00	1,000.00	3.47	0	0	0	0
7.4	Miscellaneous Buildings	Sq.m	22,050.00	800	1.76	0	0	0	0
	Total				27.44		17.63		8.81

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
8	NETWORKS AND UTILITIES								
8.1	Gates	L.S.	63,000,000.00	1	6.3	1	6.3	0	0
8.2	Internal railway	L.S.	226,800,000.00	1	22.68	1	22.68	0.5	11.34
8.3	Electric supply and lighting	L.S.	630,000,000.00	1	63	0.1	6.3	0.1	6.3
8.4	Water supply and fire fighting	L.S.	100,800,000.00	1	10.08	0.5	5.04	0.5	5.04
8.5	Water sewage and drainage	L.S.	189,000,000.00	1	18.9	0.5	9.45	0.5	9.45
8.6	Communications and IT	L.S.	63,000,000.00	1	6.3	0.5	3.15	0.5	3.15
8.7	Aids to navigation	L.S.	22,050,000.00	1	2.21				
8.8	VTMS	L.S.	15,750,000.00	1	1.58	0	0	0	0
	Total				131.04		52.92		35.28
9	CONNECTIVITY								
9.1	Road connectivty	km	126,000,000.00	11.8	148.68	0	0	0	0
9.2	Railway connectivty	km	126,000,000.00	9.9	124.74	0	0	0	0
	Total				273.42		0		0

	ITEM	UNIT	RATE (Rs)	PHASE 1		PHASE 2		PHASE 3	
				QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)	QUANTITY	AMOUNT (Rs.Cr.)
11	LAND AQUISITION								
11.1	Road (60 m wide corridor)	Ha	6,300,000.00	70.2	44.23	0	0	0	0
11.2	Rail (40 m wide corridor)	Ha	6,300,000.00	42	26.46	0	0	0	0
	Total				70.69		0		0
	TOTAL				4,483.55		6,824.47		4,404.32
	OTHERS								
	Engineering and PMC	%	7.50%		336.27		511.84		330.32
	Provision for contingencies	%	15%		672.53		1,023.67		660.65
	GRAND TOTAL				5,492.35		8,359.98		5,395.29

13. FINANCIAL ASSESSMENT

13.1. Key Assumptions

The key assumptions used in the financial model to evaluate the financial viability of the project have been highlighted below.

13.1.1. Timelines

The financial model has been built for three options for the concession period: 20 years, 25 years and 30 years. The construction period for each phase has been assumed to be 3 years.

13.1.2. Project Cost Estimates

The project cost estimates for each of the three phases is presented in the table below. The project cost estimates comprise of the base capital costs, cost escalation due to the above phasing and other preliminary expenses including interest during construction and syndication fee. These cost estimates and capacity of each phase have been updated after the submission of 'Report on Alternative Development Concepts and Location of the Port' and details of the revised cost estimate will be provided in the final report. The escalation in capital cost has been taken as 4.7% per annum based on the CAGR of Construction Cost Indices (2007-2015) for infrastructure projects (published by Construction Industry Development Council, Government of India).

	(all figures in INR crores)		
Component	Phase 1	Phase 2	Phase 3
Preliminaries	23.6	2.8	2.8
Breakwaters	1,124.4	611.5	439.2
Berth	429.2	1,123.3	895.5
Dredging and Reclamation	809.1	1,173.3	638.6
Yards	347.3	633.2	358.7
Equipments	1,247.4	3,209.9	2,025.5
Buildings	27.4	17.6	8.8
Network and Utilities	131.0	52.9	35.3
Connectivity	273.4	0.0	0.0
Land Acquisition	70.7	0.0	0.0
Port Crafts	0.0	0.0	0.0
Total Civil Cost	4,483.6	6,824.5	4,404.3
Engineering and project management	336.3	511.8	330.3
Provision for contingencies	672.5	1,023.7	660.6
Escalation	347.5	2,237.3	3,173.1
Total Construction Cost	5,839.8	10,597.3	8,568.4
Interest During Construction	689.3	877.7	823.3
Syndication Fees	46.0	61.9	66.2
Total Project Cost for Phase	6,575.2	11,536.9	9,457.9

Table 43: Summary of Phase-wise Project Cost

6575.20
11536.90
9457.90
27570.00

13.1.3. Traffic Projection

The traffic projections included in the Traffic and Market Study Report has used in the financial analysis and has been further detailed out in the table below.

Hazardous & Reefer containers have been assumed to be 5%, while Loaded and Empty containers have been assumed in the ratio of 85%:15% based on the existing traffic at Chennai and Tuticorin Port. TEU per container ratio has been assumed to be 1.5 for estimating the number of 20' and 40' containers.

(all figures in million TEUs)

Year	Total Container Traffic	Trans-shipment		Gateway		
		Regular Containers	Hazardous & Reefers	Loaded	Empty	Hazardous & Reefers
2018	1.00	0.36	0.02	0.50	0.09	0.03
2019	1.32	0.49	0.03	0.65	0.11	0.04
2020	1.69	0.64	0.03	0.82	0.15	0.05
2021	2.22	0.91	0.05	1.02	0.18	0.06
2022	3.00	1.35	0.07	1.28	0.23	0.08
2023	3.72	1.88	0.10	1.40	0.25	0.09
2024	4.29	2.27	0.12	1.53	0.27	0.09
2025	4.91	2.70	0.14	1.67	0.29	0.10
2026	5.24	2.87	0.15	1.79	0.32	0.11
2027	5.58	3.05	0.16	1.92	0.34	0.12
2028	5.94	3.24	0.17	2.05	0.36	0.13
2029	6.33	3.44	0.18	2.19	0.39	0.14
2031	6.74	3.66	0.19	2.33	0.41	0.14
2032	7.08	3.84	0.20	2.45	0.43	0.15
2033	7.08	3.84	0.20	2.45	0.43	0.15
2034	7.08	3.84	0.20	2.45	0.43	0.15
2035	7.08	3.84	0.20	2.45	0.43	0.15
2036	7.08	3.84	0.20	2.45	0.43	0.15
2037	7.08	3.84	0.20	2.45	0.43	0.15
2038	7.08	3.84	0.20	2.45	0.43	0.15
2039	7.08	3.84	0.20	2.45	0.43	0.15
2040	7.08	3.84	0.20	2.45	0.43	0.15
2041	7.08	3.84	0.20	2.45	0.43	0.15
2042	7.08	3.84	0.20	2.45	0.43	0.15
2043	7.08	3.84	0.20	2.45	0.43	0.15
2044	7.08					

Table 44: Container traffic projection

(all figures in million containers)

Year	Total Container Traffic	Trans-shipment				Gateway						
		Regular Containers		Hazardous & Reefers		Loaded		Empty		Hazardous & Reefers		Container vessels
		20'	40'	20'	40'	20'	40'	20'	40'	20'	40'	
2018	0.66	0.12	0.12	0.01	0.01	0.17	0.17	0.03	0.03	0.01	0.01	144
2019	0.88	0.16	0.16	0.01	0.01	0.22	0.22	0.04	0.04	0.01	0.01	189
2020	1.13	0.21	0.21	0.01	0.01	0.27	0.27	0.05	0.05	0.02	0.02	241
2021	1.48	0.30	0.30	0.02	0.02	0.34	0.34	0.06	0.06	0.02	0.02	320
2022	2.00	0.45	0.45	0.02	0.02	0.43	0.43	0.08	0.08	0.03	0.03	437
2023	2.48	0.63	0.63	0.03	0.03	0.47	0.47	0.08	0.08	0.03	0.03	551
2024	2.86	0.76	0.76	0.04	0.04	0.51	0.51	0.09	0.09	0.03	0.03	637
2025	3.27	0.90	0.90	0.05	0.05	0.56	0.56	0.10	0.10	0.03	0.03	731
2026	3.49	0.96	0.96	0.05	0.05	0.60	0.60	0.11	0.11	0.04	0.04	774
2027	3.72	1.02	1.02	0.05	0.05	0.64	0.64	0.11	0.11	0.04	0.04	818
2028	3.96	1.08	1.08	0.06	0.06	0.68	0.68	0.12	0.12	0.04	0.04	865
2029	4.22	1.15	1.15	0.06	0.06	0.73	0.73	0.13	0.13	0.05	0.05	913
2030	4.49	1.22	1.22	0.06	0.06	0.78	0.78	0.14	0.14	0.05	0.05	965
2031	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	1,007
2032	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	1,000
2033	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	993
2034	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	985
2035	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	979
2036	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	972
2037	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	966
2038	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	959
2039	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	953
2040	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	946
2041	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	940
2042	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	933
2043	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	927
2044	4.72	1.28	1.28	0.07	0.07	0.82	0.82	0.14	0.14	0.05	0.05	921

Table 45: Distribution of container traffic

Based on the existing coal traffic at Tuticorin Port and discussions with Power sector experts, it is expected that 30% of coal would be imported and 70% indigenous. The indigenous coal is expected to be transported in Handymax and Panamax vessels, while the imported coal is expected to be transported in Panamax and Capesize vessels, considering the vessel trends and draft at Paradip, Haldia and Vizag ports for indigenous and Indonesian ports for imported coal.

Year	Coal traffic	Vessels		
	(mn Tonne)	Handymax	Panamax	Capesize
2018	0.0	0	0	0
2019	0.0	0	0	0
2020	0.0	0	0	0
2021	0.0	0	0	0
2022	1.1	3	7	3
2023	2.2	7	14	5
2024	3.3	10	21	8
2025	3.3	10	21	8
2026	3.3	8	19	9
2027	4.4	11	25	12
2028	5.5	13	32	15
2029	6.6	16	38	18
2030	6.6	16	38	18
2031	6.6	16	38	18
2032	6.6	16	38	18
2033	6.6	16	38	18
2034	6.6	16	38	18
2035	6.6	16	38	18
2036	6.6	12	35	22
2037	6.6	12	35	22
2038	6.6	12	35	22
2039	6.6	12	35	22
2040	6.6	12	35	22
2041	6.6	12	35	22
2042	6.6	12	35	22
2043	6.6	12	35	22
2044	6.6	12	35	22

Table 46: Coal traffic projection

13.1.4. Tariff structure

During the traffic study, it has been established that for Colachel port to be competitive with Colombo Port, the charges for Trans-shipment traffic need to matched. Hence, for this analysis, the charges for Trans-shipment traffic have been assumed as per the Scale of Rates of Colombo Port. In addition, we have assumed a discount of 15% on the above tariff for the first 5 years.

For Gateway Container and Coal traffic, the charges for Chennai, Tuticorin and Cochin port were compared. For gateway traffic, the port can fix higher charges as seen in globally for ports with a mix of trans-shipment and

gateway traffic. Hence, the charges in the financial model have been assumed as per Cochin Port's scale of rates, since they were higher than Chennai and Tuticorin Port. Despite the higher rates, Enayam will be able to attract traffic compared to Tutcorin, because there will be overall logistic cost saving over Tuticorin due to higher productivity and since the exporters and importers will save on one set of port charges by coming directly to Enayam.

The detailed tariff structure is provided in the tables below.

Vessel related charges (Trans-shipment)		
Port Dues		
Light dues	2.0	INR per GRT
Entering dues	2.7	INR per GRT
Pilotage		
Pilotage dues	2.7	INR per GRT
Pilot fee (up to 30,000 DWT)	1,440	INR per move
Pilot fee (above 30,000 DWT)	1,920	INR per move
Tug services charge	9,660	INR per tug
Moves per call for pilotage	50	
Tug per call	10	
Berth Hire/ Dockage		
Berth Hire charges	0.13	INR per GRT per hour
Average Berth Occupancy time	25	hours
Cargo related charges (Trans-shipment)		
Terminal Handling Costs		
20' container	2,220	INR per container
40' container	3,450	INR per container
Storage charges		
First 21 days	0	INR per day
Thereafter	312.0	INR per day

Table 47: Tariff structure for Trans-shipment traffic

In order to attract traffic in the first few years, we have assumed a discount of 15% on the above tariff for the first 5 years.

Vessel related charges (Gateway)			
	Coastal	Foreign	
Port Dues	9.6	21.5	INR per GRT
Pilotage Fees			
Upto 30000 GRT	20.9	46.7	INR per GRT
30000 - 60000 GRT	16.7	37.4	INR per GRT
Above 60000 GRT	14.6	32.7	INR per GRT
Berth Hire Charges	0.17	0.33	INR per GRT per hour
Average Berth Occupancy time	25	hours	
Cargo related charges (Gateway)			

Container Handling and Transportation charges (all inclusive)			
	Coastal	Foreign	
	Loaded		
20'	3,221	5,058	INR per container
40'	4,831	8,078	INR per container
	Empty		
20'	2,260	4,182	INR per container
40'	3,390	6,274	INR per container
	Hazardous		
20'	4,025	6,730	INR per container
40'	6,040	10,110	INR per container
	Reefer - Electricity Supply and Monitoring charges		
20'	312	413	INR per container
40'	526	692	INR per container
	Wharfage charges		
	Coastal	Foreign	
	Loaded		
20'	507	846	INR per container
40'	761	1,269	INR per container
	Empty		
20'	107	178	INR per container
40'	160	266	INR per container
Storage charges (Gateway)			
	Loaded (20')		
First 7 days	0	0	INR per container per day
8th to 15th day	279	385	INR per container per day
16th to 30th day	558	769	INR per container per day
Thereafter	1,117	1,537	INR per container per day
	Loaded (40')		
First 7 days	0	0	INR per container per day
8th to 15th day	559	769	INR per container per day
16th to 30th day	1,117	1,538	INR per container per day
Thereafter	2,234	3,074	INR per container per day
	Empty (20')		
First 3 days	0	0	INR per container per day
4th to 10th day	279	385	INR per container per day
11th to 35th day	558	769	INR per container per day
Thereafter	1,117	1,537	INR per container per day
	Empty (40')		
First 3 days	0	0	INR per container per day
4th to 10th day	559	769	INR per container per day
11th to 35th day	1,117	1,538	INR per container per day
Thereafter	2,234	3,074	INR per container per day

Table 48: Tariff structure for Gateway Container traffic

Cargo related charges (Coal)			
Wharfage charges	56		INR per Tonne
Vessel related charges (Coal)			
	Coastal	Foreign	
Port Dues	7.7	17.2	INR per GRT
	Pilotage Fees		
Upto 30000 GRT	21.5	48.2	INR per GRT
30000 - 60000 GRT	17.2	38.6	INR per GRT
Above 60000 GRT	15.1	33.7	INR per GRT
Berth Hire Charges	0.15	0.29	INR per GRT per hour
Average Berth Occupancy time	55	hours	

Table 49: Tariff structure for Coal traffic

The escalation rate for tariff has been taken as per the Wholesale Price Index (WPI). The CAGR for WPI from 2004 to 2014 is 6.6%. The escalation rate has been tapered down over the concession period, from 6% in first 15 years to 5.5% in the last 15 years.

13.1.5. Operation and Maintenance costs

For the purpose of estimation, O&M cost has been bifurcated into following six broad components:

- Power charges
- Fuel charges
- Repair & maintenance
    - Civil
    - Equipment
- Insurance expenses
- Labour cost, Salary and Administrative Cost

The assumptions for the first five components have been assumed as per the prescribed guidelines of 'Tariff Authority for Major Ports (TAMP)', while for the last component, the value has been assumed as per the global BCG benchmarks of existing container-based ports.

They key assumptions for these components are provided in the table below.

Power for Container	8.00 kwh/TEU
Fuel (Diesel) for Container	4.00 ltrs/TEU
Power for Coal traffic	1.40 kwh/Tonne
Cost of Power	6.35 INR/ kwh

Cost of Diesel	52.76 INR/ ltr
Repair & Maintenance - Civil	1.0% of civil assets
Repair & Maintenance - Equipment	2.0% of equipments
Insurance	1.0% of gross fixed assets
Labour, salary and Administrative Cost	40.0% of total O&M Cost

Table 50: O&M cost assumptions

The escalation rate for O&M costs has been taken as per the Wholesale Price Index (WPI). The CAGR for WPI from 2004 to 2014 is 6.6%. The escalation rate has been tapered down over the concession period, from 6% in first 15 years to 5.5% in the last 15 years.

13.1.6. Funding structure

The funding structure has been assumed as per industry benchmarks for port projects that developed through private sector participation. A debt-equity ratio of 70:30 has been assumed. Other details of the funding structure are provided in the table below.

Debt: Equity	70:30
Interest Rate	12.5%
Moratorium	3 years
Repayment Period	12 years
Syndication Fee	1.0%
Cost of Equity	16 - 18%
WACC	10.6%

Table 51: Assumptions for Funding Structure

The interest rate and debt terms have been used as per the terms of commercial lending by Indian banks for large infrastructure projects. In case, government is able to procure funding from multilateral and bilateral agencies such as ADB, World Bank, JICA etc., the interest rates could be around 1 - 3% and the payback period could be up to 30 years. The VGF required in that case, maintaining an equity IRR of 16-18%, will be to the tune of 10-15%. The financial model has been made flexible to adjust the debt-equity ratio and cost of capital.

13.1.7. Tax and Depreciation

The assumptions for taxation structure are as follows:

Corporate Tax rate	33.99%
Minium Alternate Tax (MAT) rate	20.96%
Carry forward of losses	8 years

Carry forward of MAT	10 years

Table 52: Tax assumptions

The depreciation for P&L statement has been calculated as per straight line method and the depreciation rates have been taken as per the latest Companies Act. For taxation purposed, the depreciation has also been calculated as per the written down value method and the depreciation rates for this method has been taken as per the Income Tax Act. The depreciation rates are as follows:

Companies Act (SLM)	
Building (Phase 1)	3.70%
Building (Phase 2)	4.17%
Building (Phase 3)	5.26%
Plant & Machinery	12.5%
Pre-operating expenses (amoritisation)	10.0%
IT Act (WDV)	
Building	10.0%
Equipments	15.0%
Pre-operating expenses (amoritisation)	20.0%

Table 53: Depreciation rates

The key assumptions are summarised below.

Timelines	
Concession Period	30 years
Start Year	2015
Operation Start Year	2018
Concession End Year	2044
Phase 1	2018-20
Phase 2	2021-25
Phase 3	2026-30
Tariff structure	
Trans-shipment Traffic	As per Colombo Port's Scale of Rates *(15% discount provided for the first 5 years)*
Gateway Traffic	As per Cochin Port's Scale of Rates
Funding structure	
Debt	70.00%
Interest Rate	12.50%
Moratorium	3 years
Repayment Period	12 years
Syndication Fee	1.00%
Cost of Equity	16 -18%
WACC	10.60%

13.2. FINANCIAL RESULTS

This section presents the summary of results of the financial analysis after running the financial model using projected traffic figures and industry benchmarks for port projects. The financial analysis identifies and estimates various revenue streams, project costs, phasing or implementation schedule, cash flows and the financial viability of the project. The financial analysis of the Enayam Port is based on set of assumptions and inputs based on the industry benchmarks and from analysis & experience in the Port sector in India and globally. A detailed financial model has been developed for a Concession period of 30 years; the financial viability of the project has been assessed on the Discounted Cash Flow (DCF) and Internal Rate of Returns (IRR) method.

The key results of the discounted cash flow analysis based on the above mentioned assumptions are as follows:

NPV	INR 380 Crores
Project IRR	10.8%
Equity IRR	11.0%
Phase 1 Project IRR	9.2%
Phase 1 Equity IRR	8.6% [1]

Table 54: Financial results

As can be seen in the results above, the project IRR is above WACC of 10.6%, but the equity IRR is lower than the cost of equity of 16-18%. In order to make the project financially viable, viability gap funding (VGF) will be required. It has been estimated that a VGF of 20-30% is required to achieve the target equity IRR of 16-18%.
Further, it can be seen that the difference between the project IRR and equity IRR value is low. This is because the value of project IRR is very close to WACC. Despite the low difference in IRR values, it is advisable to take debt because of the large amount of capital expenditure required across the three phases and the difference between cost of debt and equity will be much large in terms of actual value, which the IRR value does not indicate.
On a standalone basis Phase 1 Project IRR (9.2%) is lower than overall IRR as benefits of the initial investments in breakwater, connectivity, reclamation etc. are not completely realized within Phase 1 only. Hence, it is advised that financial returns from the entire project are considered instead of returns from only Phase 1 in isolation.
The detailed P&L statement and cash flows (capital expenditure, interest payment and debt repayment), used in arriving at the above results, have been provided in the Annexures.

13.3. SENSITIVITY ANALYSIS

[1] EIRR is lower than Project IRR for Phase 1 as the Project IRR itself is lower than the Cost of Debt.

Concession Period, Revenue, O&M cost and capital costs are key parameters that affect the Equity IRR value. Further, it is important to understand the sensitivity of revenues from Trans-shipment and Gateway container traffic. The tables below highlight the impact of increase and decrease in these parameters by 5% and 10% and their combination.

Concession Period		
30 years	25 years	20 years
11.0%	9.8%	3.2%

Table 55: Sensitivity of Equity IRR to Concession Period

Revenue – Capex					
	(10.0%)	(5.0%)	0.0%	5.0%	10.0%
(10.0%)	10.0%	11.3%	12.6%	13.8%	15.0%
(5.0%)	9.3%	10.5%	11.8%	12.9%	14.1%
0.0%	8.6%	9.8%	11.0%	12.1%	13.3%
5.0%	7.9%	9.2%	10.3%	11.4%	12.5%
10.0%	7.4%	8.5%	9.7%	10.7%	11.8%

Table 56: Sensitivity of Equity IRR to Revenue and Capex

Revenue - Opex					
	(10.0%)	(5.0%)	0.0%	5.0%	10.0%
(10.0%)	9.6%	10.8%	10.9%	13.1%	14.2%
(5.0%)	9.1%	10.3%	10.5%	12.6%	13.7%
0.0%	8.6%	9.8%	10.0%	12.1%	13.3%
5.0%	8.1%	9.3%	9.5%	11.7%	12.8%
10.0%	7.6%	8.8%	9.1%	11.2%	12.4%

Table 57: Sensitivity of Equity IRR to Revenue and Opex

Trans-shipment Revenue - Gateway Revenue					
	(10.0%)	(5.0%)	0.0%	5.0%	10.0%
(10.0%)	8.6%	8.9%	8.2%	9.5%	9.8%
(5.0%)	9.5%	9.8%	9.1%	10.4%	10.7%
0.0%	10.4%	10.7%	10.0%	11.3%	11.6%
5.0%	11.3%	11.6%	10.9%	12.1%	12.4%
10.0%	12.2%	12.4%	11.7%	13.0%	13.2%

Table 58: Sensitivity of Equity IRR to Trans-shipment Revenue & Gateway Revenue

13.4. ECONOMIC IMPACT OF THE PROJECT

Development of a new port can be a potential boost for the economy of the country. The port itself is a profitable entity which gives back to the economy in terms of tax payments, employment generation and re-investments in infrastructure. It also provides cost competitiveness to the local businesses that use the port for imports and

exports; these businesses further add back to the economy in form of taxes, employment and investments. Colachel is a large scale port project; it is expected to drive economic growth in the country especially in the hinterland area. The following section discusses the nature of economic impact of Colachel and quantifies it.

13.4.1. Economic impact of the port

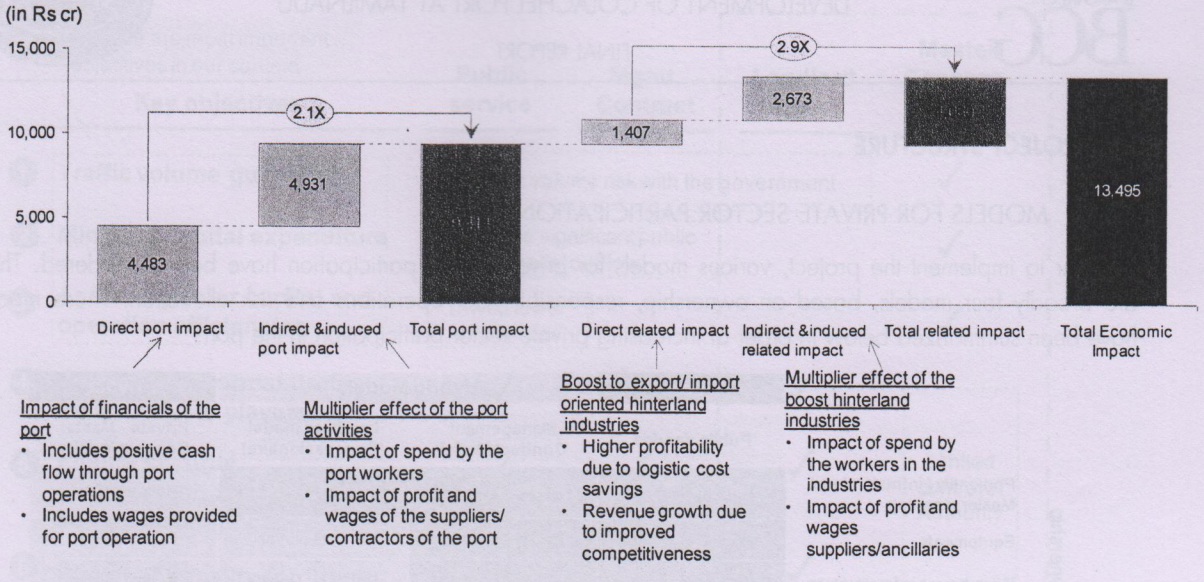
Colachel port will capture a substantial share of India's trans-shipment cargo which today gets trans-shipped in the foreign ports. It will also capture traffic from other countries in the region specially traffic from the Indian sub-continent countries. The cargo handling revenue generated by the port in 2030 is ~Rs 4,500 crore (it excludes revenue from traffic shifted from other Indian ports to Colachel); this is accounted as the direct economic impact of the port.

Additionally, the port operations will benefit the ancillary port based businesses including inland transportation businesses in the region. The port will also employ a large pool of employees for port operations. Impact on economy due to growth of ancillary industries and increased spending by port employees is accounted for in indirect impact of the port. This is estimated through an economic multiplier of 2.1. The economic multiplier is calculated based on economic impact studies for different port projects (E.g. Economic Impacts study of ports of Hamburg and Le Havre, Port of Auckland, South Carolina State Port etc.) and corrections made for the Indian context through BCG-TYPSA benchmarks. The indirect economic impact of the port is estimated to be ~ Rs 4900 crore in 2030.

13.4.2. Economic impact through businesses that would benefit from the port

The Colachel port will shift hinterland cargo which is currently getting trans-shipped in Colombo to direct gateway cargo through Colachel. This is primarily due to elimination of one leg of cargo handling in Colombo. This will reduce the logistics cost of the importers and exporters in the hinterland area (the chapter on traffic study discusses this in details). The logistics cost reduction accounts for Rs ~ 1,400 cr of savings for the related businesses in 2030. This will make them more competitive in the export markets and hence help grow their businesses further. It is estimated that the related industries will receive a profit boost of ~ Rs 1,500 cr (inclusive of wages, assuming a cost elasticity of trade of 0.8) in 2030. This further will have an indirect impact on the economy of ~ Rs 2,600 cr in 2030 (assuming an economic multiplier of 2.9 based on economic impact studies in India including Quantifying the Income and Employment Multipliers for Mumbai Region by National Council of Applied Economic Research)

The total economic impact of the project is estimated at ~Rs 13,500 cr in 2030. The following figure summarises the economic impact for the Colachel port project. Please note, this is an estimate arrived at on the basis of secondary studies; a further social-economic impact assessment study can be done for refining the economic impact estimates.



Source: BCG Analysis, Economic impact study of European ports – Hamburg and Le Havre, Economic Impact study of industries in Mah arashtra

Figure 150: Economic impact of the port project

14. PROJECT STRUCTURE

14.1. MODELS FOR PRIVATE SECTOR PARTICIPATION

In order to implement the project, various models for private sector participation have been considered. There are broadly four models, based on ownership, responsibility for operations and risk allocation. These models have been summarized below in order of increasing private sector participation in the port.

		Public	Hybrid Models		Private
		Public service	Management Contract Model	Landlord model (Concessionaire)	Private - Master Concessionaire
Ownership	Port entity / infrastructure/ Master planning	Public Authority	Public Authority	Public Authority	Private player
	Equipments	Public Authority	Public Authority	Private player	Private player
	Ware-house infrastructure	Public Authority	Public Authority	Public or Private	Private player
	Connectivity infrastructure	Public Authority	Public Authority	Public Authority	Public or Private
Operations	Channel and access (dredging, navigation)	Public Authority	Public Authority	Public Authority	Private player
	Terminal operations	Public Authority	Private player	Private Player	Private player
	Warehouse mgmt.	Public Authority	Public or Private	Public or Private	Private player
Risks	Capital Risk	Public Authority	Public Authority	Shared	Private player
	Volume Risk	Public Authority	Public Authority	Public or Private	Private player
	Pricing Risk	Public Authority	Public Authority	Public or Private	Private player
		Dominant model pre 80s	Few examples in 80's and 90's	Popular model in recent years	Selectively used

Figure 151: Models for private sector participation

In recent times, landlord model has been the most popular model. Authorities have also used Master Concessionaire model in cases where the role of a strong port operator is important in achieving success either to build traffic or achieve high levels of productivity.

The next section talks about the key objectives that have been considered in order to arrive at suitable project structure models for Enayam.

14.2. KEY OBJECTIVES

While selecting a suitable model, it is important to balance the objectives of the government and mitigate the risks of private players. The figure below discusses the common priority objectives of the government and how these are fulfilled in each of the PPP model.

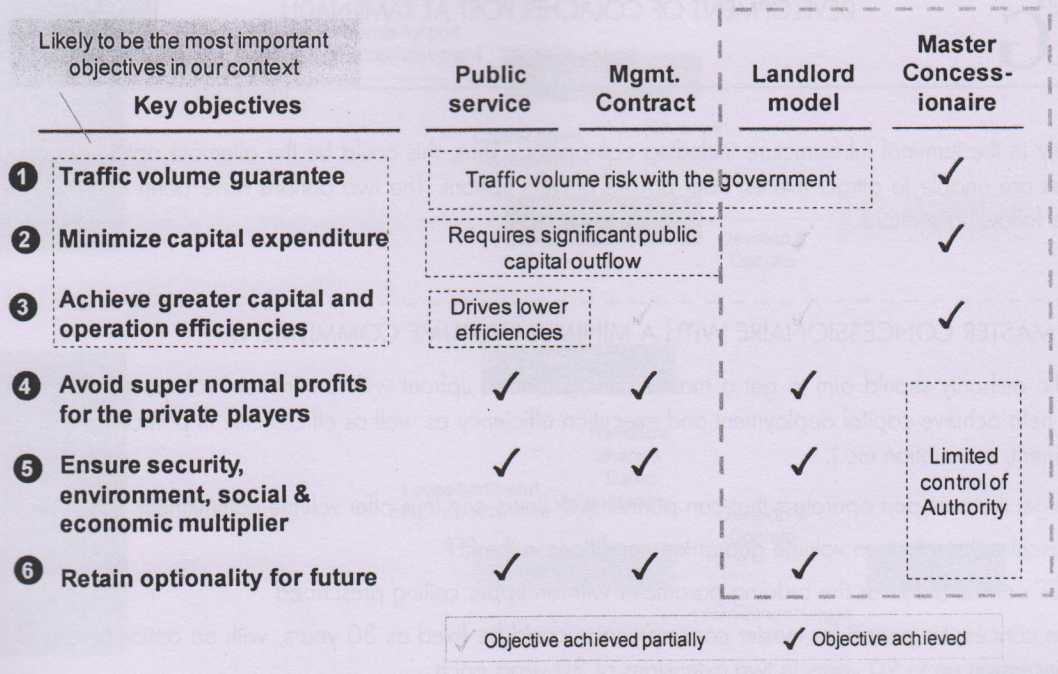


Figure 152: Key objectives of government

Given, securing volume is a critical success factor for Enayam, Master Concessionaire model will be an attractive option as the project structure. Though, as described in the figure below, Green field projects typically have very high risks associated with them and thus often find it difficult to attract private players.

Investor considerations

Investors evaluate assets basis the risk / return profile and the total capital outflow required

Higher the capital outflow, greater is the sensitivity to risks

Risks evaluated on many dimensions

- Volume risks
- Price Risks
- Land acquisition risks
- Risks of delayed connectivity/ Infra development

Green field projects carry significant risks

	Green field	Mature Asset
Volume risk	High	Low
Pricing Risk	High	Low
Land Acquisition risk	High	Low
Logistic project risks	High	Low
Regulatory risks	High	Medium

Figure 153: Investor considerations

In order to attract private investors, it is important to mitigate the capital and volume risk associated with this greenfield project. The land lord model alleviates the capital risk, land acquisition and risks of delayed connectivity, since the port infrastructure and connectivity is developed by the authority and the terminal operators

invest only in the terminal infrastructure including equipment. Thus, this could be the alternate option in case the authorities are unable to attract interest from private players upfront. The two options have been further detailed out in the following sections.

14.3. MASTER CONCESSIONAIRE WITH A MINIMUM VOLUME COMMITMENT

The public authority should aim to get a master concessionaire upfront with a minimum volume guarantee. This will also help achieve capital deployment and execution efficiency as well as efficiencies in port operations (yard management, evacuation etc.).

- Target liners or port operators that can partner with liners and thus offer volume commitment
- Prescribe the minimum volume guarantee conditions in the RFP
- VGF can be made as the bidding parameter with an upper ceiling prescribed
- The concession period for master concessionaire could be fixed as 30 years, with an option to extend the concession up to 90 years in two extensions of 30 years each

Given this is a Greenfield project with high perceived risks, the public authority will have to give firm assurance / commitment on the following, in order to attract target partners

- Firm assurance on feeder network availability (potentially through Cabotage law relaxation)
- Timely completion of connectivity projects with some financial compensation in case of delays
- Financial incentives in order to bring equity IRR to 16% -18% (potentially as VGF)
- Assurance on potential tax/ duty exemptions, required for setting competitive tariffs

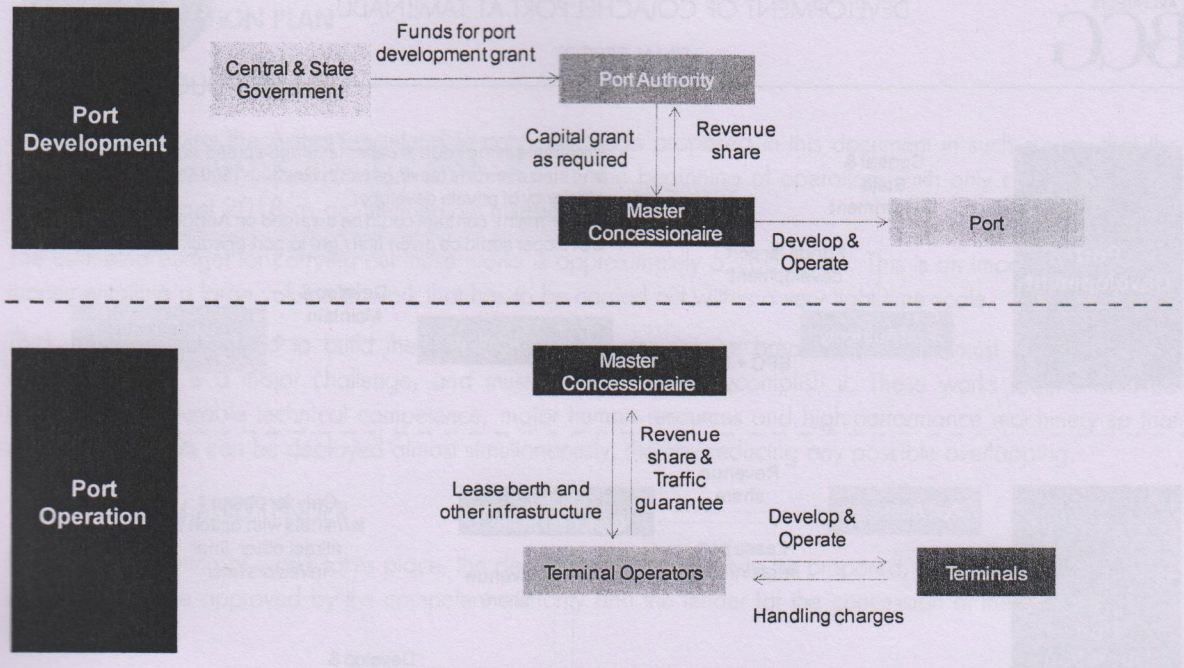


Figure 154: Master Concessionaire Model

It is advisable that the authority engages with a few operators and main liners to understand their risk appetite and willingness to invest at the development stage. In case, the interest is not high despite the above mentioned assurances, the government can consider Landlord model as described below.

14.4. LANDLORD MODEL AND PRIVATE TERMINAL CONCESSIONS

In case it appears difficult to attract target investors with volume commitment upfront, the government may have to develop the port themselves to reduce the perception of risk. The authorities should engage with liners and try to get MoU / firm assurances of investment in the terminal if and when the port is developed.

Further, to achieve capital and execution efficiencies, an EPC and maintenance contract for development should be considered. The authority should also offer a first right of refusal on terminal 1 concession to the bidder for EPC contract. This may help attract consortiums with participation of leading port operator / shipping liner companies. This will then ensure that the expert inputs from the port operators / liners are available and incorporated in the development phase. Also, the authorities will be able to get the operators / liners involved upfront in the project.

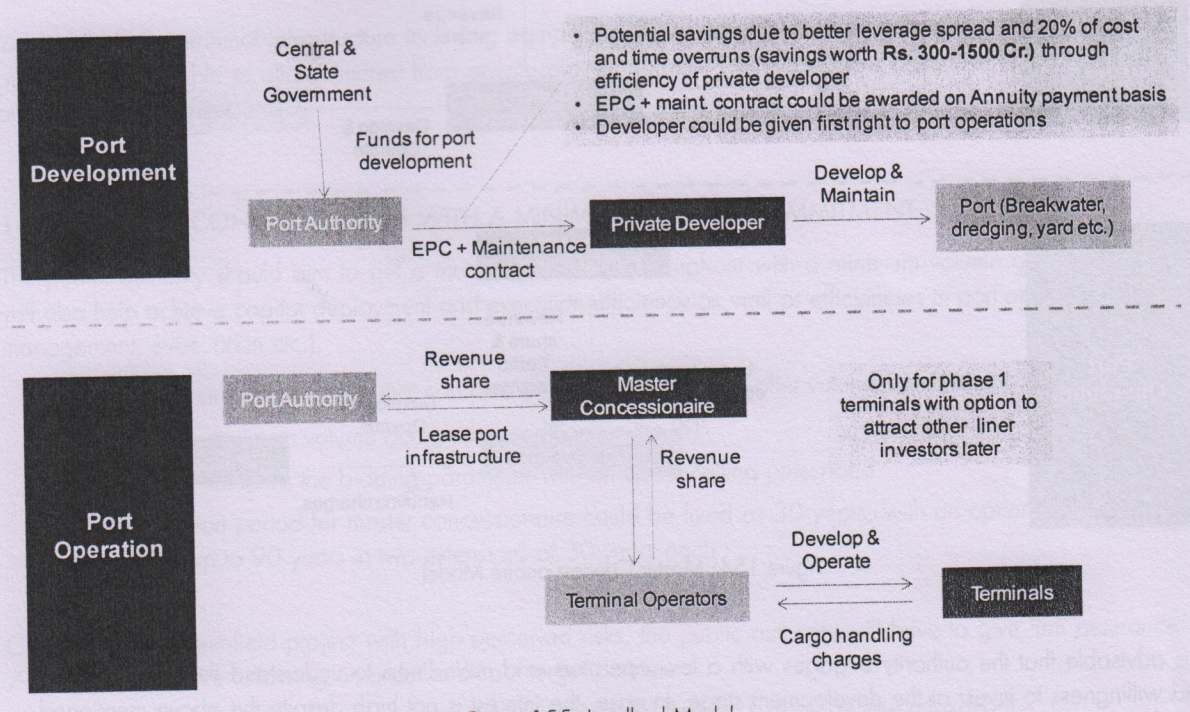


Figure 155: Landlord Model

14.5. FEASIBILITY OF COLACHEL AS A SATELLITE PORT TO VOCPT

Colachel Port can either be, developed and implemented by VOCPT as a satellite port, or by a new authority as an independent port. It is advisable to implement Colachel Port project as an independent port under a new public authority, in order to mitigate risk of conflict of interest and achieve global productivity levels as a greenfield port. If VOCPT considers it suitable they may invest equity in the new port authority, along with Ministry and State Government.

15. IMPLEMENTATION PLAN

15.1. INTRODUCTION

It is well known that the Authorities intend to carry out works proposed in this document in such a way that the terminal should be fully operational by 2018. Besides, the beginning of operations with only one berth should occur before August 2018 as an intermediate milestone.

The estimated budget for carrying out these works is approximately 5,500 crores. This is an important amount of money entailing a large volume of work that has to be carried out within a very tight time scale.

Thus, companies selected to build the terminal and to carry out the breakwater works must understand and assume that this is a major challenge, and must be capable to accomplish it. These works require detailed planning, considerable technical competence, major human resources and high-performance machinery so that different work units can be deployed almost simultaneously, thereby reducing any possible overlapping.

15.2. DESIGN AND TENDER

Before the beginning of works takes place, the design documents have to be prepared, the environmental impact process has to be approved by the competent authority and the tender for the concession of the terminal has to be drawn up.

Within the design process to be done, the following surveys and studies should be included:

- **Field surveys**: A bathymetric and geophysical survey, including side scan sonar and a sub-bottom profiler should be made on an area large enough to include all expected phases and approach channel. It should be completed by a geotechnical survey including boreholes, laboratory tests and soil sampling. Besides, a detailed topographic survey should be carried out at the port area and at the related connectivity corridors.
- **Models and studies**: Numerical models should be developed on ship manoeuvring, sediment transportation and wave tranquillity (updating and upgrading the study included in this report). Also, scale models could be done to assess and optimize the design.
- **Engineering works**: This should include an optimization on breakwaters design and basic design on berth structures, pavements, foundations, buildings, networks and utilities. Regarding connectivity, a deeper study on the proposed railway and road linkages should be done, including optimization of alignments, traffic study, and design of drainage, structures, pavements, signalling, etc.
- **Environmental and social impact assessment**: A Comprehensive EsIA Report and a Land Acquisition Report should be developed in order to identify the impacts on private and public properties of the project.

A 6 month period for both the design and tender process is expected, although some overlap can be expected too.

15.3. CONSTRUCTION SCHEDULE

The construction works will begin by setting up the site installations, determining where the offices should be placed and where machinery and materials should be stored (e.g. concrete breakwater armour units, rip-rap,

reinforcing bars etc.). This zone should make it possible for the different work units to carry out their work reducing distance for transportation and increasing machinery performance. The timeline presented here implies dividing the building work into four parts:

- **Maritime works** (26 months): Breakwaters, rubble mound and berths.

  The first task is the breakwater works (18 months): this begins by building the main rubble mound breakwater that runs for the first 1,300 m and is then vertical for another 2,500 m. During this period, the rubble mound breakwater to protect the landfill at the south-eastern part of the terminal will also be carried out.

  Both the main breakwater and the east breakwater will be carried out in advance using land-based and maritime means. The vertical breakwater comprises reinforced concrete caissons that will be built by maritime means (a floating shipyard for caissons) in a zone that has a sufficient draught or in a prepared land area. Then, they will be floated to where they are to be put in place. Before they are anchored, the area will be prepared by creating the rip-rap and the gravel bedding layers. Once they have been submerged, the cells are filled with granular material and the crowning slab is put in place. The breakwater work ends with the creation of the protective breakwater crown wall.

  The dredging work begins by digging the trench for the bedding layer of the vertical breakwater. As soon as the mound breakwater has been built and provides sufficient protection, work should begin on the inner basin (multi-purpose and ancillary berths) up to level 15.00 and subsequently the outer basin up to level 20.00. The material that is dredged up should be pumped into the zone where the future terminal is to be situated, so that it can be used as landfill.

  The dredging work can be affected by the monsoon season which falls between the months of May to September. During this period, the south west swell implies higher waves, which in turn means a reduction in the performance of the dredging equipment. It is estimated that the dredging works should take around 17 months.

  In much the same way, the piers (container, multi-purpose and ancillary berths) shall begin to be built as the breakwater progresses. There is a 16-month deadline. This work shall be carried out using maritime means (pontoons or jack-up barges), and land-based means once the rubble mound bunds have been created. The piles will be put in place first, then the sloping rip-rap protection and finally the reinforced concrete superstructure (beams and slabs).

- **Land works** (16 months): Yards, networks, utilities and buildings.

  Work on the terminal will be carried out during this phase, beginning with the work to consolidate the landfill and the creation of the walkway on which paving blocks will be laid. These tasks will take 12 months.

  Thereafter, work will be carried out on the terminal access facilities (gates), on the internal railway (8 months) and also on the installations that serve the terminal and the docks (electricity, lighting and water supply, fire fighting elements, bunkering, sewage and communications).

  It is estimated that it will take 10 months to construct the buildings (port management buildings and operation and maintenance buildings). They will be built in parallel to the aforementioned tasks.

- **Equipment** (7 months): STS Cranes (quay), A-RMG Cranes (yard), RMG Cranes (rail yard) and others.

  The operating equipment for the berthing line and for the yard will be purchased and installed gradually, as the berthing line and the container yard becomes operational. As stated above, the first container berth should be operational on August 2018. This means around half the container handling equipment must be operational by this date.

- **Connectivity** (25 months): Road and railway construction works

  The road and railway providing access to the terminal will constructed continuously throughout the 25 months that it takes to carry out the works. They should be operational on August 2018 to allow gateway traffic entering and leaving the port easily.

The schedule included in next page shows the times and relations of each task and subtasks explained above.

Although the design of Phase 2 and 3 follows the forecasted traffic the construction of facilities for these Phases should be carried out when the existing ones are near congestion so that the productivity and profitability of the port can be optimized.

Id
Nombre de tarea
2016
2017
2018
07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12
1 COLACHEL PORT IMPLEMENTATION SCHEDULE
2 DESIGN AND TENDER PROCESS
3 Project design
4 Tender process
5 CONSTRUCTION
6 PRELIMINARIES
7 Surveys and studies
8 Site Clearance, site offices, fencing
9 Temporary berthing facilities
10 BREAKWATERS
11 Rubble mound breakwater
12 East breakwater
13 Vertical breakwater
14 DREDGING AND RECLAMATION
15 Reclamation bunds
16 Dredging of sand and pumping into reclam. area
17 Ground improvement
18 BERTHS
19 Ancillary berth
20 Multipurpose berth
21 Container berth
22 YARDS
23 Container Yard
24 General Services and Multipurpose Area
25 NETWORKS AND UTILITIES
26 Gates
27 Internal railway
28 Electric supply and lighting
29 Water supply and firefigthing
30 Water sewage and drainage
31 Bunkering
32 Communications and IT
33 Aids to navigations
34 BUILDINGS
35 Port Management Buildings
36 Operation and maintenance buildings
37 EQUIPMENT
38 STS Cranes (Quay)
39 A-RMG Cranes (Yard)
40 RMG Cranes (Rail yard)
41 Others (SCs, RSs, Tractors...)
42 CONNECTIVITY
43 Road construction works
44 Railway construction works

16. MANAGEMENT AND SUPERVISION DURING CONSTRUCTION

As mentioned above, the execution of the works described in this report in such a short time requires a great effort on planning and monitoring of works, as well as great technical expertise not only by the contractor, but also by the project management and supervision consultancy.

The proposed team to carry out Project Management is divided as follows:

- Project Manager: This position will coordinate the construction works and will deal not only with the contractor and supervision, but also with the Authorities involved in the project (Ministries, TNMB, Collectorate, Municipalities...).
- Project Management Staff: A group of specialists will be supporting the Project Manager on his duties. Contracts, planning, costs and quality control specialists will be required, as well as a document controller and other support and administration staff.

Regarding Supervision of works, the proposed team is divided in three sections for each of the suggested construction contracts; Marine works, land works and rail & road works. The three teams will be leaded by resident engineers, who will share a group of technical senior advisors on each main engineering field: The

- Marine works: In addition to the resident engineer, four assistant engineers (dredging, reclamation, breakwaters and quay works) will be included. Some other technical staff (QA/QC and HSE superintendents, land and marine surveyors and site inspectors) and other support staff will form part of the team.
- Land works: This team follows the same structure. Again, four assistant engineers will be needed (pavements, utilities, buildings and networks), supported by technical and administration staff.
- Connectivity works (Rail and Road). Earthworks, pavements, structures, tracks and networks & utilities assistant engineers will form part of this team.
- Technical senior advisors: A group of high degree of expertise engineers and specialists will be helping the supervision teams on any technical decision or issue. This team will guarantee all decisions are made with the required level of analysis.

Figure 156 shows the organization of the Management and Supervision team:

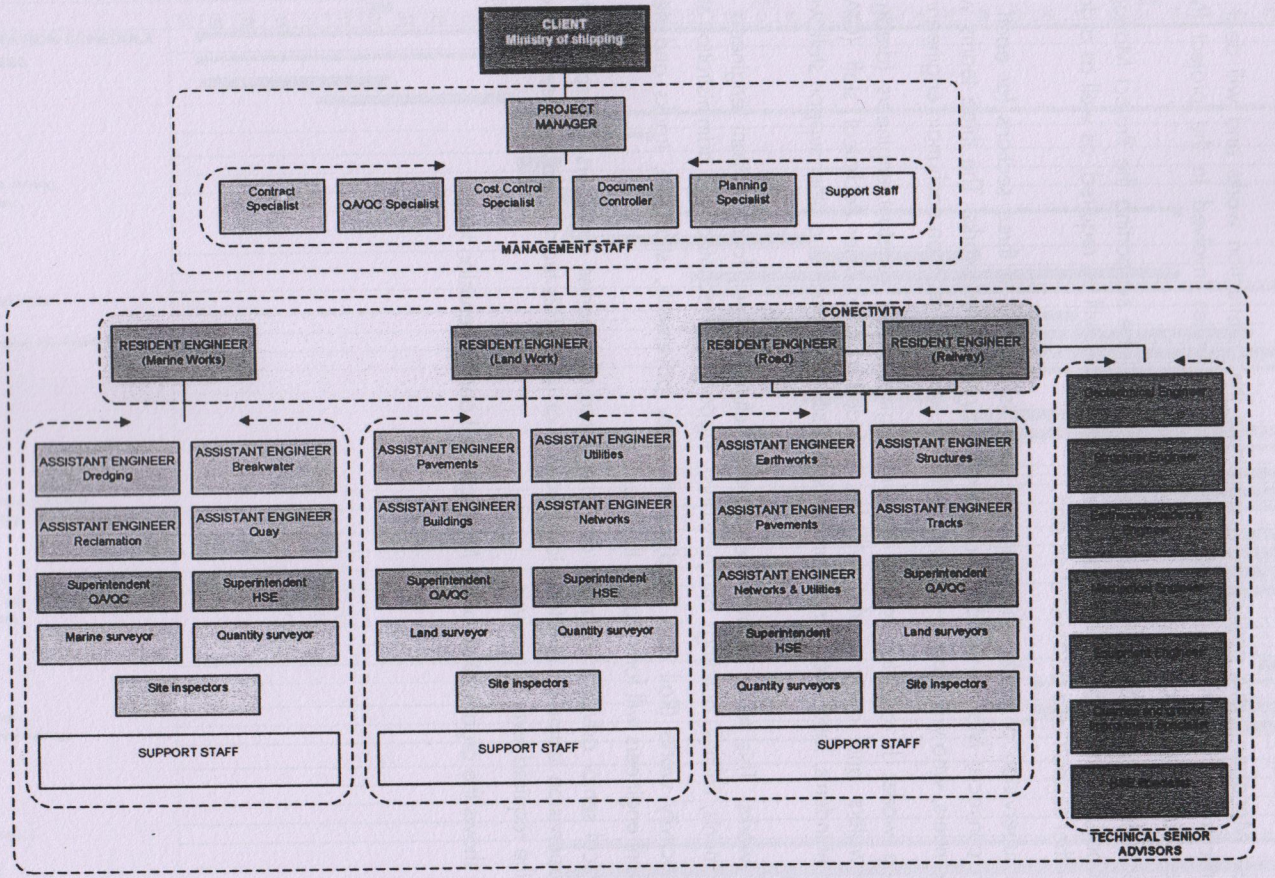


Figure 156: Management and supervision staff chart

17. RISK ANALYSIS

17.1. LEGAL AND CONTRACTUAL RISKS

Types of risk	Risk description and mitigation
Risk of disputes	With private sector participation in project development and operation, conflicts may arise between private players and government. The concession agreement should be balanced and a robust dispute resolution mechanism should be incorporated
Change in law	An unexpected change in current legal / regulatory / policy regime in port sector can have a material adverse impact on the project. Any policy formulation should keep this in mind and the contractual arrangement should suitably address this possibility.
Delays in project development	▪ The Project contracts should provide for significant penalties for such delay ▪ Public authority may assist the developer in obtaining consents and clearances from governmental agencies.
Funding risk	▪ The port development is dependent of availability of funds. It is vital that the project and contractual arrangement be structured to make the project attractive to banks and equity investors. ▪ Depending on the project development option, funding risk has to be borne by the private player.
Project completion risk	▪ Concession Agreement should address the issues related to Concessionaire's default in this case. ▪ Strict project monitoring by the Authority/Independent Consultant is required. ▪ EPC contracts for mandatory works may be structured as a fixed-price and fixed-schedule contract, with stiff liquidated damages for non-compliance. Performance guarantees may also be stipulated. ▪ Insurance package involving Contractors All Risk, Third Party Liability, and Advance Loss of Profit may be taken during the construction period
Delay in land acquisition	As this is a green field project, land acquisition would be required for connectivity and other surrounding industries. Public authority being the owner should take responsibility for acquiring land for project development.
Interest rate risk	These are factors affecting the availability and cost of funds. To mitigate this risk, hedging instruments or fixed rate loans to be used.

Inflation risk	The possibility that the actual inflation rate will exceed the projected inflation rate. This risk is to be borne by the infrastructure developer, whether government or private player.

Table 59: Legal and contractual risks

17.2. REVENUE RISKS

Types of risk	Risk description and mitigation
Risk of traffic volumes	Traffic volumes projected for the port (which forms the basis of capacity planning of the port) is subjective to Enayam port being competitive to major trans-shipment hubs on key metrics like productivity, availability of feeder network etc. It is necessary that all the key imperatives as mentioned in the Key Success Factor chapter are implemented on ground
Risk of cost pressure on tariffs	Tariff structure of Enayam would need to be competitive with major trans-shipment hubs. Any escalation of costs due to increase in labour rates etc. can make it difficult to maintain competitive tariffs. Strong cost control mechanisms including efficient manning, procurement etc. should be put in place from the onset.
Risk of price war	Competing trans-shipment hubs in the region may .respond in price war once they start losing traffic to Enayam. Enayam should focus on getting into long term contracts with shipping operators and try to attract investments from them .
Risk of new competitor taking share of traffic	New competing port in the region may take away part of Colachel's share. For Indian competitors, GoI must measure impact on Colachel's traffic before commissioning new container hub in the region.

Table 60: Revenue risks

17.3. TECHNICAL AND ENVIRONMENTAL RISKS

Types of risk	Risk description and mitigation
Risk of flood	Tamil Nadu is a high rainfall region that experiences localised flooding due to heavy rainfall especially during the SW monsoon, resulting damage to life and property. The Colachel district comes in high risk zone. Since a number villages in the district are *flood affected areas*. The project can be affected by flash floods, which occurs on the coast when high intensity rainfalls in a localised area happens over a short period of time, in

	combination with high and spring tide. Most of the flooding problem in the area is due to poor or choked drainage conditions. Some measures to avoid this risk are conducting a flood route analysis, installation of water pumping stations, Installation of warning systems (alarm, audio-visual public address system, etc.) and coordination with State and district level disaster management authorities.
Risk of cyclone or wind storm	Tamil Nadu is also vulnerable to cyclones and experiences high winds due to the westward movement of the cyclonic storms crossing the State coast. A great part of the State falls in high wind speed areas and the Colachel district falls under medium level risk zone. Measures to reduce risk are designing port facilities such as buildings, transmission systems, storage, etc. Taking this risk into account. Coordination with State and district level disaster management authorities will be useful too.
Coastal Hazards	Coastal Hazards such as erosion, storm surge, tidal waves, swell waves, etc.; have the potential to harm the people, property and the environment. Erosion control structures in critical areas, shoreline protection walls and coordination with other authorities are measures to be taken.
Tsunami	The Tsunami was one of the most devastating disasters in modern history. In 2004, Indian Ocean Tsunami struck the 11 countries and killing more than 225,000 people. In Colachel the tsunami waves hit the District, which resulting in the death of a large number of persons and damaged houses. Safety measures in accordance with mathematical study of Tsunami waves height, tsunami warning systems and coordination are measures to reduce this risk.
Ship mishaps and vessel accidents	During towing and berthing of the ships, owing to natural calamity or piloting errors, there can be remote possibility of mishap of one to one ship collusion or ship hitting against the wharf or ship getting grounded. During such events, the ship may sink or break. Direct control and management of the movement, position, timing and manner in which a vessel may enter and leave the port waters, maintenance of safe and navigable channels and coordination of vessel movements are the best measures to reduce this risk.
Oil Spillage	The risk of accidental spillage of oil from ship and cargo handling pose a threat to marine and land based resources. This requires careful and

	advance planning to ensure that the impact of the oil spill on environment is minimised or contained. Proactive measures such as display of zero tolerance information boards for all kinds of pollution in all important areas of Operation is expected to lead to extra care with regards to pollution.
Fire/explosion	There is risk of fire or explosion due to the electrical fault, handling, transportation and use of petrochemical and flammable products. Recommendations that may be implemented are installation of Audio-Visual public address system to alert the personnel working in the terminal, smoke or fire detectors will be placed at critical locations in the terminal, fire alarm systems, periodic inspection and maintenance and adequate measures in the safety system design, Personal Protective Equipment (PPE) such as masks, respirators etc. may be provided to the workers.
Hazardous Material handling	Hazardous materials have adverse effect on public health and safety as well as environment due to the release or leakage of hazardous materials. Hazardous materials that may be stored, transported and handled within the Port area are classified by the following: (Hazardous Waste Management handling rules 1998 (amended)

18. CONCLUSION

This rapid techno-economic feasibility report discusses five key aspects of the port: 1) technical feasibility, 2) traffic potential, 3) financial viability, 4) key imperatives for the success of the port and 5) the way forward.

Technical feasibility

After studying and comparing four locations, Enayam has been chosen as the most suitable location. Further, detailed port layout, design and cost estimation for Phase 1 of the port has been undertaken to assess the technical feasibility of the port. From the technical point of view, the port is highly feasible due to the site conditions and the proposed design. These characteristics are listed below:

a) Site conditions:

- Enough natural depth. This helps the port to have high draft ad to be designed without long approach channels.
- Proximity to main shipping routes.
- Low population on the vicinity of the port. This allows the port to be well connected to main transport networks, and industries to be settled near the port.
- Enough available shoreline to expand the port easily.
- Geotechnical conditions are expected to be favourable, being the soil easy to dredge and with enough bearing capacity for foundations.

b) Design conditions

- Terminals have been designed with a high productivity in a semi-automated operation mode. Productivity can reach 2,000 TEU per meter and per year.
- Permeability between port and land is very high.
- The port layout gives very low downtime for container berths (less than 2 days per year).
- Taking advantage of available shoreline, an expandable port has been designed, with an approx. construction cost of Rs. 19,300 Crores for 3 phases. Eastward expansions can quadruplicate the container handling capacity, reaching 8 million TEUs per year if all shoreline is used.
- Further, this capacity can be expanded to 16 million TEUs by expanding the port seawards and taking advantage of the vertical breakwater to use it as a berth line.

Traffic Potential

A comprehensive traffic and market study was conducted to determine the traffic potential of the port. It has been estimated that the port has a potential of 6.8 Mn TEUs container traffic (2.9 Mn TEUs gateway and 3.9 Mn TEUs trans-shipment) and 6.6 Mn Tonnes of Coal traffic in 2030.

Financial Viability

The financial viability of the project has been assessed by developing a discounted cash flow model using the capital cost inputs from technical study, revenue stream from traffic and operating cost based on port benchmarks. The tariff structure has been evolved to make the port competitive with Colombo Port. With a project IRR of 10.8% and equity IRR 11%, it has been estimated that the project would require capital support from the government in the form of 20-30% viability gap funding to make the project financial feasible at a target equity IRR of 16-18%.

Key Imperatives for the success of the port

Discussions with all leading shipping liners, leading Indian and International port operators have been conducted and other major container ports in the world have been studied to understand the 'key imperatives' for Enayam. While, these key success factors have been analysed with the view of establishing a large competitive trans-shipment port, the same factors are also applicable for attracting gateway container traffic.

Basis these discussions, the following imperatives have been identified for ensuring success:

1. Deep draft
2. Proximity to main shipping routes
3. Scale of capacity and sufficient gateway traffic
4. Sufficient feeder capacity and cost efficient network
5. Competitive port related logistics cost
6. Efficient customs approval process
7. Hinterland road and rail connectivity
8. Cheap bunkering services

The location and design of Enayam already meet the requirement of deep draft, proximity to main shipping routes, sufficient scale of capacity and potential of gateway traffic. Government needs to take steps towards meeting the other key imperatives for the success of the project.

Way forward

In order to decide the way forward on project structure and investment plan, it is important to keep the key imperatives in mind. One of the key imperatives for project success will be to get the right partner on board. Securing a large liner as an anchor investor will be crucial in getting volumes and achieving critical scale of operations. Also, given the need to achieve high productivity, the port should be operated by an experienced and best in class port operator. At the same time, one of the other big objectives for Government will be to optimize financials and minimize capital cost for the project.

It is advisable that the authority engages with a few operators and main liner to understand their risk appetite and willingness to invest at the development stage. If they are willing, the master concessionaire model can be considered. In case, the interest is not high due to perception of high execution risks, the government can consider the landlord model.

19. DRAWINGS