MEASURING EFFICIENCY OF INDIAN MAJOR PORTS FOR DEVELOPMENT OF PERFORMANCE INDEX

By

NOOKALA BHANU PRAKASH

COLLEGE OF MANAGEMENT AND ECONOMICS STUDIES
(DEPARTMENT OF ACCOUNTING AND FINANCE)

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Under the Guidance of

Guide
Dr. Tarun Dhingra
Associate Professor & Head
Department of Strategic Management,
CoMES, UPES

Co-Guide
Dr. T. Bangar Raju
Professor & Head
Department of Transportation,
CoMES, UPES

External Co-Guide
Dr. B.V.R. Rao
Academic
Coordinator
IMU, Visakhapatnam

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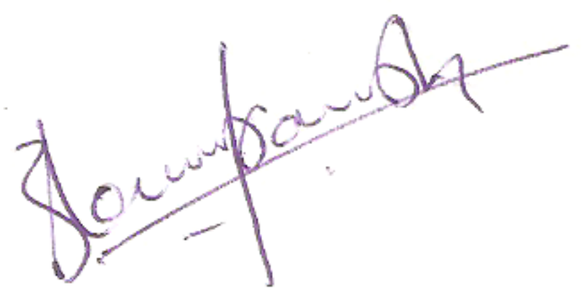
DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.



N. BHANU PRAKASH

THESIS COMPLETION CERTIFICATE

This is to certify that the thesis on "**Measuring Efficiency of Indian Major Ports for Development of Performance Index**" by N. Bhanu Prakash in partial completion of the requirements for the award of the Degree of Doctor of Philosophy (Management) is an original work carried out by him under out joint supervision and guidance.

It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other University.

Guide	Co-Guide	External Co-Guide
(Dr. Tarun Dhingra)	**(Dr. T.Bangar Raju)**	**(Dr. B.V. Ramalingeswara Rao)**

Executive Summary

The growth trends of Indian economy have attracted business investments resulted in growth of trade volumes. With the increase in trade volume shipping has become the natural option for foreign trade as it has advantages of being safe and cost effective in movement of heavy cargo between long distance destinations. And the entire shipping business is heavily depended on existence of vibrant ports that enable smooth connectivity between the sea and land. Existence of efficient ports that maintain high level of infrastructural setup results in swiftness in handling cargo. Thus, the working of port sector has been a matter of interest for both the governments and industry alike. Sea ports have been a source of international trade from ancient times when the European merchants traded with Asian counterparts. The discoveries of sea routes and trade destinations have given opportunity for evolution of ports across the world, including India, which has ably helped exchange of goods across the world.

Growing demand of port sector mandated them to perform better in the competitive markets. This has led to a focus on evolution of port performance indicators proposed by UNCTAD. Soon, experts in industry as well as researchers working on port performance have started assessing efficiency and productivity of world ports on the basis of available indicators. On the other hand, privatisation has been considered as a viable mode to improve port efficiency and was started during the second half of 20th century by most countries. Advent of private projects has resulted in efficiency gains in areas of service provisions, operations, and financials at most of these ports. The process of private participation at major ports in India has initiated during the middle of 1990's with an aim to improve their efficiencies. However, it is imperative to know if the ports have improved in their efficiency and productivity levels due to privatisation. Taking as a cue this research framed the following **business problem**.

> Reforms in the form of private participation at major ports of India were started in 1995-96 (Maritime Agenda 2020) to improve their performance. In spite of the reform program, the port sector is still struggling with lower efficiencies leading to business losses in industries that are directly and indirectly depended on it.

An attempt to gather available literature on port efficiency and productivity has initiated with a few key words such as 'port performance', 'port efficiency', 'port productivity', 'port reforms', etc. was made. A total of over 250 research works from over 25 journals of

international repute were gathered. The gathered research works are segregated broadly into themes of ‘port performance indicators’, ‘port efficiency – World ports’, ‘port efficiency – Indian ports’, ‘port productivity – World ports’, ‘port productivity – Indian ports’, ‘port sector reforms’. The review of literature brought out certain outcomes that port performance can be assessed through operating and financial indicators with a backdrop of physical infrastructure at individual port; research studies assessing port efficiency either considered limited timeframes or limited number of variables. Existing studies also reveal that for improvement in efficiency and productivity, privatisation need to be supported with strong regulatory and economic policies;. The overall gaps traced from literature review covering themes include, existence of limited research works covering holistic performance of ports and non-existence of studies covering the reform period.

From the above gaps, the following research problem, research questions, and research objectives are derived:

Research Problem:

Although in existing literature port performance has been measured for shorter timeframes with limited number of operational and financial variables but post-reform trends on port efficiency and productivity is not known.

Research questions:

1. What is the level of overall efficiency improvement achieved by major ports during the post reform period?

2. What are the trends in productivity improvements at major ports in post reform scenario?

Research Objectives:

1. To study the post reform efficiency improvements attained by major ports of India.

2. To develop an index representing operational, financial, and physical parameters of major ports of India.

Selection of methodology holds key for precision in analysis. This research has selected 'Postpositivism Approach' for the study and considering the temporal orientation of research question 'Explanatory Backward Looking' method is selected for the study. Two of the research questions focus on measuring of 'efficiency' and 'productivity' at ports are assessed with non-parametric techniques of DEA and MPI. Using DEA technique the research measured efficiencies under Constant Returns to Scale and Variable Returns to Scale. To measure the total factor productivity, MPI technique is used. This technique has advantage of measuring overall productivity by considering technical and technological changes at the ports.

Assessment of port efficiency and productivity for total period is done by segregating the entire period of 19 years as 1995-96 to 2006-07 (pre commencement of Ennore Port) and 2006-07 to 2013-14 (post commencement of Ennore port). The results show that technological investments resulting in mechanisation of ports has greater influence in improving efficiency and productivity. For better productivity technological improvements have been found more important than technical improvements. The study also found that older ports depending on manual procedures struggle in improving efficiency and productivity.

LIST OF ABBREVIATIONS:

ATAT	Average Turnaround Time
BCC	Banker, Charnes, Cooper
BOT	Build Operate Transfer
BTO	Berth Throughput
CAGR	Compounded Annual Growth Rate
CbPT	Chidambaranar Port Trust
CCR	Charnes, Cooper, & Rohdes
ChPT	Chennai Port Trust
CPT	Cochin Port Trust
CRS	Constant Returns to Scale
DBFOT	Design Build Finance Operate Transfer
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EBIT	Earning Before Income Tax
EBITDA	Earnings Before Interest Tax Depreciation and Amortisation
EMS	European Maritime Safety
EPC	Ennore Port Trust
FDI	Foreign Direct Investment
FEM	Fixed Effect Model
GATT	General Agreement of Tariff and Trade
GCB	General cum Cargo Berth
GDP	Gross Domestic Product
GOI	Government of India
GRT	Gross Registered Tonnage
GT	Gross Tonnage
HDC	Haldia Dock Complex
IMF	International Monetary Fund
IPA	Indian Port Association
ISPS	International Ship and Port Security Convention
JNPT	Jawaharlal Nehru Port Trust

KDS	Kolkata Dock System
KHPT	Kolkata Haldia Port Trust
Kms	Kilo Meters
KPT	Kandla Port Trust
LLKM	Local Linear Kernal Model
LP	Linear Programming
MbPT	Mumbai Port Trust
MGPT	Mormugao Port Trust
MoS	Ministry of Shipping
MPI	Malmquist Productivity Index
MT	Million Tons
Mtrs	Meters
NEP	Normalised Pairwise Estimation
NH	National Highway
NMDP	National Maritime Development Program
NMPT	New Mangalore Port Trust
NOB	Number of Berths
NOC	Number of Cranes
NOV	Number of Vessel-calls
NRT	Net Registered Tonnage
OHSAS	Occupational Health and Safety Standard
OITTO	Operating Income to Total Output
OLS	Ordinary Least Square
OR	Operations Research
PCA	Principle Component Analysis
PEC	Pure Efficiency Change
PFP	Partial Factor Productivity
PMS	Performance Management System
PPP	Public Private Partnership
PPT	Paradip Port Trust
QMS	Quality Management System
RDEA	Recursive Data Envelopment Analysis

RMGC	Rail Mount Gantry Crane
RO	Research Objective
ROA	Return on Assets
ROE	Return on Equity
RPE	Revenue Per Employee
RTGs	Rubber Tyre Gantry
SEC	Scale Efficiency Change
SEM	Structured Equation Model
SFA	Stochastic Frontier Analysis
TAMP	Tariff Authority for Major Ports
TC	Technological Change
TEC	Technical Efficiency Change
TEUs	Twenty Equivalent Units
TFP	Total Factor Productivity
TNEB	Tamil Nadu Electricity Board
Tp	Throughput
TSLS	Two Stage Least Square
Typ	Tons per year
UN	United Nations
UNCTAD	United Nations Conference for Trade And Development
VLCC	Very Large Crude Carriers
VRS	Variable Returns to Scale
VSPT	Visakhapatnam Port Trust
WF	Workforce
WTO	World Trade Organisation

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Chapter 1
Introduction

While the development of policy towards ports must take account of domestic transport problems as a whole as well as shipping need, the essential function of a port must be to serve the shipping industry. Moreover, the ship/port interface is both more critical and more important by its very nature than is the port/inland transport interface. (Rochdale Inquiry, 1970).

1.1 Introduction:

The chapter starts with an overview of economic growth and foreign trade across the world and role of port and shipping. It further discusses on the role of infrastructure in world economy and how ports, as part of this sector, have supported the world trade. Focusing on the reform programs of world economies and how they have provided both opportunities and challenges for the growth of ports sector are also enumerated. The chapter further checks the efficiency gains observed at port sector and prove the rationale and need for studying port efficiency. The chapter then highlights the business problem of the current research followed by outline of the study. It gives an idea about the organisation of the study highlighting the various chapters proposed and ends with overall conclusions of this current chapter.

1.2 Background:

The kinship between economic growth and foreign trade is obvious and proven (WTO, 2007). No other development of the recent decades has had this immense effect on public life and prosperity across the world than rapid intensification of world trade and international division of workforce. International shipping has played an anchoring role in the movement of cargo across the world (Corbett & Winebrake, 2008). Sea ports form an essential component of modern economic environment (OECD, 2011). Technical and technological advances at both port and shipping sectors have significantly influenced the development dynamics of world trade (Hoffman & Kumar, 2010). Progress of maritime shipping, the principal approach of transport for intraregional and intercontinental trade is well supported by ports and harbours that facilitated with loading and unloading of cargo.

Economies across the world are depended on agriculture, manufacturing, and infrastructure sectors (Soubbotina & Sheram, 2000). While the first two sectors result in physical output, the infrastructure sector supports the first two by providing the required support in garnering their outputs. Infrastructure sector is further classified as social and physical infrastructure (Torrisi, 2009). Although there is no unanimity regarding its definition, different committees, authors, and agencies have given their own list to reflect the components of this sector. Some of them are quoted as below:

1.3 Infrastructure: Definitions and Meaning

1. **World Bank:**

   The World Bank treats power, water supply, sewerage, communication, roads & bridges, ports, airports, railways, housing, urban services, oil/gas production and mining sectors as infrastructure.

2. **Dr. C. Rangarajan Commission's Notion of Infrastructure (2001)**

   Infrastructure is recognized as a key input to the economic development. However, there is no clear definition for it in Indian usage. For the policy formulation, setting of sectoral targets and monitoring projects, a clear understanding of what is covered under the gamut of 'infrastructure' is necessary for ensuring consistency and comparability in the data collected and reported by different agencies over a period of time. The **National Statistical Commission** headed by Dr. C.Rangarajan, attempted to identify infrastructure based on certain characteristic features.

   The commission indicated six characteristics of infrastructure sectors,

   (a) Natural Monopoly,

   (b) High-Sunk Costs,

   (c) Non-Tradability of output,

   (d) Non-rivalness (up to congestion limits) in consumption,

(e) Possibility of price exclusion, and

(f) Bestowing externalities on society.

Based on these features (except b,d, and e), the commission recommended inclusion of following in infrastructure in the first stage:

- Railway tracks, signaling system, stations
- Roads, bridges, runways and other airport facilities
- T&D of electricity
- Telephone lines, telecommunications network
- Pipelines for water, crude oil, slurry, waterways, port facilities
- Canal networks for irrigation, sanitation or sewerage.

The commission further recommended that considering characteristics (b), (d), and (e) also, the list may be extended to include the following in the second stage:

- Rolling stock on railways
- Vehicles, aircrafts
- Power generating plants
- Production of crude oil, purification of water
- Ships and other vessels.

3. Reserve Bank of India (RBI) circular on Definition of Infrastructure:

The Reserve Bank of India (RBI) in its circular dated November 30, 2007 (DBOD No. BP.BC. 52/21.04.048/2007-08), defined Infrastructure as: "Developing or developing and operating or developing, operating and maintaining an infrastructure facility in Energy, Logistics and Transportation, Telecom, Urban and Industrial Infrastructure, Agro Processing, Construction for storage Agro Products, Schools and Hospitals, Pipelines for Oil, Petroleum and Gas, Water and Sanitation."

As per the RBI, a credit facility is treated as "infrastructure lending" to a borrower company which is engaged in developing, operating and maintaining, or developing, operating and maintaining any infrastructure facility that is a project in any of the following sectors, or any infrastructure facility of a similar nature:

a) A road, including toll road, a bridge or a rail system;
b) A highway project including other activities being an integral part of the highway project;
c) A port, airport, inland waterway or inland port;
d) A water system project, irrigation project, water treatment system sanitation and sewerage system or solid waste management system;
e) Telecom services whether basic or cellular, including radio paging, domestic satellite service (i.e. a satellite owned and operated by an Indian company for providing telecom service), network of trunking, broadband network and internet services;
f) An industrial park or special economic zone;
g) Generation or generation and distribution of power;
h) Transmission or distribution of power by laying a network of new transmission or distribution lines;
i) Construction relating to projects involving agro-processing and supply of inputs to agriculture;
j) Construction for preservation and storage of processed agro-products perishable goods such as fruits, vegetables and flowers including testing facilities for quality;
k) Construction of educational institutions and hospitals;
l) Any other infrastructure facility of similar nature.

4. **Economic Survey:**

The Economic Survey considers power, urban services, telecommunications, posts, roads, ports, civil aviation, and railways under infrastructure sector.

5. **Decision of the Empowered Sub-committee of the committee on Infrastructure on definition of infrastructure:**

The Empowered Sub-Committee of the Committee on Infrastructure in its meetings held on 11th January, 2008 and 2nd April 2008 under the chairmanship of Deputy Chairman, Planning Commission discussed the subject matter. There was consensus on including the following in the broad definition of infrastructure:

a) Electricity (including generation, transmission, and distribution) and R&M of power stations,
b) Non-Conventional Energy (including wind energy and solar energy),
c) Water supply and sanitation (including solid waste management, drainage and sewerage) and street lighting,
d) Telecommunications,
e) Road & bridges,
f) Ports,
g) Inland waterways,
h) Airports,
i) Railways (including rolling stock and mass transit system),
j) Irrigation (including watershed development),
k) Storage,
l) Oil and gas pipeline networks.

From the above definitions, it is evident that Port industry is an integral part of infrastructure and, thus, plays an important role in the growth and development of international trade. The sector has been supporting trade among distant nations from time immemorial. The turn of 21st century has resulted in reduction of trade barriers among nations of the world and with numerous multilateral trade agreements, international trade has improved drastically. This

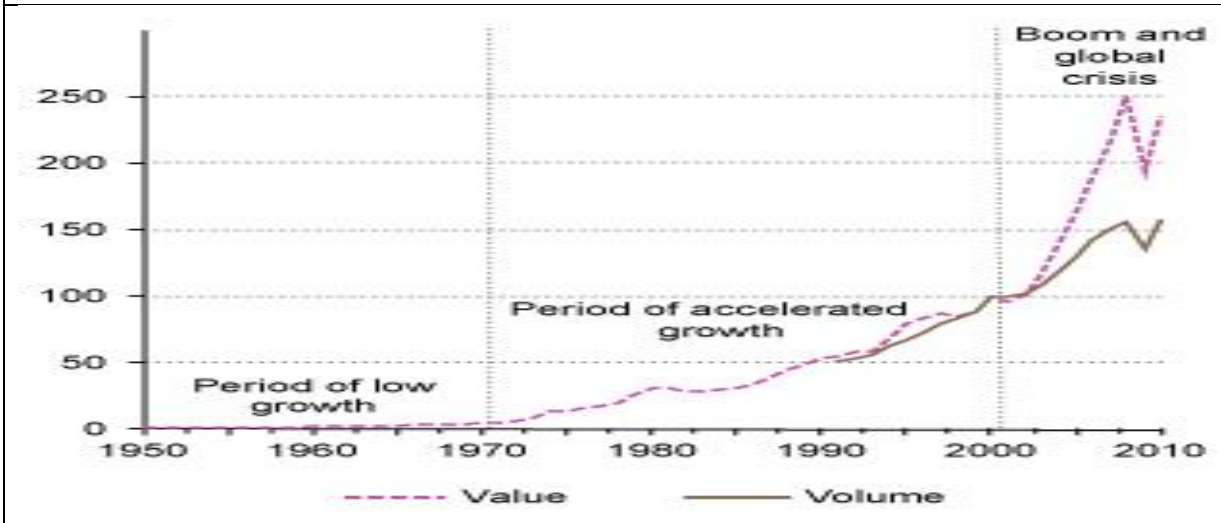
spurt in trade volumes has helped the growth of shipping industry and port sector that supports it as a point of loading and unloading. The ever growing trade volumes have mandated speedy movement of cargo which can be achieved only through the support of robust and vibrant port sector.

1.4 World Trade & its Trends:

An unidentified saint once said that world trade is the engine that drives human civilisation. Truly, the world trade has developed and facilitated the availability of goods and supplies of both raw material and finished goods across the nations. With this growth, both trade patterns and cargo compositions have changed. Cost effectiveness of sea transport has helped in transfer of huge volume of cargos to be moved from one destination to another (Korinek 2011). The change also mandated evolution of newer and specialised ships that enable the quick, reliable, and cost-effective movement of cargo. As the ship size and models evolved, the demand of port infrastructure and service quality had to be enhanced to support the need of international business (Michel & Noble, 2008).

The following figure depicts the trends in merchandise exports during 1950 to 2010, clearly indicating a spurt in trade volumes after the 1970's. It may be noted that during the period of reforms the growth of trade volume has increased at faster pace.

Figure: 1.1, Long-term trends in value and volume of merchandise exports, 1950-2010
(Index numbers, 2000 = 100)



Source: UNCTAD secretariat calculations, based on UNCTADstat and CPB Netherlands Bureau of Economic Policy Analysis, world trade database; http://dgff.unctad.org/chapter1/1.1.html

A successful reform process is expected to relieve governments from unnecessary expenditures, releasing funds for high priority social programs, ease bottlenecks to trade and economic development; and motivate the adoption of new regulations that protect environment and improve worker and navigational safety (Port Reform Toolkit, 2007). While reforms and privatisation are seen as significant contributors for improving efficiency, assessment of their actual success needs to be constantly checked. It is important to note that success of privatisation is largely depended on government's commitment to regulatory and legal reforms. Privatisation, coupled with appropriate structural reforms, generates incentives to enhance economic efficiency, increase investment, and adopt new technologies (Filipovic, 2005). The reform period has bestowed both opportunities and challenges to nations. (Corbett & Winebreak, 2008) argues that by opening their boundaries and markets to foreign investment and trade, many countries have seen astonishing economic growth. While, opportunities like better scope for business opportunities and newer markets for exports have supported trading nations, up gradation of overall physical infrastructural setup to meet the growing demands has posed as a challenge. Governments are forced to have a relook in their existing structures and frame policies and programs for impending requirements.

At the same time, competitive environment has also contributed to a greater change in management and working of ports across the world. Ports, being a significant contributor in facilitation of foreign trade have been an area of focus for development. Key components of ports such as ownership, financing, physical infrastructure setup, mechanisation and automation of operations have been rejuvenated drastically to accommodate competitiveness among ports.

1.4.1 Ownership:

Due to capital intensity, long gestation periods, service orientation, and security reasons, ports in most countries, especially third-world countries, were started, owned, and operated under public sector (Mukherjee & Schdeva, 2003). However, by the later part of 20th century, the process of economic reforms was initiated and governments started off loading their stakes in public sector, including port sector. The primary reason for this reform process is to support liberalisation and globalisation initiatives that enable in reduction of trade barriers across the world (IFS, 2005). The reforms were expected to bring in private entrepreneurship and capital along with commercial orientation among business units and improve their

efficiency. The process of change in ownership in port sector across the world has to a greater extent improved efficiency of in the sector (Cheon, 2007).

1.4.2 Financing:

Port industry is a capital intensive sector demanding huge capital outlays and long gestation periods. Owing to poor capital availability with private entrepreneurs, ports were opened under public sector with service orientation (Lall, 2007). Government funding has led to huge investments in physical infrastructure in these ports. However, just as in other sectors, port sectors have also experienced operational and financial inefficiencies. By the mid 1900's governments had to reconsider their ownership in these ports. By the latter part of 20th century economic reforms were initiated and due to the constraints of capital formation from public sector, governments have contemplated for a change in port ownership (Kapoor, 2002; Bossche et. al., 2012). Privatisation has been seen as right choice due to the growth in private capital formation in countries like China, Brazil, India, etc. (World Bank, 2007; Zou, 1994). At the same time, relaxation of FDI norms in these countries has also led to huge capital inflows into these countries. Thus, the process of privatisation has been initiated in this sector leading to change in port ownership models (World Bank, 2007).

1.4.3 Physical Infrastructure:

Physical infrastructure include facilities like berths, channel and draft, number and types of cranes, hinterland connectivity through roads and railways, and other physical equipment required for movement of cargos plays a key role in the cargo handling capabilities of a port. A port that can handle the cargo at faster pace with high standard of service can attract better business (Lund & Blease, 2013). Timely up gradation of the physical infrastructure enables a port to develop at a faster pace and meet the aspirations of its clientele and maintain financial and operational efficiencies (EY, 2012). Ports under public ownership could not maintain the momentum in their infrastructural investments due to consistent financial constraints. However, privatisation has resulted in huge investments in both physical infrastructure and technological advancement at these ports and has resulted in better efficiencies (De, 2002).

1.4.4 Working Mechanism:

To achieve optimum efficiency in operations, physical infrastructure of ports need to be supported by right work mechanism at a port (Haver, 2011). Most often physical infrastructure itself determines the work mechanism. Public sectors ports were featured by outdated infrastructural setup that has led to over dependence on workforce. Ports in most of the developed nations are equipped computer aided mechanisation and therefore they perform with high standard of efficiency. Privatisation of ports has contributed to huge investments in port infrastructure and resulted in efficiency gains.

1.5 Business Problem:

Reforms in the form of private participation at major ports of India were started in 1995-96 (Maritime Agenda 2020) to improve their performance. In spite of the reform program, the port sector is still struggling with lower efficiencies leading to business losses in industries that are directly and indirectly depended on it.

The identification of business problem has given an opportunity to search for existing literature on port efficiency and productivity measurement across the world. The search started with tracing of contribution of ports to international trade and how the standards of performance measurement have evolved. It furthered into works comparing port performance, its measurement techniques, and the impact of reforms on efficiency and productivity. At attempt to understand the literature works pertaining to Indian ports is conducted to know the scope and need of a research requirement in this vibrant and fast growing economy.

1.6 Topic and Purpose:

To further probe on business problem, a thorough literature review was carried out. A review of existing port performance indicators proposed by various competent authorities, the methods applied by various researchers to assess port efficiency and port productivity across the world comparing ports operating in different parts of the world. A review of literature pertaining to economic reforms and corresponding ports sector reforms on the efficiency and

productivity of ports across the world is also done to know the growth patterns observed in this sector. A detailed review of the literature is presented in Chapter 2.

1.7 Port efficiency and productivity measurement process:

Ports industry has developed leaps and bounds over a period of time, especially, during the last three decades due to reform process (UNESCAP, 2005). Governments across the world are continuously striving to provide them much impetus to this sector so as to accelerate economic growth (UNCTAD, 1998). Numerous initiatives in the areas of port infrastructural facilities, hinterland connectivity, financial autonomy to port authorities etc., have contributed to growth in the sector. Of these, privatisation has been the most important initiative that has led to improvement in both financial and operational efficiency of ports across the world. Ports of both developed and developing countries have considerably gained due to this move (Maritime Agenda-2020, 2011).

However, the level of gains achieved has been uneven (Estache et. al. 2003). While some ports have shown initial improvement in their efficiency, some others have shown improvement in only few of the parameters of efficiency. Few researchers argue that privatisation is no complete solution (Cullinane et. al. 2005) and strongly recommended that government control and strong regulatory framework are required to maintain the growth momentum (Rodriguez-Alvarez & Tovar 2012, Cheon et. al. 2009, Serebrisky & Trujillo 2007, Pallis & Syriopoulos 2007, Liu 1995).

Ports in developing countries, especially, India have numerous challenges and researchers are skeptic about efficiency improvements due to privatisation. At the same time, unlike most ports of developed countries that handle containerised cargo, Indian ports handle multiple cargos. Thus an in depth study covering overall performance of the major ports of India is essential to check the growth achieved by these ports due to their privatisation.

Studies on port performance including port efficiency and port productivity are conducted by numerous researchers across the world. Studies on port efficiency and productivity using techniques such as Cobb-Douglas production function, regression analysis, correlation analysis, chi-square test, linear equation method, weighted score method, financial ratios, etc., were done by some of the researchers. Many of the researchers have applied complex

mathematical techniques of DEA and SFA to check the efficiency. A few of other authors have applied MPI technique to develop port performance index. While most studies have considered operational variables, some have also considered financial parameters of port performance.

In most of the studies, the selection of ports for assessment has been on their either geographical location – like **World** (Baran & Gorecka, 2014; Cheon et. al. 2009, Herrera & Pang 2008, Park & De 2004, Poitras et. al. 1996), **European** (Simoes & Marques 2010, Caldeirinha et. al. 2009, Cullinane & Wang 2006, Trujillo & Tovar 2005) **American** (Turner et. al. 2004, Hoffmann 2001, Circha 2001) **Asian** (Jiang & Li 2009, Liu 2011 Chudasama & Kota 2007, Lee et. al. 2005, Cullinane, et. al. 2002) **Australian** (Tongzon 2001).

Most authors have also studied on container ports/terminals and include (Chu et. al. 2013, Mokhtar & Shah 2013, Lightfoot et. al. 2012, Lu & Wang 2012, Park & Ro-Kyung 2008, Cullinane & Wang 2006, Tongzon & Heng 2005, Lee et. al. 2005, Cullinane et. al. 2005, Cullinane et. al. 2002).

Often times, these studies selected ports with different sizes and/or working under varied economic and ownership framework. This has resulted in certain biasness in these studies as these ports did not share any common features and economic backdrop.

1.8 Ports in India

Indian ports share an entirely different scenario. Unlike most international ports, Indian ports handle multiple cargos and have numerous challenges like poor hinterland connectivity, poor infrastructural facilities. At the same time with unshackling program of these ports from government ownership and control has given newer opportunities for development (OECD, 2009; Krimpen, 2011). So there is a strong need for assessment of efficiency and productivity enhancements at these major ports during the reform process that has allowed in private participation (Cheon, 2007). Absence of a research works assessing efficiency and productivity gains with the backdrop of reform has resulted in non-assessment of the level of gains

The reform process in Indian was given a new direction and impetus with the formulation of the Industrial Policy 1991. India has been a late starter in economic reforms. But the economic performance during the post reform period has numerous positive features (Ahluwalia, M.S. 2002). The reforms process is required to support long-term prospects of the economy with foolproof mechanism. Government policies should not follow but be in place before the actual processes are initiated (Kaushik, 1997). It is, thus, imperative to have clear regulatory and legal environment to support the privatisation process.

Although, process of reforms was initiated in the year 1991, it took some time for the government to extend the process across the different sectors in the economy. Aiming to have strong policy framework government of India has extended the scope of reforms to various sectors over a period of time. Privatisation process at public sector ports was initiated during the year 1995-96 (Maritime Agenda-2020, 2011). Private sector was allowed to own and manage certain selected aspects of port operations like terminal operations, berth operations, yard maintenance, operational dredging, stevedoring, cargo handling, etc. The permissions for such projects were awarded through competitive bidding in PPP mode and as BOT contracts for a concession period ranging from 15 to 35 years. Privatisation of facilities at major ports is aimed to achieve the objectives like improvement in efficiencies, reduction in costs, and capacity enhancements (Sundar, 2000). Like same, under the reform process, port authorities managing these ports are given operational autonomy and made responsible for sustainable efficiencies in the competitive business environment. Consequently, port sector reforms gave an opportunity for installation of sophisticated equipment at ports and terminals run by private operations creating opportunity for efficiency growth (De, 2002). Up-gradation of physical infrastructure and technological set has enabled ports to improve their efficiency.

Thus, it is obvious that reforms and privatisation have resulted in improvements at port infrastructure and its output in the form of cargo handling abilities. Port reforms were initiated with an aim to improve their efficiency. However, it is important to cross check the actual improvements with the standards set. Checking of the efficiency gains facilitates an opportunity to compare the actuals with targets. It also presents a chance to suggest necessary corrective measures in policies of government.

1.9 Problem Statement:

Although studies are made with some variables on port performance, post-reform productivity improvements covering operational, financial, & physical parameters are still, conspicuously, missing.

1.10 Need of Research:

Need for research and business problem are derived on the basis of challenges faced by port sector during the course of its growth. Port ownership and mode of operations are significant for its efficiency in the dynamic economic scenario. Privatisation has given an opportunity for port sector to revive from their existing bottlenecks such as poor infrastructure, financial constraints, and poor hinterland connectivity. It is expected to offer newer investments in physical infrastructure and improvements in work culture of these ports.

While private participation is seen as a natural part of reforms process, keeping a check on the level of efficiency improvements during this period provides a chance to maintain parity between actual and expected gains. An assessment of the actual progress made by major ports during the course of reforms would give an opportunity to gauge the efficiency gains at each of these ports and trace the reasons for such improvements. It is empirically proven that not all ports register same level of efficiency improvement. There may be ports where, in spite of reforms, inefficiencies remain. A holistic research is required to bring-out the reasons for efficiency/inefficiency gains observed at various ports. It also brings to light factors that contributed for efficiency gains at certain ports and inefficiencies at some other ports.

1.11 Outline of the study:

It is apparent the India needs to encourage private participation in port sector as an alternative and viable model for supporting the growing foreign trade needs in the vibrant economic scenario. Service sector in Indian economy is growing is at a faster pace in comparison to other key sectors like agriculture and industry. The GDP contribution of services sector to Indian economy is over 57% and employs about 28% of Indian population (Budget, 2015). However, a holistic study on the performance of ports, especially the major ports, to check the overall efficiency gains is due to inclusion of private operators and finance is still not checked.

Indian port sector is deemed to have achieved considerable growth due to the advent of private sector, both as participants in major ports and as completely owned private ports. But the level at which this growth has happened in real terms is still to be assessed. Issues such as the parity between growth anticipated and actually recorded, future course of action to upgrade the growth momentum are not thoroughly studied.

This thesis has taken up exhaustive review of literature to understand the port performance, port efficiency, port productivity, impact of reforms on port sector. Research works across the world are assessed by grouping them on the basis of continents as well as world basis, where studies pertaining to inter-continental comparisons are involved, to gather inferences on real term efficiency growth observed at ports compared. A separate analysis of ports of India has is made to understand the trends observed at Indian ports in efficiency and productivity aspects.

The review of literature has given an opportunity to understand efficiency and causes of inefficiency. The literature survey resulted in gathering around 133 variables used by different researchers to assess port efficiency and productivity. It is also noted that of the 133 variables, only a few variables, 6 in number, were used frequently. Further, port performance indicators proposed by various agencies were reviewed and the final variables for the research are selected. Assistance from officials of Indian Port Association, New Delhi and selected major ports of India was taken to identify the final variables of the study.

The identified variables are used to check efficiency and productivity at major ports during the period 1995-96 to 2013-14 using DEA & MPI techniques respectively. The MPI results are used to create an index representing the port productivity during this period. The analysis of the same is presented in chapter 5 and 6 of this document.

1.12 Organisation of Report:

The entire study is encapsulated **seven chapters**. The first chapter titled **Introduction** includes the growth trends in maritime trade and ports across the world. It discusses vivid topics of port ownership models, port performance indicators, port sector reforms, and constraints in development of ports. Since the focus of the study is on Indian major ports, a brief idea on Indian ports along with government initiatives is also discussed in this chapter.

The second chapter is **review of literatures**, details about the existing studies on port efficiency, productivity, and ranking. The reviews research works are broadly categorised on the basis of thematic studies to derive concrete inferences and gaps. The literature review is also classified on geographical basis to assess the level and types of existing studies. The review is also aimed to derive certain pertinent variables that can be considered for the current study.

The third chapter **research design** focuses on the rationale of this current study followed by statement of research problem, objectives of study, research questions, scope of the study, data collection methods, data analysis strategy, operational definitions of variables identified.

The fourth chapter **port sector** gives an in-depth understanding of Indian port sector, their growth, reforms, current status of each of these 12 ports, and information on the growth of non-major ports in India.

The fifth chapter named **Data Analysis – I** discusses about the sources of data followed by selection of data. Correlation analysis of the selected variables and validation of selected data and subsequently data analysis using DEA technique are also detailed with their interpretations.

The sixth chapter **Data Analysis – II** explains about the data analysis using MPI technique with interpretation of results.

Finally, the seventh chapter provides **Conclusions & Suggestions**. Bibliography is given at the end as reference.

1.13 Concluding Remarks:

This chapter discussed the context and background of this research. Impact of economic reforms across the world on trade volumes has given opportunity to improvement in cargo movement through ships. This spurt in trade volumes has mandated the improvement of port facilities. Ports being a key part of infrastructure sector play a key role in the progress of a country and thus, their efficient operations become detrimental to the pace of economic growth of the country. With the growing pressure on port to handle cargo with efficiency,

governments are forced to opt for their privatisation through sectorial reforms. Privatisation of ports is expected to enhance their efficiency. The business problem is derived from this background, and attempts to probe the level of actual efficiency gains achieved by major ports of India during the privatisation phase and identify the reasons for such efficiencies/inefficiencies.

The business problem has led to further exploration of literature. A thorough literature review on port performance indicators proposed by various agencies followed by actual assessments of port efficiency and productivity made by numerous authors is made. Literature collected on both efficiency and productivity is segregated on the basis of world ports, Indian ports to understand the works done at both levels. A separate segregation is made to understand the impact of port sector reforms on their efficiency and productivity.

Subsequently the problem statement is derived and an outline of the study explaining the mode in which research aims to assess port efficiency and productivity are explained. The chapter, at the end, also highlighted the proposed chapter of the research work.

Chapter 2
Review of Literature

2.1 Introduction:

This chapter is focused on understanding hitherto published research works and reports on performance, efficiency, and productivity of port sector across the world. It also attempts to review upon the guidelines, rules, and provisions on port performance that are propounded by various authorities such as UNCTAD, World Bank on port sector. Clarity of thought on the existing body of literature is expected to help in segregating the known and unknown facets of port efficiency and productivity. The chapter, initially, discusses on the procedure followed to gather seminal woks and reports by identification of certain '*key words*' that are used across various database to search for available research works. The identified research papers are gathered and subsequently categorised into different themes. Basic concepts of performance, efficiency, and productivity both in general and in port sector parlance are reviewed to understand the progress made in this key segment of infrastructure. Further the research works on ports are segregated on the basis of world and Indian context to understand the progress observed at both levels. Port sector reforms envisaged by governments across the world and their impact of efficiency, productivity, are also assessed from the studies made by different researchers. Review of literature has helped in identification of numerous variables that are used by different researchers for assessing ports. The review has also given an opportunity to know the various statistical, mathematical and other techniques used to assess port efficiency, productivity, and ranking of ports. The final outcome from these reviews has given an opportunity in tracing the existing 'research gaps' that have helped in initiation of the proposed research work. Based on the observed research gaps valid conclusions are drawn at the end of the chapter.

2.2 Objectives of Literature Review:

1. To study the significance of measuring port performance;
2. To study modes of assessing port performance across the world;
3. To make a thematic segregation of the research works;

4. To study the performances of ports across the world with a special reference to reforms and change in ownership model;
5. To study the growth trends and current status of ports in India;
6. To study the different techniques used for assessment of efficiency, productivity, and ranking of ports; and
7. To identify research gap in the existing body of knowledge.

2.3 Performance Measurement:

"Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it." – H. James Harrington.

Performance measurement is the fundamental building block of management (Henri, 2004). Traditionally financial aspects such as profit were the basis for performance measurement. However, financial information provide little support in checking quality of organisational progress as they fail to map process performance and improvements that are seen by clientele. In a sequence of never-ending organisational progress, performance measurement plays a key role by identifying and tracking progress against organisational goals, by identifying opportunities for improvement, and in comparing performance against internal as well as external standards. Performance measures are generally categorised on the basis of effectiveness, efficiency, quality, timeliness, productivity, and safety (Artley & Stroh, 2001).

The journey of assessment of working of ports has initiated with at attempt to understand performance measurement and how it has been taken-up by researchers. Keeping this in view, it is apt to check and understand the 'intricacies' of performance measurement. Review of research works on performance is discussed below.

Performance measurement holds key for growth irrespective of the type of organisation. Ian O'Boyle & David Hassan (2014) and Moxham (2013) attempted to measure performance at non-profit and public sector organisations to find existence of numerous measurement criteria that failed to give a holistic picture on performance and that in most public sector organisations, performance measurement to be merely for compliance rather than for service improvements.

Numerous authors attempted to study performance measurement factors and its significance. The performance measurement methods have a common ground regarding what is to be measured, but there is a lack of clarity and understanding on factors to be considered for such measurement. (Choong, 2013). Studies also found that since the environment developed dynamically, the strategies of organisations need to change over time and when a strategy changes, some performance measures must change too (Striteska, 2012). A study on assessment of operational performance measures metrics and the common mistakes made led to conclusions that measurement metrics, even if developed with strategic measurement systems based on tools as balanced scorecard, key performance indicators, computerised dash boards etc., are generally taken with a lack of comprehension of what is important to enterprise success, and of a fundamentally unstructured approach to performance and improvement (Hammer, 2007).

Neely et. al. (1997) proposing a technique for solving problems of performance measurement at manufacturing sector concluded that performance measure record sheet tested on 200 managers of 50 companies has given positive results with his technique.

Works on transports sector performance measurement systems like Canadian Transportation Agency (2010) reporting on understanding the framework of performance and measurement of Canadian ports found that time lags exist between collection of data and their interpretation which generally affects the decision process.

With changing ownership models of ports some researchers proposed newer mechanism for performance measurement. Langen et. al. (2007) aimed development of new port performance indicators to suit changing port ownerships and commercial preferences. They concluded that due to multiple reasons most ports did not collect port performance indicators in a structured way. At the same time, performance indicators used at different ports differ substantially. The study proposes a couple of potentially useful new PPIs based on the annual reports of leading port authorities. Similarly, Baird (1999) studying port privatisation models, their prioritisation, essential elements involved in effective functioning of port, advantages & disadvantages highlighted. The study concluded that privatisation results can be obtained only when adequate and comprehensive supportive mechanism exists in the system.

From the above, it can be found that performance measurement systems are required at every organisation, whether profit oriented or service oriented, for future planning and growth. It may also be inferred that port sector, one of the key segment in infrastructure sector, is no exception and thus, performance measurement systems are required even for them. At the same time, with the changing business environment newer metrics for performance measurement evolve in every sector so that the performance enhancements due to these developments, like privatisation, can be judged.

2.4 Efficiency:

"Modern technology has become a total phenomenon for civilisation, the defining force for social order in which efficiency is no longer an option but a necessity imposed on all human activity." – Jacques Ellul.

Efficiency is represented by linking output with inputs. More output per unit of input represents better efficiency. Firm efficiency represents a relationship between output units that the firm produced with a given set of inputs. Full efficiency is attained by a firm if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs.

2.5 Port efficiency has been a topic of curiosity to policy makers, industry players and researchers due to its significance in international trade and business environment. Evaluation of port performances plays a significant role in deciding policy proposals, selection of port destinations, and as a research avenue for different stakeholders. Performance measurement that started with mere proposals specifying indicators has extended to concepts of efficiency, productivity and currently extended to into ranking of the ports being considered. Measurement of efficiency and productivity are expected to help in understanding the growth trends in this important sector of an economy. With the initiatives of reforms and changing ownership models across the world, studies on efficiency and productivity are expected to enhance ability to holistically trace resultant efficiency/inefficiency and help understand actual growth levels at the ports. These studies help port authorities and respective governments to frame suitable policies and programs that contribute in building their economy.

2.6 Productivity:

"If you don't understand how to run an efficient operation, new machinery will just give new problems of operation and maintenance. The sure way to increase productivity is to better administrate man and machine." – W. Edwards Deming.

"If we boost productivity, we can improve economic growth." – Tony Abbott.

Productivity in general terms refers to ratio between an output and the factors that made it possible. Lovell (1993) defined productivity of a production unit as the ratio of its output and its input. The ratio is easy to compute if the unit uses single input and single output factors. However, calculation of productivity becomes complex with multiple input and output variables. Total Factor Productivity (TFP) refers to the usage of all input and output variables that represent a firms performance in measuring its productivity. Nadri (1970) opines that measurement and interpretation of behavior of productivity at microeconomic and macroeconomic levels require untangling of many complex factors; it is a task that has been a major challenge to economists and of extreme interest to entrepreneurs and policy makers. Spring (2011), in his book on integrated management of productivity activities discussed about the need and different measures of integrated productivity and the usage of the results. OEDC Manual (2001), on productivity measurement discussed the overview of productivity measurement, various inputs, outputs, and interpretation procedures required to gauge productivity levels.

With an aim to understand the developments in port sector and to have a lucid picture on the research works, the current study segregated them on the basis of efficiency, productivity, and ranking. Review of literature is taken up on these parameters considering the pre and post reform scenario.

2.7 Selection of Key Words:

The search for literature holds key in accurate navigation of the proposed research. Identification of key words has commenced with some of the general words like 'performance measurement', 'efficiency measurement', 'production function' and slowly drifted towards domain terms such as 'port performance', 'performance indicators', 'port governance', 'port ownership', 'port privatisation', 'port evaluation', 'port efficiency', 'port

productivity', 'maritime developments', 'port sector reforms', and 'performance index'. Techniques used for checking efficiency and productivity that are used by various researchers such as 'Data Envelopment Analysis', 'Total Factor Productivity', 'Malmquist Productivity Index' were also searched to gather research.

2.8 Literature Search Process:

To ensure thorough research, online database like Taylor & Francis, Elsevier, Palgrave, Scopus, Emerald, and Google Scholar were searched for available literature between 1976 and 2014. A total of 22 Journals of National and International repute and over 15 reports published by various national and international agencies are reviewed.

Table 2.1 List of Journals Explored

1. Journal of Maritime Research	12. Port Economics
2. Alliance Journal of Business Research	13. OR Spectrum
3. International Journal on Production Management	14. Geoforum
4. Journal of Transport Geography	15. Transport Research
5. Transportation Planning and Technology	16. World Development
6. Maritime Policy & Management	17. Maritime Policy
7. International Journal of Logistics Research and Applications	18. IUP of Infrastructure
8. International Journal of Environmental Sciences	19. Transportation Research
9. International Business Research	20. Transport Policy
10. Journal of Economics & Business	21. Transport Reviews
11. European Journal of Operational Research	22. Applied Economics

Table 2.2 List of Reports Searched

Report	**Agency**	**Year**
1. Port Performance Indicators, 1976	UNCTAD	1976
2. Maritime Agenda – 2020	MoS, GoI	2011
3. Port Reform Toolkit – Module 1, 2, & 3.	World Bank	2007
4. Regulation of Indian Port Sector	World Bank	2011

5. Infrastructure Public Private Partnership Financing in India	World Bank	2014
6. India's Transport Sector: The Challenges Ahead–Vol. 1,2	World Bank	2002
7. Guidelines for Private Sector Participation in Ports	IPA	2009
8. Trade and Development Reports	UNCTAD	2000 to 2014
9. Review of Maritime Transport – Year wise Reports	UNCTAD	2011 to 2014
10. Guidelines for Port Authorities and Government on privatisation of port facilities	UNCTAD	1998
11. Financing Port Development	UNCTAD	1996
12. Manual of a uniform system of port statistics and performance indicators	UNCTAD	1987
13. Port Organisation and Management	UNCTAD	1993
14. Update on Indian Port Sector	MoS, GoI.	2012 to 2014
15. Coordination of business plan for major ports of India, Vol. 1 & 2	IPA	2007

2.9 Author-wise details of the research papers gathered:

Research works covering performance, efficiency, productivity, and ranking of ports both across the World and India are listed in the following table. This comprehensive list covers details of author(s), context of study, their finding/conclusion, variables used by them, and model/technique used by them on the basis of year of such studies. A total of 133 variables covering 39 operational, 31 financial, 19 physical, 32 others were traced from the literature review and are listed at the end of this chapter.

Table 2.3 Literature Review based on author, context, findings/conclusions, variables considered, and model/methodology applied.

Authors	Context	Findings/Conclusions	Variables	Model/ Methodology
Baran & Gorecka (2014)	Checked efficiency and productivity gains at selected ports across the world	To access port performances in competitive environment, the study also decomposed efficiency into technical efficient, technological efficient, scale efficient, pure technical efficient, and pure technological changes. The study successfully showed efficiency and productivity level of the ports selected for the year 2012.	3, 76, 81, 83, 91.	DEA, MPI
Rajasekar et. al. (2014)	Measured operational efficiency of Major Ports of India 1993-2011,	Proved that size does not determine port efficiency. Found smaller ports to compete with bigger ports. Suggested need for long-term plans to maintain efficiency. Study suggested for inefficient modernising the ports.	2, 3, 76, 98, 85, 100,	DEA
Song & Cui (2014)	Efficiency at Chinese container terminals due to huge	With investments study attempted to trace productivity improvements.	2, 81, 86, 100	MPI

	investments during 2006-2011.	Found improved productivity due to technological progress. Technical growth which is possible due to improvements is due to scale efficiency has little influence on productivity.		
Ian O'Boyle & David Hassan (2014)	Examined the present status of organisational performance management & measurement at non-profit oriented sports organisations.	Concluded that numerous performance measurement criteria exist, but not many studies made on performance management as a holistic approach.		Review Paper
Pagano, Wang, Sancez, &Ungo (2013)	Compared financial efficiency and effectiveness for ports of Panama, and US with various degrees of privatisation.	Assessment of 10 privatised container ports suggests positive impact on efficiency.	2, 40, 41, 42, 75, 97, 98, 103, 125.	Stochastic Frontier Analysis (SFA) through panel regressions
Schellinck, Brooks (2013)	Identifying and prioritising investments at ports to enhance productivity.	Developed mapping process on determinant/ performance gap analysis addressing conflicting signals among methodologies evaluating effectiveness and help investments.	74, 104, 126.	Mapping process developed

Caldeirinh, Felicio, & Dionisio (2013)	Influence of infrastructure on efficiency, productivity, activity level, and customer satisfaction at 12 Portuguese and Spanish container terminals.	Aimed to know disparity in success among container ports using smaller sample size.	77, 79, 80, 103, 105, 106, 127, 132.	Developed Structural Equation Modeling (SEM)
Chu, Fwa, & Nishijima (2013)	Operational performance assessment for container ports	Studied opportunities to develop significant predictive model of annual throughput from web sourced data.	2, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90.	Case Study Methodology using regression analysis
Mokhtar, Shah (2013)	Developed productivity index measuring operational efficiency in container terminals.	Studied container efficiency to find strong relationship between size and efficiency. Found efficiency enhancement with resource allocation and operators but not terminal size.	2, 81, 82, 83, 85, 89, 91, 92.	DEA – Model, CCR & BCC.
Wang, Knox, Lee (2013)	Efficiency levels at 46 privatised and publicly operated US ports during 1997-2006.	Found improved financial performance with privatisation.	3, 41, 42, 43, 103.	SFA and Panel Data Regression Analysis

Yang, Chin, Chen (2013)	Progress in port throughput in China with reforms from 1952 to 2009	Positive correlation observed between growth in throughput and investments. Throughput influenced with macro-economic policies.	42, 50, 76, 111.	Granger Causality Test on Vector Error Correction Model & Co-integration Test with Break.
Obed, Ndikom (2013)	Assessed port privatisation policy and productivity in Nigeria.	Reforms improved efficiency & productivity resulting higher revenue and cargo volumes. High dedication among shippers and workers observed.	2, 122, 123.	Chi-Square Test
Diaz-Hernandez, Martinez-Budria, Jara-Diaz (2013)	Reforms and port productivity in Span.	Observed efficiency and technical changes during reforms, found initial improvements but stagnant technologies affected technical efficiency.	2, 3, 15, 16.	DEA and MPI
Dama & Zawar (2013)	Port developments linked with economic progress of India	Observed positive correlation between Indian economic development and port developments. With improved outlook of major and non-major ports, future is expected to see tough competition among ports.		Review Paper

Choong (2013)	Study on adequacy of research on Performance Measurement Systems and implications of such studies.	Concluded that the existence of a common ground on what is to be measured. However, there exists lacks an understanding on what factors of measurement are to be considered.		Review Paper
Moxham (2013)	Studied performance of public sector voluntary services, measuring, improving in quality of services.	Concluded that measurement systems of public sector are designed to assess compliance, rather that engender continuous service improvement.		Review Paper
Rajasekar , Deo (2012)	Linkage between size and efficiency at Indian major ports 1993 – 2011.	Found little influence of size on efficiency. Suggested containerisation and long-term planning for productivity.	2, 17, 73, 76, 81, 85, 86, 87, 88, 89, 90.	DEA – Additive Models
Pjevcevic ,Radonjic , Colic (2012)	Serbian River Port efficiency measurement	Assessed inefficiency sources and formulated proposals for improving services.	3, 81, 86, 128.	DEA Window Analysis
Odeck, Brathen (2012)	Meta-analysis of DEA and SFA studies on technical efficiency of seaports	Compared fixed-effects versus random-effects *Tobit* model with mean technical efficiency estimates to find latter as better.		Review Paper

Lightfoot et. al. (2012)	Output input relationship at 5 Australian container ports during 1997 – 2010.	Observed improvement in labour and Total Factor Productivity (TFP) with decreasing returns to scale.	2, 15, 16, 19, 20, 21, 53.	Cobb-Douglas Function – simple & time-dependent.
Barros, Felicio, Fernandes (2012)	Observed efficiency improvements using TFP at 23 Brazilian ports 2004-2010.	Partitioned productivity change as an index of efficiency and technological change. Further index of technological change are partitioned as output-input biased and magnitude. Found port location strategically important to attract traffic.	2, 3, 73, 81, 86.	DEA and MPI – input based of total productivity.
Nwanosike, Tipi, Smith (2012)	Reforms and efficiency improvements at 6 Nigerian ports 2004 - 2010.	Cargo throughput and traffic improved significantly with concessionaire agreements.	3, 21, 81, 85, 86, 87, 88, 89, 90, 100.	DEA
Rodriguez-Alvarez, Tovar (2012)	Reforms and ownership models on Spanish ports during 1993-2007.	Pace of economic reforms to have positive relationship on efficiency.	3, 18, 44, 53, 73, 83, 107.	Fixed Effect Model (FEM) to estimate short run total cost frontier.

Xu & Chin (2012)	Port governance on sea and river ports of China.	Traced efficiency gains and success in problem solving due to change in governance. Reforms and open door policy of Chinese government has created room for development of ports.	75, 76	Review Paper
Halkos, Tzeremes (2012)	Measured productivity at Greek seaports' between 2006 and 2010.	Found number of terminals as crucial determinant of productivity, and long berths and stagnated technology negatively influencing productivity.	2, 18, 42, 73.	MPI with bootstrap techniques. Local Linear Kernal Model (LLKM)
Striteska (2012)	Contemplated to analyse, compare and summarise the strong & weak points of performance measurement systems.	Found that due to dynamic developments of environment, strategies of organisations need to be change over time and when a strategy changes, some performance measures must change too.		Review Paper
Lu & Wang (2012)	Measurement of operating efficiency of 31 east-Asian major container	Attempted to trace reason for inefficiency, potential areas of improvement at inefficient terminals by	3, 81, 82, 85, 86, 93,	DEA

	terminals.	applying stake variable method, and used returns to scale approach to assess if each of the terminals is in increasing, decreasing, or constant returns to scale.		
Brooks, Schellinck, &Pallis (2011)	Studied users perception on efficiency at Canadian Ports	Perception differs while evaluating level of satisfaction, competitiveness and service delivery effectiveness.	108, 131.	Normalised Pairwise Estimation (NEP) Analysis
Wanke, Barbastefano, Hijjar (2011)	Efficiency determinants at 25 Port terminals in Brazil	Efficiency indicators grouped basing inputs and outputs for production function analysis. Found private terminals to be more efficient.	1, 3, 76, 83, 94, 95.	DEA – BCC & CRR, and SFA
Liu (2011)	Evaluation of operational efficiency of 10 Asia-Pacific Ports for 1998 – 2001.	Both models showed lower efficiency by ignoring environmental factors, managerial inefficiency, and statistical noises. Efficiency estimates of 3 stage DEA model are highest.	3, 4, 5, 6, 7, 8, 24, 45, 46, 47, 48, 73, 76, 83, 85, 96, 97, 98, 99, 108, 109, 110.	CCR, BCC, and 3 stage DEA Models.

Rajasekar, Deo (2011)	Studied efficiency of Indian major ports from 1995-96 to 2007-08.	Probed reasons for different levels of performance and stressed on facility improvements.	2, 3, 9, 10	Case Study Methodology
Bhatt, Gaur (2011)	Impact of containerisation on port efficiency at JNPT and Mundra Ports.	Improved berth operational efficiency at container terminals with privatisation. Not studied yard efficiency.	11, 12, 13, 14, 16, 31, 89.	DEA
Gaur, Pundir, Sharma (2011)	Efficiency assessment at Indian Ports	Stressed on improved capacities from effective to potential and to absolute levels. Developed efficiency index benchmarked at three levels – Effective Performance, Potential Performance Index, and Absolute Performance Index	2, 9, 10, 17, 72.	Developed Performance Index.
Nihar (2011)	Forecasted capabilities of Indian Major Ports on their performance	Investments, business & operational acumen are required for efficiencies. Policies to handle multiple commodities, berths for foreign ships. Suggest newer techniques to study growth, expansion plan & success.	17, 49, 51, 52.	Linear Equation Method

Kent, Hochstein (2011)	Studied impact of limited competition on port reforms and privatin in Colombia, Costa Rica, & Nicaragua	Offered guidance to assure ports competitive pressures even with limited cargo volumes.	2, 40, 51.	Review Paper
Xiao et. al. (2010)	Worked on integrated economic model to analyse effects of port ownership, competition, capacity investment, and pricing at ports.	Developed a model to prove that capacity investments and congestion level are influenced by ownership forms, presence of inter-port competition and possible externalities due to port operation. Study further proposed a good framework to analyse a range of ownership options within one consistent model.		Model Development
Bergantino & Musso (2011)	Studied various influencing factors on port efficiency using a multi-step approach.	Both external and internal factors are checked to assess their influence on port efficiency. The study found environmental factors such as economic condition, port accessibility, and employment level to have varied degree of influence on port efficiency.	3, 8, 77, 78, 80, 81, 83, 84, 108, 118, 129	DEA, SFA

Simoes, Marques (2010)	Performance of 41 European ports in 2005	Study found inefficiency by reducing noise, presence of outliners and 'curse of dimensionality'.	2, 3, 18, 51, 53.	DEA and Free Disposal Hull techniques by using Order-m and bootstrap methods.
Wu, Goh (2010)	Port operations efficiency in emerging markets.	Regardless of input-output volumes, planning facilities based on actual cargo demand achieves efficiency. Ports of emerging economies lack heavy equipment but are operationally competitive than advanced ports.	2, 81, 83, 85, 86, 87, 88, 89, 90.	DEA
Canadian Transportation Agency (2010)	Reporting on understanding the framework of performance and measurement of Canadian ports.	Study found that time lags exist between collection of data and their interpretation which generally affects the decision process.		Report
Cheon et. al. (2009)	Efficiency gains with reforms across 98 ports from 1991 to 2004.	Improved management and container operations; scale adjustments; technological progress result in efficiency gains. Restructuring of ownership enhances TFP. Demand influences output and efficiency gains require long-term planning,	2, 81, 83, 130.	TFP using MPI.

		strategic management, and effective market regulations. Government to focus on policy-making leaving planning, financing and investment to private sector.		
Nan, Yiqun, Yuan (2009)	Impact of Reforms and Privatisation on port performance.	Analysed motives of privatisation, privatised activities, option for privatisation in China.		Review Paper
Jiang, Li (2009)	Performance Measurement of Seaports in Northeast Asia	Propose technical efficiency parameters, proved availability of substantial efficiency improvement opportunities & heterogeneity.	2, 81, 85, 86, 122, 123, 129.	DEA – Radial and Non-radial Approach
Panayides, Maxoulis, Wang, & Ng (2009)	Review & critical analysis of DEA as technique measuring port efficiency.	Suggested for use of greater number of input-output variables with adequate sample size.	Review Paper	DEA Model
Chudasama (2009)	Ranking of Indian major ports in 2007	Considering operational indicators and physical facilities assigned weights derived from Principle Component Analysis (PCA).	2, 3, 9, 10, 17, 28, 72, 76, 82, 85, 86, 87, 88, 89, 90, 91, 93.	Weighted Score Method

Guerrero, Rivera (2009)	Total Productivity Changes at Mexican container ports from 2007 to 2009.	Found productivity gains at medium-sized ports. MPI as tool suitable to calculate productivity but need to be supplemented with other strategic planning techniques.	2, 73, 85, 91, 98.	MPI
Caldeirinha, Felicio, Coelho (2009)	European ports performance using financial and operational indicators.	Suggested that port features significantly impact efficiency, performance, competitiveness, & growth. Operational performance depends on location and economic characteristics of the region. Port physical infrastructure investments, specialisation leads to efficiency.	2, 3, 22, 23, 41, 64, 75, 77, 81, 82, 85, 86, 103, 112, 113, 120.	DEA – BCC & CCR
Gonzalez & Trujillo (2009)	Reviewed existing papers on efficiency and productivity at ports.	The study found usage of multiple input and output variables for port efficiency assessment. While DEA is being used in many studies, SFA techniques are not that popular due to difficulty in obtaining in depth data on financial aspects. Study observed that most works proved improvement in efficiency due to port		Review Paper

		reforms. Study also highlighted need for regulators to collect data to be used for better studies. The study concludes that if greater amount of data is made available, better studies could be made.		
Herrera & Pang (2008)	Gauged efficiency at 86 container ports across the world using non-parametric methods.	Study found excess usage of 20 to 40 percent inputs by inefficient ports. Authors observed that huge infrastructure costs at around 40% of total maritime transport costs. Reduction of costs by 12 % by moving from inefficient extreme of the distribution to the efficient would improve efficiency levels. Study also found that at European and Indian ports efficiency & performance to be leading variable. It also suggested that most ports in developing nations can reduce inefficiency by through scale operations.	2, 83, 85, 86, 89	DEA
Jim Wu, Lin (2008)	Implications of port competitiveness in India	Found freight industry to be more competitive than transportation.	2, 3, 4, 6, 18, 24, 42, 48, 53, 73.	DEA

Barros &Mangi (2008)	Efficiency drivers at 39 Japanese Seaports, 2003-2005.	Technical efficiency scores of unique assets exhibit differentiated levels. Hub port strategy improved efficiency. Units with similar asset configurations pursued same strategies & similar performances & differentiated strategies result in different efficiency scores.	2, 3, 17, 85, 86, 100.	DEA Two Stage Model – CCR & BCC.
Pallis, Vitsounis (2008)	Proposed external factors determining port performance.	Efficiency and effectiveness are linked to internal and external information respectively. Ports, often, study internal information ignoring overall assessment.		Review Paper
Chudasama, Pandya (2008)	Measured efficiency of Indian Ports in competitive environment 2002-2006.	Performances have been diverse with some ports registering better technical efficiency and some on scale of operations.	3, 17, 76, 85, 86, 87, 88, 89, 90.	DEA
Sajikumar (2008)	Changing ownership models at Indian major ports	Decentralisation is effective with efficient government regulations and policies with autonomy on operational, financial, administrative and audit aspects to operators.	25, 133.	Review Paper

Ganzalez, Trujillo (2008)	Technical efficiency in port infrastructure services at Spain with reforms 1990-2002.	Proved suitability of distance function to measure technical efficiency. Evaluated efficiencies by capturing multiple outputs and inputs. Proved linkage between location & reforms in technical efficiency.	2, 3, 18, 73, 76, 77, 83,124.	Distance Function
Park, Ro-Kyung (2008)	Verified 24 Korean Container-port Efficiency for 3 years	To understand efficiency and for future planning, results of both techniques used are required.	2, 5, 73, 81, 84, 85.	DEA - Bootstrap Approach
Pallis, Syriopoulos (2007)	Examination of financial performance of governance model at 12 Greece ports.	Port and real reforms go hand-in-hand. Reduced entry barriers in service provision allow competition. Absence of matching environmental-structure-strategy framework adversely affects financials.	40, 52, 54, 55, 56, 57, 58, 59, 68, 69, 71.	Financial Ratios
Haddad, Hewings, Perobelli, Santos (2007)	Studied Post Decentralisation port efficiency improvements in Brazil.	Formal consideration of nodes in transportation network required to consider implications of transportation costs. Choice for investments significantly impacts port-hinterland services.	29, 70, 60.	

Serebrisky, Trujillo (2007)	Studied post reform efficiency gains at Argentinian ports.	Sustainable gains are possible with policies that accommodate environmental factors. Cross-border alliance enhances healthy competition and incentives allow adjustment to changes and cost reductions disseminated to end users.	2, 5, 6, 22.	Review Paper
Langen, Nijdam, & Horst (2007)	Proposed new port performance indicators.	Studied indicators that measure, compare, and trace gaps in performance. Divided operations as cargo transfer, port logistics, and port manufacturing by deriving indicators for them.	9, 30, 62, 66, 101, 114, 115, 116, 117, 118, 119, 121, 132.	Review Paper
Chudasama, Kota (2007)	Compared development and management aspects of Indian Ports with Dubai, UAE, and China ports.	Port and macro-economic development are closely related. Efficient movement of goods in and out of hinterland ensures capacity building.	2, 26, 75, 76, 81, 83, 84, 85, 86, 87, 89, 88, 90.	Review Paper
Cheon (2007)	Impact of institutional reforms on efficiency from 1991 to 2004.	World ports improved due to improved management, technological progress, & scale adjustments. Scale efficiency is a key factor.	2, 21, 83.	DEA and MPI.

		However overdependence on technologies has limitations. Decentralised corporate structure leads to higher productivity.	
Hammer (2007)	Assessed operational performance measures metrics and common mistakes made.	Concluded that measurement metrics, even if developed with strategic systems that are based on tools as balanced scorecard, key performance indicators, computerised dash boards etc., are generally taken with a lack of comprehension of what is important to enterprise success, and of a fundamentally unstructured way of improvement.	
Langen et. al. (2007)	Attempted to development of new port performance indicators to suit changing port ownerships and commercial preferences.	Study found that due to multiple reasons most ports do not maintain port performance indicators in a structured way. Like same performance indicators used by ports differ substantially. The study proposes a couple of potentially useful new PPIs based on the annual reports of leading port authorities.	Review Paper

Kaisar, Pathomsiri, Haghani (2006)	Efficiency measurement of US ports	Identified set of best practices for inefficient ports & sources and extent of inefficiency that port should focus to improve operations.	2, 81, 83, 85, 86.	DEA
Blonigen, Wilson (2006)	Measuring US ports' Efficiency	Proposed model to measure of efficiency & advised commodity-wise comparisons.	122,123.	Regression & Correlation Analysis
Cullinane, Wang (2006)	Efficiency of 69 container terminals with over 10,000 TEUs throughput across 24 European countries during 2002.	With large data, found low efficiency. Found linkage betweent cargo volumes and performance. Proposed further studies on performance and location significance.	2, 83, 85, 86, 87, 88, 89, 90.	DEA – CCR & DEA – BCC.
Cullinane, Wang, Song, & Ji (2006)	Compared DEA & SFA for technical efficiency of container ports	Robust efficiency results derived with models used. Higher technical efficiency associated with scale, greater private-sector participation and transshipment as opposed to gateway ports.		Review Paper
De (2006)	Assessed Total Factor Productivity at Indian ports 1980-81 to 2002-03.	Study found ports to be becoming capital intensive. Study also found that contrary to popular belief,	3, 17, 22, 100,	TFP

		economic climate in post-reform period is yet to make any substantial impact on TFP at Indian ports.		
Tongzon, Heng (2005)	Studied efficiency and competitiveness among selected container ports.	Privatisation to certain extent, but not in total, improves efficiency. Suggested regulatory powers to state, and land ownership and operational autonomy to private sector. Proved linkage between operational efficiency and competitive advantage.	2, 22, 81, 83, 85, 103.	SFA
Lee, Chou, Kuo (2005)	Port Efficiency at 16 Container Terminals in Asia Pacific Region	Ranked selected container ports in Asia Pacific region considering operational efficiency.	2, 6, 20, 24, 73, 76, 83, 85, 86.	Recursive DEA (R-DEA)
Trujillo, Tovar (2005)	Studied evolution of European Port Legislation and checked technical efficiency of European Ports.	Efficiency holds key for policy considerations and reforms with clear mandate to responsible authorities ensure that captive users and tax payers are not required to finance unduly expensive operations.	2, 3, 18, 83, 73.	SFA with Distance Function.
Cullinane, Ji, &	Studied relationship of privatisation on	Neither DEA contemporaneous nor inter-	2, 75, 83, 85, 86,	DEA

Wang (2005)	efficiency at Container ports	temporal analyses showed improvement due to privatisation. Privatisation is no solution for all ills at ports.	87.	
Turner, Windle, & Dresner (2004)	Container Port Productivity in North America between 1984-97	Observed economies of scale at container terminals and linkage between infrastructure productivity and railway connectivity.	2, 81, 83, 85.	DEA
Bichou, Gray (2004)	Performance through logistics and supply chain management	Studied concept of efficiency as vague and assessed its difficulty in applying to port organising that extends into production, trading and service industries.		Action Research Paradigm
Park & De (2004)	rRviewed existing studies on port efficiency measurement across the world.	The study divided overall efficiency into several stages by transforming inputs and outputs in each stage showing efficiencies according to production process and stage-wise role of inputs and outputs.		Review Paper
Puri (2003)	Reviewed experiences of private sector progress in	Linked government policies on privatisation and achievements at		Review Paper

	Indian transport sector.	various subsectors. Identified gaps in government policies and initiatives.		
Estache, Fe, Trujillo (2003)	Efficiency sources with reforms at Mexican terminals between 1996-99	Reforms facilitated new technologies. But some ports lagging behind from expected performance levels.	2, 53, 73.	MPI
De, Ghosh (2003)	Studied relationship between performance and traffic at Indian Ports	Comprehensive policy to improve performance is needed. Indexing helps policy-makers to strengthen weaker factors and overall performance.	6, 9, 10, 28, 32, 37, 52, 57.	Developed composite port performance index with PCA.
De (2002)	Technological changes in Indian ports.	Found productivity, efficiency improvement in Indian ports due to reforms.	2, 9, 52, 61, 76, 85, 86.	Production Function – Linear Programming, K/L ratios.
Tongzon (2002)	Identified and assessed factors of choice and performance for Port Ranking	Factors like high efficiency, shipping frequency, adequate infrastructure, location, low charges, quick response to user needs and reputation for cargo safety are determinants of port selection.	2, 6, 21, 22, 33, 76.	Regression Analysis

Wang, Song, Cullinane (2002)	Reviewed studies assessing efficiency and productivity of container ports	DEA is effective to assess efficiency, subject to exercise of caution over various aspects of usage.	2, 3, 6, 15, 17, 21, 31, 33, 73, 109.	Review Paper
Cullinane, Song, Gray (2002)	Efficiency enhancements at selected container terminals in Asia	Study yielded no definitive and irrefutable link between degree of privatisation and productive efficiency levels.	2, 81, 83, 85, 86, 87, 88, 89, 90.	SFA
Marlow, Paixao (2001)	Proposed theoretical framework for measuring lean ports performance.	Suggested qualitative and quantitative indicators for sustenance development of agile ports. Suggested and measured sub-processes of multi-model process.		Review Paper
Estache, Gonzalez, Trujillo (2001)	Efficiency gains at Mexican ports due to reforms	Efficiency gains of 6-8% observed with better usage of ports infrastructure. However, trends are uneven.	3, 53, 63, 73.	SPA, Cobb-Douglas & Translog Production Function.
Tongzon (2001)	Measured efficiency of 16 Australian & other international ports in 1996.	Assuming linear technology, results show 10 ports as inefficient. DEA is viable measuring option for relative efficiency.	2, 6, 17, 24, 33, 35, 73, 76, 83, 85, 86.	DEA

Hoffmann (2001)	Performance patterns in Latin American ports due to reforms and privatisation.	Government policies like privatisation and landlord model have resulted in efficiency improvements. Found privatisation of port operations to be helpful in structural reforms of economy. Privatisation has resulted in less public involvement in port planning, investment and regulation.	Review Paper
Circha (2001)	Studied concepts of port privatisation and structural adjustment programs at Canadian and US ports to assess effectiveness of Canadian ports.	Study found that in spite of contemporary reforms, US ports have performed well and that Canadian ports reforms need to a number stringent policies to unshackle them from the constrains of federal government control. The study also suggested that Canadian ports reforms need to take up multi-stage process to make them work on commercial lines.	Review Paper
Juhel (2001)	Studied need for public private partnership in port developments	Found a need for better coordination among various stakeholders to enhance port efficiency in the reform setup. Study	

		suggested for a conductive environment with institutional framework for optimal utilisation of facilities, distribution of risk and reward in privatised scenario. Study advised regulatory support of government to facilitate private operations.		
Haralambides & Behrens (2000)	Port Restructuring in India.	Multiplicative effects of foreign investments on entire economy, technology and know-how transfer are awaited. Policies should offer foreign investors attractive terms and returns.	2, 3, 6, 9, 10, 17, 28, 37, 74, 102.	Review Paper
Sunder (2000)	Port Restructuring in India	Government aims for landlord port model. Assessed existing constraints and found long scope and need for government initiatives.		Review Paper
Baird (1999)	Studied on port privatisation models, their prioritisation, essential elements involved in effective functioning of port.	Concluded that privatisation results can be obtained only when adequate & comprehensive supportive mechanism exists in the system.		Review Paper

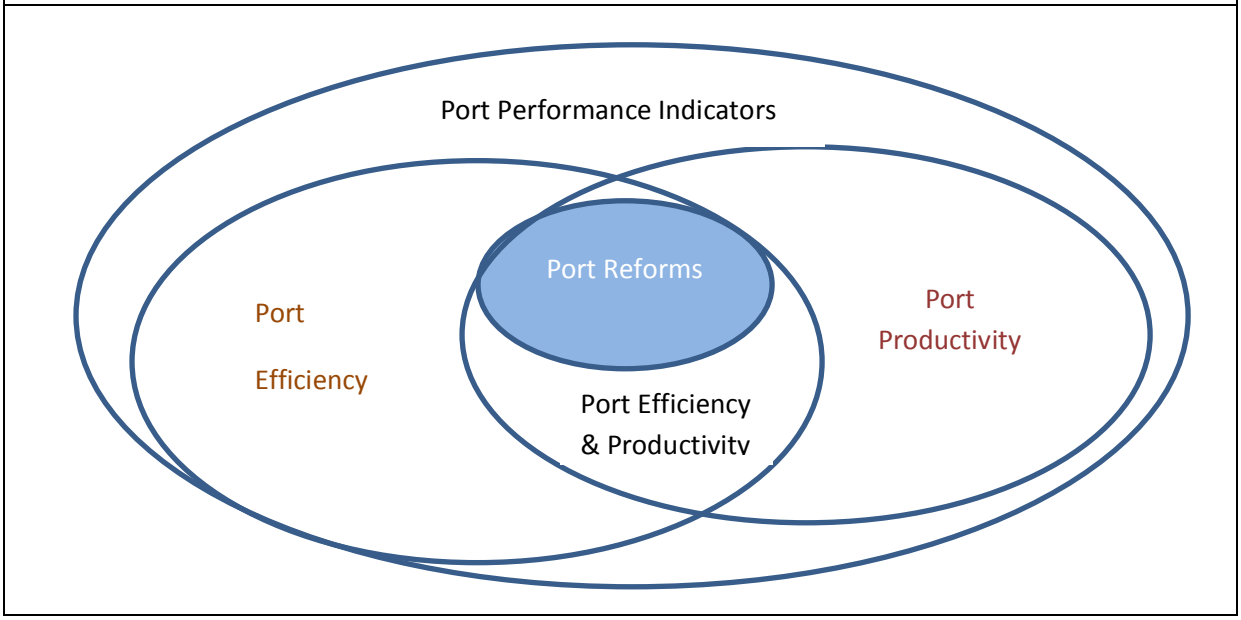
Neely et. al. (1997)	Proposed a technique for solving problems of performance measurement at manufacturing sector.	Concluded that performance measure record sheet tested on 200 managers of 50 companies has given positive results.		Review Paper
Poitras, Tongzon, & Li (1996)	Efficiency ranking of 5 Australian and 18 international ports.	Methodological contribution demonstrates DEA as viable option allowing multiple factors to get relative efficiency/inefficiency by giving chance for raking.	2, 17, 19, 35, 85.	DEA
Liu (1995)	Checked performance of public and private ports in Britain.	Study could not establish ownership to be a significant factor of production. Study could not prove that private ports perform better than publicly owned ports.	53, 100	Frontier Production Models
Tongzon (1995)	Empirical relevance of terminal efficiency and overall port performance factors.	Developed a model proving terminal efficiency as vital just like any waterfront reform for improving performance and efficiency.	17, 23, 38, 39, 64, 65, 67, 75, 93.	Multiple Linear Regression– Two Stage Least Square, Ordinary Least Square, Goldfield – Quandt Test

Author wise list, given in the above table, has given an opportunity to have a bird's eye vision of the studies on port efficiency, productivity, and ranking across the world. It has also given an opportunity to understand the techniques applied by various authors to measure the working of ports. Impact of reforms on port efficiency, productivity, and ranking has been one another key learning from the above cited works. Finally, this review has given some clarity on tracing gaps in the existing literature that cover themes of port efficiency, port productivity, port ranking, and impact of port reforms on their working.

2.10 Thematic Review of Literature:

To have a clear vision on the evolution and flow of research made till now, reports and literature collected through the search process are categorised into broad themes of Port Performance, Port Efficiency, Port Productivity, and Impact of Reforms on Port Efficiency and Productivity for further understanding. Segregation into different themes is made with an intention to synthesise on the manner in which the sector has evolved, its growth trends, and the modes in which researchers have attempted to assess this sector. The following Figure 2.1 depicts the thematic segregation along with their overlapping. It shows that both efficiency and productivity are based on port performance indicators. The review has led to gathering of literature where authors have assessed on efficiency, productivity, efficiency and productivity, and post-reform efficiency and productivity.

Figure: 2.1 Thematic Segregation of Literature



2.11 Studies on Port Performance, Efficiency, & Productivity:

'*Performance*' represents capability of doing some work. Port performance is comparison between port's actual performance vis-à-vis targets. Numerous reports and research works have proposed a variety of methods to measure port performance. However, strangely, none has defined 'port performance'. "Given that robust theory building and accurate interpretation of empirical data cannot take place before formal definitions are established." (Wacker, 2004)

Port performance may be evaluated from the standpoint of technical efficiency, cost efficiency and effectiveness by comparing the port's actual throughput with its economic technically efficient, cost efficient and effectiveness optimum throughput, respectively (Tally, 2007).

2.12 Indicators of Port Performance:

United Nations Conference on Trade and Development (UNCTAD), 1976 report on Port Performance Indicators identified two primary reasons for calculation of performance indicators as usage of such data for improving port operations and also as an appropriate basis for planning future port development. The report framed financial indicators and operational indicators providing information on as follows:

Table 2.4 Port Performance Indicators specified by UNCTAD, 1976

Financial	Operational
1. Tonnage worked	1. Arrival rate
2. Berth occupancy revenue per ton of cargo	2. Waiting time
3. Cargo handling revenue per ton of cargo	3. Service time
4. Labour expenditure per ton of cargo	4. Turn-around time
5. Capital equipment expenditure per ton of cargo	5. Tonnage per ship
6. Total contribution	6. Fraction of time berthed ships worked
7. Contribution per ton of cargo	7. Number of gangs employed per ship per shift
	8. Tons per ship hour in port
	9. Tons per ship hour per berth
	10. Tons per gang hour
	11. Fraction of time gangs idle

The indicators suggested by UNCTAD, 1976 report was followed by suggestions of various researchers working for World Bank and other agencies.

Kek Choo Chung (1993) suggested, apart from the proposals of UNCTAD, for extensive and intensive utilisation of physical assets and financial benefits of operations as key for port efficiency measurement. The work done on behalf of World Bank, further proposed for bifurcation of ship turnaround time on the basis of type of ships; tonnage per day/hour; congestion status at port; homogeneity of cargo handled; cargo based dwell time; asset utilisation; berth efficiency; and GRT/NRT based financial comparison to trace real efficiency of a port.

Patrick Fourgeaud (2000) proposed customised approach of indicators to monitor port performance, forecast development and set targets in port sector projects. While highlighting need for reliability of data collected, the author suggested that data maintained by port on their operations are reliable in comparison to data on landward operations. Further, based on objective of the individual study, selection of indicators would differ for each of the port being measured. The study found that while the port authorities concentrate on technical efficiency, shipping lines look for schedules of ship handling, costs involved, quality of services, port's adaptability to handle customised cargo, performance standards, and hinterland connectivity.

It may, however, be noted that as the port sector grew as a body of knowledge and as a sector in a competitive business environment over a period of time, new indicators tend to evolve (De, 2002). From the above it is evident that identification of new indicators is still in progress, especially, with the concept of privatisation being taken up seriously around the world.

The indicators so proposed would be useful for policy makers and port authorities to assess and understand the working of their ports and formulate policies and measures to streamline the developments in this vibrant sector of economy. The indicators are useful for checking the performance of both publicly owned and privately owned ports.

2.13 Port Efficiency – World Scenario:

Port efficiency has been an issue of interest and debate among policy makers and researchers alike. While efficiency gains are expected to steer future development plans for policy makers, development of new and improvement of existing techniques for assessment are of greater interest to the researchers.

A total of 51 research works on port efficiency across the world by various authors including (Navarro-Chavez & Zamora-Torres 2014; Dooms 2014; Pagano et. al. 2013; Hargono et. al. 2013; Wang et. al. 2013; Caldeirinha et. al. 2013; Pjevcevic et. al 2013; Chu et. al. 2013; Barros et. al. 2012; Khalid 2012; Odeck & Brathen 2012; Lightfoot et. al. 2012; Adolf K.Y. Ng 2012; Wanke et. al. 2011; Brooks et. al. 2011; Liu 2011; Padilla & Eguia 2010; Wu & Goh 2010; Simoes & Marques 2010; Ablanedo-Rosas 2010; Cheon et. al. 2009; Jiang & Li 2009; Caldeirinha 2009; Panayides et. al. 2009; Herrera & Pang 2008; Barros & Mangi 2008; Pallis & Vitsounis 2008; Ganzalez & Trujilo 2008; Pallis & Syriopoulos 2007; Haddad et. al. 2007; Langen et. al. 2007; Kaiser et. al. 2006; Blonigen & Wilson 2006; Cullinane & Wang 2006; Cullinane et. al. 2006; Tongzon & Heng 2005; Lee et. al. 2005; Trujillo & Tovar 2005; Bichou & Gray 2004; Tovar de la Fe & Trujillo 2003; Tongzon 2002; Tongzon 2001; Cullinane et. al. 2002; Marlow & PAIXAO 2001; Liu 1995; Tongzon 1995) reveal the usage of various indicators to gauge the efficiency of ports. Based on the type of studies being made, different authors have selected different variables for their research. At times the variable selection also depended on availability of data from reliable sources.

For a better assessment on research works on port efficiency, they are further classification and presented in the following sections. The first section covers research works that reviewed existing literature, the second concentrates of research works that assessed linkage between port efficiency and economic development, the third section has research papers that attempted to assess linkage between environmental factors and working of ports, the penultimate section encapsulates research papers that linked efficiency to its location and type of services provided at ports, the segment attempts to relate port ownership to its efficiency.

1. **Few of the researches attempted to know the level of studies existing in port sector & review papers**

Measurement of port performance has been an issue for a long time now. But, as most of these ports were under the control of government, research on their performance did not get the required quantum of attention. A few of researchers attempted to assess the level and mode of studies existing of port sector. Dooms (2014) argued that the academic research on port level industry has been relatively low in comparison to other infrastructure industries. Ntow-Kummi (2012), assessing port performance, concluded that existence of different definition and different objectives make performance measurement a challenge. Current performance monitoring system is unable to measure overall performance because of its concentration on the ship-shore interface. They ignore land-side activities. Odeck & Brathen (2012) attempted meta-analysis of DEA and SFA studies on technical efficiency of seaports. The study compared fixed-effects versus random-effects *Tobit* model with mean technical efficiency estimates to and found latter to be a better model. Panayides et. al. (2009) reviewed and critically assessed usage of some of the technique employed for measuring port efficiency. The study suggested for use of greater number of input-output variables with adequate sample size. Esu & Inyang (2009), studying port performance concluded that absence of Performance Measurement Standards (PMS) has contributed to high rate of business failures in public sector. Pallis & Vitsounis (2008) reviewed existing literature of efficiency and proposed external factors in determining port performance and found that ports, often, confine to assessment through internal information by ignoring overall assessment. They suggested that for a holistic picture on efficiency and effectiveness further studies based on both internally and externally generated information are required. Langen et. al. (2007) proposed new port performance indicators to measure, compare, and trace gaps in performance. The study divided port operations as cargo transfer, logistics, and manufacturing and derived indicators for these operations. Cullinane et. al. (2006) compared DEA & SFA for technical efficiency of container ports. Researcher concluded that robust efficiency results are derived with DEA or with distributional assumptions of SFA. The study also observed higher technical efficiency associated with scale, greater private-sector participation and transshipment as opposed to gateway ports. Park & De (2004) reviewed existing studies on port efficiency measurement across the world. The study divided overall efficiency into several stages by transforming inputs and outputs in each stage showing efficiencies according to production process and stage-wise role of inputs and outputs.

Marlow & Paixao (2001) reviewed existing research works to propose theoretical framework for measuring lean ports performance and suggested that both qualitative and quantitative indicators to be significant for sustenance development of agile ports.

The above works suggest that ports under public sector were not studied extensively and that the variables considered in existing studies do not provide a holistic picture of port efficiency. The studies also suggest that progress observed in port efficiency is more due to growth in world trade and not due to the inherent efficiencies of ports.

2. Impact of ports on economy of a country are studied by authors including

Ports hold a significant status in an economy and their efficiency/inefficiency influences the growth trends of the nation. However, they are setup as public sector entities and studies on their performances are limited due to non-availability of data in public domain. Some of the research works attempted to focus on relationship between ports and an economy.

Hargono et. al. (2013), studied correlation and interrelationship between export activities and growth in other sectors of the economy and concluded that developments in economy & increasing income with people attract port users towards greater level of foreign trade. Wu & Goh (2010) assessed efficiency of port operations in emerging markets and found that regardless of input-output volumes, planning facilities based on actual cargo demand achieves efficiency. They also observed that ports of emerging economies lack heavy equipment but are operationally competitive than most of the advanced ports. Trujillo & Tovar (2005) studying evolution of European port legislation checked their technical efficiency. The research suggested that efficiency holds key for policy considerations and reforms with clear mandate to responsible authorities ensure that captive users and tax payers are not required to finance unduly expensive operations.

These studies prove the significance of ports in an economy. But, it is important to note that ports do not work in isolation and their efficiency is depended on multiple factors, including the environment in which they exist. Port performance is influenced by the growth in activities of different stakeholders.

3. **Environmental Factors**:

Interestingly, port efficiency is also influenced by numerous environmental factors and some of the research works addressed this segment to ascertain its level of impact on ports across the world. Bergantino & Musso (2011) attempted to study various influencing factors on port efficiency by using a multi-step approach by checking both external and internal factors. The study found environmental factors such as economic condition, port accessibility, and employment level to have varied degree of influence on port efficiency. Liu (2011) evaluated operational efficiency of 10 Asia-Pacific Ports for 1998 – 2001 and traced lower port efficiency by ignoring environmental factors, managerial inefficiency, and statistical noises. Tongzon (1995) studied empirical relevance of terminal efficiency and overall port performance factors. The study developed a model and proved terminal efficiency as vital, just like any other waterfront reforms, for improving performance and efficiency.

From the above, one can understand that port grow in tandem with the growth of other segments in the economy and that both external and internal factors influence their working to a greater extent.

4. **Impact of port services & location on efficiency**:

While environment plays an important role in port efficiency, port location and services provided by a port will also have an impact on efficiency. Locational advantage gives an additional boost in attracting shippers. State of art services apart from mere cargo handling act as combos for improving the working of a port. Researchers who have worked on this segment include, Barros et. al. (2012) assessed operational efficiency improvements at 23 Brazilian ports for the period 2004-2010 due to technological advancements and further traced port location as strategically important to attract business. Ng, Adlof (2012) studying the impact of growth strategies on port performance found that ports in East Asia have gradually reemphasised from technical efficiency and capital investments to regional competitiveness, catalysed by rapid transformation of the global and regional economies. Pjevcevic et. al. (2012) measured Siberian river port efficiency and identified sources of inefficiency. The study proposed some measures for improvement in port services to enhance overall efficiency. Brooks et. al. (2011) attempted to assess user perception on efficiency at Canadian Ports. They traced differences in user perception during evaluation level of

satisfaction, competitiveness and service delivery effectiveness. Padilla & Eguia (2010) studied relative efficiency of 8 government oriented seaports in Mindanao from 2001 to 2006. Technical and allocative efficiencies results show that they are not influenced by geographical location and administrative subordination. Simoes & Marques (2010) studied operational efficiency levels of 41 European ports during 2005 and found inefficiency by reducing noise, presence of outliners and its dimensions. Jiang & Li (2009) studied performance measurement of Seaports in Northeast Asia. They proposed technical efficiency parameters, proved availability of substantial efficiency improvement opportunities and heterogeneity. The study further suggested that proper management of ports and markets leads to enhancement of efficiency. Caldeirinha (2009) assessed European ports performance using financial and operational indicators and found that port characteristics significantly impact efficiency, performance, competitiveness, and growth. The study also traced dependence of operational performance of a port on location and economic characteristics of the region. The research work further found that port physical infrastructure investments, specialisation would also lead to efficiency. Ganzalez & Trujilo (2008) studied technical efficiency in port infrastructure services at Spain during 1990-2002 and proved suitability of distance function to measure technical efficiency. The study evaluated efficiencies by capturing multiple outputs and inputs and traced location advantage as leading factor in efficiency improvement. Barros & Mangi (2008) assessed efficiency drivers at 39 Japanese Seaports between the years 2003–05 and concluded that hub port strategy has resulted in improved efficiency. The study further suggested that units with similar asset configurations pursued similar strategies and with similar performances and differentiated strategies result in different efficiency scores. Haddad et. al. (2007) estimated measures of efficiency for different ports in Brazil using international trade data. The study evaluated efficiency gains under three scenarios of achieving international standards, impact of decentralisation of port management, and regional differentiation. Kaisar et. al. (2006) assessed efficiency at selected US ports and identified a set of best practices for inefficient ports. The study suggested that sources and extent of inefficiency that a port should focus to improve operations. Blonigen & Wilson (2006) measured efficiency levels at US ports and proposed new measures of efficiency. The study also suggested for commodity-wise comparison of efficiency improvements. Bichou, Gray (2004) studied performance of logistics and supply chain management with relevance to port sector. This study found that the concept of efficiency to be vague and its assessment to be difficult at port organisation. It further suggested that port activities extending into production, trading and service industries make assessment more

complex. Estache et. al. (2003) studied sources of efficiency improvement at Mexican terminals between 1996 and 1999. The study observed constrained efficiency improvement at ports in spite of improved technologies with a large gap between actual and expected performance levels. Tongzon (2002) studying factors influencing port choice, identified factors like high efficiency, shipping frequency, adequate infrastructure, location, low charges, quick response to user needs and reputation for cargo safety as key determinants of port selection. Tongzon (2001) measured efficiency of 16 Australian & other international ports for the year 1996. Assuming availability of linear technologies, the study assessed DEA results and found 10 ports to be inefficient. The study also concluded that DEA as a suitable and viable option to measure relative efficiency. Weille & Ray (1974), studied capacity of port operations that can maximise the net benefits to both port authority and ship owners and concluded that specialised berths would enhance the performance for ports. The study also suggested that reduction in service time can enhances efficiency levels.

An understanding of the above segment, leads us to endorse the inference that a port is influence by its location and nearness to markets. Infrastructural support at the location of the port will help it to better its performance and meet the requirements of its clients. However, public sector ports could not take some of these advantages and thus, port privatisation process has come into picture across the world. Privatisation of ports was initiated with an intention of efficiency improvements (Cullinane et. al. 2005). The degree and pace of privatisation across the world has not, probably, given same results (Tongzon & Heng 2005).

5. **Public and private sector ports**:

With the advent of private sector into port segment researches compared the performance of public and private sector ports. Arguments supporting and opposing privatisation of ports have gathered momentum across the world. Researchers also attempted to trace the possible and actual improvements in efficiency due to port privatisation. Wang et. al. (2013) assessed efficiency levels at 46 privatised and publicly operated US ports during 1997-2006 and found improved financial performance due to privatisation. Wanke et. al. (2011) studied efficiency determinants at 25 Port terminals in Brazil and grouped efficiency indicators on the basis of inputs and outputs for production function analysis. The study found private terminals are more efficient in comparison to publicly owned terminals. Cheon et. al. (2009) checked efficiency gains with reforms across 98 ports from 1991 to 2004 and found better

management and container operations, scale adjustments, and technological progress resulting in efficiency gains. They also found that demand for port influences throughput and for efficiency gains long-term planning, strategic management, and effective market regulations are required. The study further suggested that government should confine to policy-making and private sector should concentrate on planning, financing and investing in port infrastructure. Pallis & Syriopoulos (2007) examination financial performance at 12 Greece ports under different governance models. The study propounded need for port and real reforms in an economy to go in tandem. The study traced that relaxation in entry and exit barriers in service provisions would improve competition among ports. The study also found that absence of matching environmental structures and strategies would adversely impact financial efficiency of port. Liu (1995) checked the performance of public and private ports in Britain and found no strong relationship between privatisation and gains in usage of the factors of production. The study could not prove that privately owned port perform better than publicly owned ports.

The later part of 20th century, apart from privatisation, is marked with a major development in cargo composition called 'Containerisation'. Cargo movement through containers has gained momentum due to its natural advantages such as ease of carrying and speedy movement. Dedicated terminals to handle container cargo have evolved and researchers have started gauging their efficiency levels. Studies by researchers like Navarro-Chavez & Zamora-Torres (2014) analysed allocative and economic efficiency of 32 container ports across the world for the year 2012. The results on efficiency realised the need to advance strategies for reduced costs and a better mix of inputs. Pagano et. al. (2013) compared financial efficiency and effectiveness at various ports of Panama, and US with varying degree of privatisation. The study assessed 10 privatised container ports and found gains in efficiency due to privatisation. Caldeirinha et. al. (2013) studied influence of infrastructure on efficiency, productivity, activity level, and customer satisfaction at 12 Portuguese and Spanish container terminals and found strong relationship between privatisation and efficiency gains. The study was aimed to know disparity in success among container ports using smaller sample size. Chu et. al. (2013) checked the operational performance assessment at selected container ports. The study assessed opportunities available for development of significant predictive models to improve annual throughput. Khalid (2012) measuring performance of Malaysian container ports noted that in spite of existence of common way to measure performance among stakeholders, it is important have some key differentiating factors to compare performance of efficient and

inefficient ports. The study suggested that the factors driving and influencing performance of different ports differ due to numerous environmental constraints. Port's competitiveness and environmental complexities might hamper the performance of even better ports. Lightfoot et. al. (2012) studied output and input relationship at 5 Australian container ports during 1997 – 2010. The research observed improvement in labour and total factor productivity (TFP) with decreasing returns to scale. Herrera & Pang (2008) gauged efficiency at 86 container ports across the world using non-parametric methods. The study observed excess usage of 20 to 40 percent inputs by inefficient ports. The authors observed that if the current level of 40% infrastructure costs can be reduced to 12%, all the inefficiency ports can revive and become efficient. They also suggested that most ports in the third world can reduce their inefficiency by contracting scale of operations. Park & Ro-Kyung (2008) verified efficiency of 24 Korean Container ports for period of 3 years to understand efficiency and for future planning. The study found efficiency gains at most of the ports due to privatisation. Cullinane & Wang (2006) studied efficiency of 69 container terminals with over 10,000 TEUs throughput across 24 European countries during 2002. The research used large data and found low efficiency under two DEA techniques of CRS and VRS. The study also found that ports handling higher volumes registering better efficiencies. Tongzon & Heng (2005) studied efficiency and competitiveness among selected container ports. The research traced that privatisation to certain extent, but not in total, improves efficiency. The study also suggested that regulatory powers over ports should be with government and land ownership along with operational autonomy shall be with private sector operating such ports. The study further suggested that higher operational efficiency will give competitive advantage to a port. Cullinane et. al. (2002) reviewed efficiency enhancements at selected container terminals in Asia. Study yielded no definitive and irrefutable link between degree of privatisation and productive efficiency levels.

Researchers who assessed privatisation of ports, by and large, have found that it resulted in efficiency gains across the world. However, few of the authors (Tongzon & Heng 2005) suggested existence of strong policy and regulatory environment from the government's side. They have also highlighted the need for regular checks on performance of private sector ports. They have identified a need for a strong mechanism and with comprehensive indicators for holistic assessment of port performance. It can also be inferred that privatisation process should be backed with strong policy framework and government control. (De, 2002).

2.14 Outcome – World Port Efficiency:

The above research demonstrates existence of works on operational efficiencies of port performance. However, an in depth probe proves the inclination of researchers to work more on berth side efficiencies. This has resulted in overlooking of many other activities, inkling yard side operations, of ports. It may also be observed that due to numerous compelling compulsions, such as lack of data availability, the existing studies could not provide a holistic picture on port efficiency. Financial parameters which play a vital role in port efficiency are rarely used. At the same time most studies concentrated on container terminals leaving bulk cargo segment which is still a dominant part of port industry. The timeframe considered in most of these studies extended from 1 year to 10 years.

2.15 Port Efficiency – Indian Scenario:

Considering the requirement of the preset study, it is important to know about the research works done on India ports and trace the present status of research and their existing gaps. Ports in India have been under government control for a long time and it was only after the liberalisation program of 1991 that private sector was allowed into this sector. Presently 100% FDI under automatic route is allowed in this sector. Even at the publicly owned major ports, private participation is allowed from the year 1995-96 through PPP mode. Research works covering Indian ports are limited, especially, during the public sector regime. But a lot of interest among researchers to check the efficiency of ports has given rise to some studies on the performance of 12 of the major ports of India. 11 research works by various authors including (Rajasekar et. al. 2014; Mokhtar & Shah 2013; Rajasekar & Deo 2012; Rajasekar, Deo 2011; Bhatt & Gaur 2011; Gaur et. al. 2011; Nihar 2011; Ghosh et. al. 2010; Wu & Lin 2008; Chudasama & Pandya 2008; Chudasama & Kota 2007; De & Ghosh 2003) were reviewed to understand the efficiency gains at major port in India.

Rajasekar et. al. (2014) measured operational efficiency of selected Major Ports of India 1993-2011 and proved that size of a port does not determine efficiency. The study found smaller ports giving competition to bigger ports in efficiency. The study suggested that long-term plans must be envisaged by ports to upgrade infrastructure facilities to maintain efficiency. For port experiencing scale inefficiency, the study suggested for modernising the ports. Mokhtar & Shah (2013) studied operational efficiency and found strong relationship

between size and efficiency at selected container ports. The study found efficiency enhancement with resource allocation and operations but not due to terminal size. Dama & Zawar (2013), aimed to study the growth economy and Indian sea ports found positive correlation with GDP. But the growth of non-major ports has higher correlation with the growth in GDP. Rajasekar & Deo (2012) studied linkage between size and efficiency at Indian major ports 1993 – 2011 and proved little influence of size on efficiency. The study further suggested containerisation and long-term planning for productivity. Rajasekar & Deo (2011) studied efficiency of Indian major ports from 1995-96 to 2007-08. The study probed reasons for different levels of performance and traced poor facilities at port infrastructure to be reasons for lower performance. Bhatt & Gaur (2011) probed the impact of containerisation on port efficiency at JNPT and Mundra Port Trust. The study traced improvement in berth operational efficiency due to containerisation and privatisation. Gaur et. al. (2011) assessed efficiency at Indian ports and proposed alternatives for enhancing efficiency. The authors stressed on improved capacities from effective to potential and then to absolute levels at Indian ports. Nihar (2011) forecasted capabilities of Indian Major Ports on the basis of their current performance. The study suggested that capital investments, business & operational acumen to be prerequisites for efficiency improvement. The research emphasised that policies on handling multiple commodities, availability of operational berths for foreign ships, and increasing idle time required. Ghosh et. al. (2010), working on growing Indian Port sector and need for private investments observed that extent of participation and investment interest shown by the private sector in different spheres of port activity despite several constraints would help in the overall growth of the sector in future. The study suggested that favorable demand-supply dynamics may support growth, the business and financial risk profiles of the port entities would have to contend with the risks arising from high project capital expenditure and temporary over capacity in container handling, besides various regulatory and systematic risks. Deveshwar (2010), tried to trace relationship between port capacity and its influence on infrastructure development found significant correlation between the two. The study suggested for investor-friendly policies by government, especially, in raising funds. The author further suggested for policy refinements like amendment of certain Acts to make the sector lucrative for private investments. Wu & Lin (2008) studied the implications of port competitiveness in India and found Indian freight industry to be more competitive than transportation. The study found that India with relative comparative advantage over many other industrilised countries needs to overhaul its port infrastructure to accommodate growing volumes of imports and exports. Chudasama & Pandya (2008) measured efficiency

of Indian Ports in competitive environment for the period 2002 to 2006. The study observed diverse performances with some ports registering better technical efficiency and some on scale of operations. The study found that performance of ports is highly depended on efficiency levels to utilise resources and so measuring port efficiency can reflect their status quo and reveal their advantages and disadvantages in competitive environment. Chudasama & Kota (2007) compared development and management aspects of Indian Ports with Dubai, UAE, and China ports. The study traced close relationship between port and macro-economic development. Authors concluded that efficient hinterland connectivity for movement of cargo ensures capacity building.

2.16 Outcome – Indian Port Efficiency:

From the above studies it is evident that Indian ports are slowly showing signs of improvement in their efficiency. These gains are primarily due to improvement in economic activity in the country that has influenced growth in foreign trade. The studies prove that improvements in physical infrastructure at ports, Containerisation, improved investments, and proactive government policies have helped in efficiency enhancements at major ports. The studies highlight a need for long-term planning including hinterland connectivity for improving overall efficiency of these ports. However, since the studies concentrated on berth side activities, a holistic picture covering all activities of ports is still not assessed.

Finally, it may be concluded that, most studies concentrated on assessing operational efficiency on berth side activities of a port. It may be noted that port efficiency refers to overall port efficiency which includes both berth and yard side activities.

2.17 Port Productivity:

After efficiency, ports across the world are assessed on the basis of their productivity. Productivity, in general terms, is defined as metrics and measures of output from production processes per unit of input. Port and terminal operators are expected to implement best possible practices and cost-cutting initiatives, lean organisations and lean operation processes so as to maintain productivity even during periods of recession. The recent economic slowdown across the world has mandated this sustainability more critical for long term productivity for ports. The economic slowdown of 2008 has hit both the container and bulk

cargo movement alike and resultantly squeezed prospects of port sector. However, this crisis has strongly vindicated importance of cost compositeness, reliability and performance, and has shaped greater demand for improving performance, enhancing reliability, and use of measurement standards.

A total of 8 research works on port productivity reviewed include 7 on world ports and 1 on Indian ports includes that of Baran & Gorecka (2014), Song & Cui 2014, Schellinck & Brooks 2013, Caldeirinha et. al. 2013, Gonzalez & Trujillo (2009), Turner et. al. 2004, Poitras et. al. 1996, and De 2009; are listed below.

Baran & Gorecka (2014) checked efficiency and productivity gains at selected ports across the world. To access port performances in competitive environment, the study also decomposed efficiency into technical efficient, technological efficient, scale efficient, pure technical efficient, and pure technological changes. The study successfully showed efficiency and productivity level of the ports selected for the year 2012. Song & Cui (2014) studied efficiency at Chinese container terminals being invested by coastal provinces and municipalities. The study considering the years 2006-2011 attempted to trace productivity improvements. The study traced improvement in productivity due to technological progress. Technical growth which is possible due to improvements is due to scale efficiency has little influence on productivity. Shanthirathne (2014), analysing the improving Productivity & minimising vessel stay at port concluded that Proposed PM pool concept is aimed to reduce congestion, improve vessel operation, improve crane productivity, and vessel turnaround time. Schellinck & Brooks (2013) attempted to identify and prioritise investments at ports to enhance productivity. Proposed mapping process on determinant/ performance gap analysis and addressed conflicting signals among methodologies evaluating effectiveness and help investments. Caldeirinha et. al. (2013) assessed influence of infrastructure on efficiency, productivity, activity level, and customer satisfaction at 12 Portuguese and Spanish container terminals. The study was made to know disparity in success among container ports using smaller sample size. Gonzalez & Trujillo (2009) Reviewed existing papers on efficiency and productivity at ports. The study found usage of multiple input and output variables for port efficiency assessment. While DEA is being used in many studies, SFA techniques are not that popular due to difficulty in obtaining in depth data on financial aspects. Study observed that most works proved improvement in efficiency due to port reforms. Study also highlighted need for regulators to collect data to be used for better studies. The study concludes that if

greater amount of data is made available, better studies could be made. Al-Eraqi (2009), Evaluated the seaport productivity for their future planning and operating strategies found that port productivity improvements observed at port side. Turner et. al. (2004) studied container port productivity in North America between the years 1984-97 and observed economies of scale at container terminals. The study found strong linkage between infrastructure productivity and railway connectivity.

2.18 Outcome – Theme Port Productivity:

From the above studies on port productivity aiming container terminals prove efficiency gains at ports due to containerisation of cargo. Studies also prove influence of infrastructure facilities, hinterland connectivity for port productivity. Some of the researchers have also ranked ports on the basis of their productivity. However, as highlighted in some of these studies, an improvement in number of variables considered and coverage of time frames is expected to bring a better and holistic picture of port productivity.

2.19 Impact of Reforms Port Efficiency and Productivity Improvement – World Scenario:

Port reforms have been one of the major developments across the world ports during the latter part of 20th century. Governments across the world have contemplated change in ports ownership from public ownership to private management. Privatisation of ports has happened in numerous manners and at various levels. With the process of privatisation, curiosity of researches and policy makers on efficiency and productivity enhancements due to reforms has also evolved. Research works addressing improvements in port efficiency and productivity due to reforms and change in ownership are reviewed and include that of, Wang et. al. (2013) studied efficiency levels at 46 privatised and publicly operated US ports during 1997-2006. The study found improved financial performance of the ports due to the process of privatisation. Yang et. al. (2013) assessed the progress in port throughput in China with the backdrop of reforms from 1952 to 2009. Study found positive correlation between growth in throughput and investments. Also traced that port throughput is influenced by macro-economic policies. Obed & Ndikom (2013) assessed port privatisation policy and productivity in Nigeria. Submitted reforms have improved efficiency & productivity resulting

higher revenue and cargo volumes at the ports considered for study. High dedication among shippers and workers observed. Diaz-Hernandez et. al. (2013) evaluated impact of reforms on port productivity in Spain. The study also measured impact of efficiency and technical aspects during reform period and found initial improvements but stagnant technologies affected technical efficiency. Rodriguez-Alvarez & Tovar (2012) studied reforms and ownership models on Spanish ports during 1993-2007. Found strong relationship between pace of economic reforms to port efficiency. Suggest for proactive reforms for better efficiency among ports due to private sector participation. Halkos & Tzeremes (2012) measured productivity at Greek seaports' between 2006 and 2010. Found direct relationship between number of terminals and port productivity. Observe lack of adequate number of terminals, shorter berths and stagnated technology to negatively influencing productivity. Xu & Chin (2012) considered devolution effects of port governance on seaports and river ports of China. Found efficiency gains and success in problem solving due to change in governance. Found development of ports due to reforms and open door policy of government of China. Nwanosike et. al. (2012) evaluated impact of reforms on efficiency improvements at 6 Nigerian ports 2004 - 2010. The study found significant improvement in cargo throughput and traffic with concessionaire agreements. Verhoeven & Vanoutrive (2012) assessed role of port authorities in changing environment where newer port governance models are being contemplated. The article provided quantitative assessment using factor analysis to identify elements that explain diversity in governance of European ports. The study found diversity in governance models European ports. Kent & Hochstein (2011) assessed impact of limited competition on port reforms and privatisation in Colombia, Costa Rica, & Nicaragua. The study offered guidelines that can help assure ports competitive pressures even with limited cargo volumes. Xiao et. al. (2010) worked on integrated economic model to analyse effects of port ownership, competition, capacity investment, and pricing at ports. The study developed a model to prove that capacity investments and congestion level are influenced by ownership forms, presence of inter-port competition and possible externalities due to port operation. The study further proposed a good framework to analyse a range of ownership options within one consistent model. Theys. C & Notteboom (2010), identifying key Considerations in awarding concession projects in European port sector found that by linking the economic theory of contract length to empirical evidence proved that investment-specific conditions are key elements in determining concession duration. There exists a strong relationship between concession duration and operator's ROI. Besides company-and-project-specific factors such as investment levels and operational

costs, decisions on taxation, potential revenue guarantees and concession fee structure will influence private investments. Cheon et. al. (2009) deliberated on efficiency gains with reforms 98 ports across the world from 1991 to 2004. Suggest that improved management and container operations; scale adjustments; and technological progress resulted in efficiency gains. Observe enhancement in total factor productivity due to restructuring of ownership through privatisation. Also found demand influences throughput and efficiency gains require long-term planning, strategic management, and effective market regulations. Argue for government focus on policy-making and private sector taking active role in planning, financing and investment at ports. Nan et. al. (2009) studied impact of Reforms and Privatisation on port performance. Analysed motives of privatisation, privatised activities, option for privatisation in China. Found enhancement in productivity of ports due to reforms. Guerrero & Rivera (2009) studied total productivity changes at Mexican container ports from 2007 to 2009 and found productivity gains at medium-sized ports. Suggest that Malmquist Productivity Index as tool suitable to calculate productivity but need to be supplemented with other strategic planning techniques. Cheon et. al. (2009) argued for stronger role of government in policy-making and engagement of private sector in planning, financing, and investment at ports. However, it may also be noted that most of these studies concentrate on container ports and terminals. Chen (2009), trying to trace the role of Port Authority after reforms and support it provides to ports in Taiwan aimed to identify the pitfalls, in any, in the process. The study found that port restructuring program is based on commercialisation basis and has some pitfalls. Port regulatory functions need to be with national authority (as landlord mode) and port need to corporatised. Wrong and delayed policies may affect the efficiencies of Taiwan ports. Nan et. al. (2009)**,** working on port privatisation and inflow of investments found that port reforms brought in more investments into the sector giving a chance to the government to own and let operations given to private parties. Ganzalez & Trujillo (2008) evaluated technical efficiency in port infrastructure services at Spain with reforms 1990-2002. Study proved suitability of distance function to measure technical efficiency. The study evaluated efficiency by capturing multiple outputs and inputs variables. Research further proved strong linkage between location & reforms in technical efficiency. Pallis & Syriopoulos (2007) examined financial performance and governance model at 12 Greece ports. Study suggests that port and real reforms go hand-in-hand. Study observes that lowering entry barriers in service provision would introduce competition. However, cautioned that absence of matching environmental-structure-strategy framework adversely affects financials. Haddad et. al. (2007) studied post-decentralisation port efficiency

improvements in Brazil. Study suggests formal consideration of nodes in transportation network to be mandatory to consider implications of transportation costs. Also finds that choice of investments to significantly impact port-hinterland services. Serebrisky & Trujillo (2007) studied post reform efficiency gains at Argentinian ports. Study suggests that for sustainable gains, government policies should accommodate environmental factors. Also emphasise for cross-border alliance to enhance healthy competition and incentives allow adjustment to changes and cost reductions disseminated to end users. Cheon (2007) assessed impact of institutional reforms on port efficiency from 1991 to 2004. The study concluded that world ports improved with advancement in their management, production scale adjustments, and technological progress. Suggested scale efficiency to be key factor for overall efficiency. Authors however, found that overdependence on technologies to have its own limitations. The study also found that higher port productivity due to decentralised corporate structure. Cullinane et. al. (2005) judged relationship of privatisation on efficiency at selected container ports. Study could not established considerable improvement in efficiency due to privatisation. Conclude that privatisation is no solution for variety of ills at ports. Wang, Ng, & Oliver (2004), studying port governance is reform era-legal, institutional, and operational questions of industrial reforms concluded that ports of China have reported efficiency enhancement due to reforms. Estache et. al. (2003) studied efficiency sources with reforms at Mexican terminals between the years 1996-99. Study observed facilitated new technologies due to structural reforms. However, found that some ports to lag behind the expected performance levels. Wang et. al. (2002) reviewed studies assessing efficiency and productivity of container ports DEA is effective to assess efficiency, subject to exercise of caution over various aspects of usage. Estache et. al. (2001) assessed efficiency gains at Mexican ports due to reforms and found efficiency gains of 6-8% with better usage of ports infrastructure. However, the study cautioned trends to be uneven. Hoffmann (2001) studied performance patterns in Latin American ports due to reforms and privatisation. The study observed that government policies like privatisation and landlord model have resulted in efficiency improvements. The research also found that privatisation of port operations help in structural reforms of economy. The study advocated that privatisation has resulted in less public involvement in port planning, investment and regulation than in European countries. Circha (2001) studied concepts of port privatisation and structural adjustment programs at Canadian and US ports to assess effectiveness of Canadian ports. The study found that in spite of contemporary reforms, US ports have performed well and that Canadian ports reforms need to a number stringent policies to unshackle them from the constrains of federal

government control. The study also suggested that Canadian ports reforms need to take up multi-stage process to make them work on commercial lines. Juhel (2001) studied the need for public private partnership in port developments. The study enquired into the need for better coordination among various stakeholders to enhance port efficiency in the post reform setup. The study suggested for a conductive environment with institutional framework for optimal utilisation of port facilities, distribution of risk and reward in privatised scenario. Study advised for regulatory support of government to facilitate private operations. Cullinane & Song (2001) studied administrative and ownership structures at Asian container ports. The study found that Asian ports experienced numerous problems like insufficient port and/or terminal capacity, inefficient management and operation, and bureaucratic administration that influence their cost of foreign trade. The study also traced that lack of competition at publicly owned ports have also affected their efficiency. To overcome this problem, Asian ports are migrating towards privatisation of ports and have significantly improved in their efficiency.

2.20 Outcome – Impact of Reforms on World Ports:

Above studies on reforms and privatisation of ports observe efficiency and productivity gains at ports. The gains at ports are due to improvements in scale adjustments, technological progress, containerised operations, and above all private management of ports. Most of the studies considered container ports and proved Containerisation of cargo at private ports is a key factor of efficiency improvement. Studies also cautioned on existence of strong environmental support, proactive government policies on overall economic reforms for sustenance of port efficiency and productivity. It may be noted that most of the studies on impact of reforms focused on container terminals.

2.21 Impact of Reforms Port Efficiency and Productivity Improvement – Indian Scenario:

Major ports of India, just as most of the organisations in public sector could not meet the market demands and targets of government plans. Subsequently government of India initiated reforms at this segment of infrastructure with an aim to revive their efficiency and productivity. So checking impact of reforms on port efficiency and productivity are limited and include, Mackie (2012) working on Challenges impending Port Reforms found that to support growing economy and to capitalise on global position, India need to address capacity

constraints of port industry. Further investment in and development of ports infrastructure, along with investor-friendly changes to regulatory regime, will be key to improving the overall performance India's ports. Patel & Bhattacharya (2009), studying development of Infrastructure sector in India concluded that results of reforms in Infrastructure are mixed. Ports sector overall lags in international productivity benchmarks. From a situation a decade back where existing port capacities were un-differentiated and were being developed by the port trusts in a "one-size-fits-all" manner, the current environment has emerged into a specialised structure that is more in conformity with the emerging patterns of merchandise trade. Only 13% of India's port capacity handles container traffic. Sajikumar (2008) studied impact of changing ownership models at Indian major ports. Found decentralisation of port management to be effective with efficient government regulations and policies. The inquiry also concluded that with autonomy on operational, financial, audit and administrative aspects improve operational efficiency and productivity at ports. Aiyar S (2008), studying the impact of Port Reforms on Performance in Gujarat found that Gujarat has demonstrated that various forms of private participation can greatly improve the availability and efficiency of port infrastructure. For good governance, the ports land-lord and regulator should avoid operating any jetties or terminals. De (2006) assessed Total Factor Productivity at Indian ports and found ports in India to be heading towards capital intensive. The study also found that contrary to popular belief, economic climate in post-reform period is yet to make any substantial impact on total factor productivity at Indian ports. Puri (2003) reviewed experiences of private sector progress in Indian transport sector. The study linked government policies on privatisation and achievements at various subsectors and identified gaps in government policies and initiatives. De (2002) studied technological changes in Indian ports. Found productivity, efficiency improvement in Indian ports due to reforms. Haralambides & Behrens (2000) studied on the need of port restructuring in India. The study found that traditional anomalies like bureaucratic delays hamper investments. Study also emphasised that India needs to see the multiplicative effects of foreign investments on the entire economy, technology and know-how transfer. The authors suggested that government of India has to offer foreign investors privatisation terms that offer attractive returns. Sunder (2000) reviewed the restructuring initiatives at Indian ports to find policies of government to be towards landlord port concept with provision and services being given to private sector operation. The study assessed the prevailing constraints and scope for developments at Indian ports. However, the study found adequate attention is not paid to strengthen the support infrastructure and streamlining of administrative and customs procedures by the government.

2.22 Outcome – Impact of Reforms on Indian Ports:

All the researchers studying on Indian ports endorsed efficiency and productivity improvements due to privatisation. However, there is no study that assessed port efficiency and productivity considering the period of reforms. Researchers, somehow, have not assessed gains made by major ports during the period of reforms. The studies have also endorsed improvements in scale adjustments, technological progress, containerised operations, and above all private management of ports. It may be noted that Indian ports are depended on handling bulk commodities like POL, Coal, etc. and so assessment of Indian ports on container movement does not result in true performances.

2.23 Port Ranking:

Port raking has been an area of study for a long time. However, it has gained momentum in the recent past with some of the researchers attempting to compare and rank ports on the basis of their efficiency and productivity. Ranking of ports on the basis of their efficiency and productivity is aimed to list the competitive comparison of the ports. Works on port ranking include, Poitras et. al. (1996) ranked 5 Australian Ports with 18 international ports. The study attempted for methodological contribution demonstrating DEA as a viable method to evaluate efficiencies allowing multiple factors to get relative efficiency/inefficiency giving a chance for port raking. Chudasama (2009) Ranking of Indian major ports in 2007. The study considered operational indicators and physical facilities assigned weights derived from Principle Component Analysis. Lee et. al. (2005) studied port efficiency at 16 container terminals in Asia Pacific Region and ranked selected container ports in Asia Pacific region considering operational efficiency. De & Ghosh (2003) studied relationship between performance and traffic at Indian Ports. The study emphasised that a comprehensive policy to improve performance of ports is needed and further advocated indexing of ports to help policy-makers to strengthen weaker factors and overall performance. Tongzon (2002) attempted to identify and assess factors of choice and performance for Port Ranking. Found factors like high efficiency, shipping frequency, adequate infrastructure, location, low charges, quick response to user needs and reputation for cargo safety are determinants of port selection.

2.24 Outcome – Port Ranking:

Studies on port raking, albeit low in number, predominantly considered container ports. Two studies pertaining to India represent ports handling multi cargo. While Chudasama (2009) studied for only one year, study of De & Ghosh proposed for creation of an index.

2.25 Techniques and Models Applied/Used:

It is interesting to note that researchers have applied numerous techniques for measuring port performance, efficiency, productivity, and ranking. The techniques used by researchers are based on individual preference considering the need of their individual study and include mathematical, statistical, financial, and production functions.

Mathematical techniques such as Data Envelopment Analysis, Malmquist Productivity Index, and Stochastic Frontier Analysis are more frequently used. Techniques such as Cobb Douglas Production Function, Financial Ratios, Case Based Analysis, Weighted Score Method, Co-integration Analysis, Linear Homogeneous Production Function, and Garner Causality Function are used by a few of the researchers. Some of the researchers reviewed existing works on port efficiency, productivity, and raking.

2.26 Overall Research Gaps:

An analysis for the thematic review leads in tracing certain gaps in the existing research works and include:

1. Literature review elucidates that most studies concentrated on berth related operations. So, scope for further study to reflect holistic picture of port efficiency covering operations of berth side, yard side, and sea side aspects is still available and much required.

2. Few of the researchers attempted to check efficiency gains due to reforms and covered only a few selected years. But efficiency gains achieved during the period of reforms is not adequately checked. This leaves an opportunity to test the efficiency

improvements achieved during the last 19 years of port reforms at major ports of India.

3. Most studies predominantly covered operational aspects of port performance and thus financial indicators are remotely studied. This leaves a scope for a study covering both operational and financial indicators for port performance.

4. Due to the ongoing popularity of containerised cargo movement, most studies attempted to assess operations of container ports alone. However, most of the third world ports, especially India, accounting to a majority of cargo trade, handle multiple cargos. So assessment and comparison of ports handling multiple cargos is required.

5. Some studies tried to assess performance of ports have heterogeneous features. These cross country and cross continent studies do not result in depiction of true performances. Since each country would have its own geographical, political, economic, factors influencing port performance, it would be ideal to assess ports homogeneous features.

6. In India, privatisation is changing the ownership model, mode of operations, and so there need a relook in working of ports with a fresh approach. However, existing studies still have used older approach of assessing port performance.

2.27 Variables found from Literature Survey:

A review of the studies has led to identification of 133 variables, as depicted in the following table, which are used by the researchers assessing port efficiency and productivity.

Table: 2.5 Variables Considered by Different Researchers

S. No.	Operational	S. No.	Physical
1	Number of Loaded Shipments in a Year	72	Average Output/Ship Berth Day
2	Throughput – TEUs	73	Direct & Indirect Labour
3	Throughput – Tons (All other Cargo)	74	Cargo Interest (Type)
4	Service Standards	75	Number & Length of Terminal(s)

5	Total Time Spent of Operations	76	Number of Berths
6	Average Idle Time	77	Port Location
7	Energy Consumed	78	Port Inland/Maritime Accessibility
8	Container Lot Size	79	Port Dynamics
9	Average Turnaround Time	80	Maritime Accessibility
10	Average Pre-Berthing Time	81	Length of Berth/Quay
11	Average Cycle for Internal Transport vehicles	82	Port Draft
12	Truck Turnaround Time	83	Terminal Area
13	Slot Density	84	Container Yard Area
14	Yard Utilisation Rate	85	Number of Quay/Container Cranes
15	Labour Hours	86	Number of Yard Cranes (RTGs/RMGC)
16	Crane Hours	87	Number of Straddle Carriers
17	Number of Vessels Handled/Total Traffic	88	Number of Prime Mover Tractors/Forklifts
18	Number of Passengers	89	Number of Trailers/Vehicles/Trucks
19	Crane Rate	90	Number of Lifters/Stackers
20	Vessel Working Rate	91	Yard Staking/Storage Area
21	Ship Rate/Frequency of ship visits	92	Number of Gate Lanes
22	Terminal Capacity in TEUs	93	Port Area
23	Size of Vessels	94	Parking Lot for Trucks
24	Number of Tugs	95	Rail-Road Connectivity
25	Strategies	96	Number of Buildings
26	Container Stacking Capacity	97	Number of Wharves/Warehouses
27	Delivery of Goods to Hinterland	98	Length/Number of Docks
28	Capacity Utilisation/Berth Occupancy	99	Number of Waterways
29	Port Proximity	100	Total Staff
30	Connectivity Index	101	Productivity Port Industries
31	Effective Working Rate		
32	Asset Performance		
33	Container Productivity/Container Lifter/Crane		

34	Transportation Modes (Hinterland)		
35	Container Movement per hour/per ship		
36	Rail Services/ Connectivity		
37	Output per ship per berth per day		
38	Work Practices		
39	Cargo Exchange (Loaded/Unloaded)		
	Financial		**Others**
40	Operating Income/Revenue	102	Dedicated Block train services by CONCOR
41	Average Revenue per Ton	103	Port Owner Ship /Terminal Organisation
42	Net Investment in Physical Assets	104	Number of Shipping Lines
43	Average Labour Cost	105	Terminal Maritime Services
44	Quasi-Fixed Input	106	Logistic Integration
45	Total Income/Revenue	107	Intermediate Consumption
46	Personnel Expenses	108	Customer Satisfaction
47	Funding Inputs	109	Average Age of Workforce
48	Depreciation	110	Average Experience of Workforce
49	Dredging Expenditure	111	Foreign Trade Volume
50	Domestic Retail Sales	112	Port Specialisation
51	Operating Expenditure	113	Maritime Services
52	Operating Surplus (Total or Per Ton)	114	Investment Level Manufacturing Sites
53	Capital Employed	115	Wage Level Port Manufacturing Industries
54	Earnings Before Interest, Taxes, Depreciation and Amortisation (EBITDA)	116	Throughput/Value Added per Square Meter
55	Earnings Before Interest & Taxes (EBIT)	117	Consumer Benefits from Lower Transport Costs
56	Revenue Growth	118	Education Level of Employees
57	Net Profit Margin	119	New Establishments
58	Capital Adequacy	120	Integration Ratio
59	Return on Equity (ROE)	121	Number of Patents
60	Dollar Value	122	US Imports

61	Share in Total Indian Port Traffic	123	US Exports
62	Wage Level of Port Industries	124	Number of Refineries Near Port
63	Intermediate Input (Investment)	125	Operational Status of Port (0/1)
64	Economic Activity/Performance	126	Supply Chain Service Providers
65	Port Charges	127	Hinterland Connectivity
66	Land Price	128	Warehouse Area
67	Container Mix	129	GDP
68	Operating Profit Growth	130	Container Tonnage
69	Liquidity	131	Channel Depth
70	Import Charges	132	% goods value added in port region
71	Return on Assets (ROA)	133	Port Functions

2.28 Conclusions:

This chapter started with an objective to review existing research works on port performance across the world. After getting clarity on issues like performance and efficiency, an attempt to gather research papers on port efficiency and port productivity was made. Using a few words like 'port efficiency', 'port productivity', 'port sector reforms', 'port governance', 'port ownership', 'port ranking' etc. the author gathered over 250 research papers. Research papers published in a total of 22 Journals were referred and 15 reports across the world, including India, were referred. The gathered research papers were then segregated on few broad themes like 'port performance indicators', 'port efficiency – World ports', 'port efficiency – Indian ports', 'port productivity – World ports', 'port productivity – Indian ports', 'port sector reforms', and 'port ranking'. A review of these works led to identification of few research gaps and around 133 variables that are used by various researchers for assessment.

Chapter – 3
Research Design

"A research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure."- Claire Selltiz et. al.

3.1 Introduction:

This chapter details with design and methodology required for conduct of research study. A research design is a grand plan of approach to the topic being considered for research (Greener, 2008). Ideally *Research Design* should be the general plan of how a researcher will go about answering the research question(s) (importance of clearly that defines research question cannot be over-emphasised). It should contain clear objectives, derived from the research question(s), specify the sources of probable data to be collected, and consider the possible constraints that a researcher will inevitably have (e.g. access to data, time, location and money) as well as discussing ethical issues (Saunders et. al., 2009). It explicitly addresses different scientific paradigms, scientific approaches, research approaches, research methods, research strategy, data collection method and data analysis strategy.

Research design is an overall approach and rationale for selecting a particular approach of study (Saunders et. al. 2009). A research design clarifies on the proposed study, the mode of inquiry (strategy) the researcher proposes to follow, and methods of data collection, analysis, and interpretation to be followed to arrive at some logical conclusions. The selection of a research design depends on the nature of research problem or issue being addressed, researchers' personal experiences, and target audiences for the study. From the above, a list of key contents of research design may be highlighted as follows:

a. Nature of the proposed study;
b. Purpose of the proposed study;
c. Location where the study is conducted;
d. Nature of data required;
e. Source of data collection;

f. Time period considered for the study;
g. Proposed type of sample design;
h. Techniques of data collection;
i. Methods of assessing data collected;
j. Manner of report generation.

3.2 Research Focus:

The focus of researchers across the world has been on understanding and assessing efficiency and productivity gains at ports. Both efficiency and productivity have been yardsticks for gauging the performance of an economic entity across all sectors in any economy. In early literature, several researchers have checked operational and financial efficiency of business units by numerous authors (O'Boyle & Hassan 2014; Choong 2013; Moxham 2013; Hong et. al 2013; Striteska & Spickova 2012; Hammer 2007; Langen et. al. 2007; Ruel 2003; Baird 1999; Neely et. al. 1997). Further, research works on productivity at various economic entities was taken-up by authors including (Spring 2011; Parida & Kumar 2009; Comin, 2006; Nordhaus, 2002; Lipsey 2004). These research works have either proposed a mechanism to quantify or used some of the existing methods to quantify the performance of entities that they have tested. They have either proposed or used both mathematical and/or statistical techniques to measure efficiency and productivity. All these studies have qualified the significance of efficiency and productivity as base for long-term viability of economic units.

Maritime trade has played an important role in world trade and seaports have been a link for world trade for time immemorial. Efficiency at which a port performs is detrimental to the foreign trade prospects of a nation. Port across the world have evolved and developed along with world trade and today account for over 90% trade by volumes and over 75% by value of international business.

Ports in India, like ports across the world, have been an important segment in the economy. However, efficiency at Indian ports has been an issue of concern as their performance has not been in line with set standards. Numerous reports (World Economic Outlook 2014; India's Transport Challenges 2002; India Inclusive Growth and Service Delivery: Building on India's Success 2006; UN report on Commercial Development of Regional Port as Logistics

Centers 2002; UNESCAP-Improvement of Transport And Logistics Facilities to Expand Port Hinterlands: Policy Guidelines 2006; UNESCAP- Review of Developments in Transport in Asia and the Pacific, 2009; UNCTAD-Trade and Development Report, 2014; UNCTAD-Review of Maritime Transport, 1995 to 2014; INCTAD-Trade and Development Report, 2012; UNCTAD-World Investment Report, 2002 to 2013; UNCTAD-Twenty Years of India's Liberalisation 2012; UNCTAD-Development and Globalisation, Facts & Figures, 2012; World Bank Group-Sustainable Infrastructure Action Plan, 2009-2011; Ministry of Shipping, GoI, Update on Indian Port Sector 2012, 2013, 2014; Ministry of Shipping, GoI; Maritime Agenda-2010-2020, 2011; Port of Rotterdam's Coordination of business plans for major ports of India, 2007) have suggested that Indian ports have a grate scope and role to play in the nation building but are constrained with multiple challenges.

It is evident from the literature review that efficient working of ports supports the growth prospects of a country. To revive and improve port performance, government of India opted for allowing private participation in the sector. These privatisation initiatives resulted in setting up of new private ports and also private participation at the publicly owned major ports of India. While new private ports are all through 100% private investments, the privatisation at major ports is through BOT projects under PPP contracts.

The privatisation process at major ports was initiated in the year 1995 (Maritime Agenda 2020) with an objective to enhance their efficiency. Along with private sector participation, these port authorities are also given greater autonomy in their management. Privatisation and subsequent reforms in the management of ports has resulted in improvement in efficiency. However, Indian ports even today face numerous challenges (Port of Rotterdam, 2007) and their progress has been uneven. The present research, focuses on the efficiency gains at observed at the major ports of India during this period, from 1995-96 to 2013-14, of reforms and assesses the development trends at each of them. The aim would be to assess the level of efficiency gains at each of these ports and to appraise the factors that have resulted in efficiency/inefficiency during this period.

It is a proven fact that efficiency gains are checked to frame policies and procedures for further improvement at a port. It would further give an opportunity to compare efficiencies of each of these ports and help in gaining inputs for improvements from the most efficient port. Efficiency gains at ports can be assessed by collecting the required information from a

reliable source. Performance indicators covering both operational and financial aspects along with physical infrastructure setup are required to quantify the progress made by these ports. The study is based on assessment retrospective data available on the performances of these ports.

Since data pertaining to 19 years for all the 12 major ports of India are to be assessed, quantitative research method would be most suitable for this study. Data pertaining to different input and out variables that hold key for the performance of ports is to be considered for assessment. Details regarding the variables selected for the study are given in Chapter Data Analysis – I.

3.3 Statement of Problem:

Although in existing literature port performance has been measured for shorter timeframes with limited number of operational and financial variables but post-reform trends on port efficiency and productivity is not known.

3.4 Specific objectives of this research work:

1. To measure the post reform efficiency improvements attained by major ports of India.

2. To develop an index representing operational, financial, and physical parameters of major ports of India.

3.5 Research Questions:

1. What is the level of overall efficiency improvement achieved by major ports during the post reform period?

The answer for this question can be explored by assessing the overall improvements in efficiency gained by the major ports after the initiation of privatisation at their facilities. Further it seeks to assess the level of gains at each of these 12 ports during this period of 19 years and the reasons for such efficiency/inefficiency improvements.

2. What are the trends in productivity improvements at major ports in post reform scenario?

To answer this question detailed productivity gains at the 12 major ports need to be assessed for the 19 years of reform period. Basing on the results of productivity enhancements, all the ports are to be indexed so as to arrive at logical conclusions regarding each of the port assessed.

3.6 Scope of the Study:

The study attempts to check efficiency and productivity gains at Major ports of India during the period 1995-1996 to 2013-14. Performance indicators representing the overall port related activities alone are considered for efficiency and productivity check. Although there are numerous indicators representing port performance, the study has confined itself to only a few of them. Indicators selected for research represent overall port aspects covering financial, operational, and infrastructural segments of port performance. The selection of the indicators is based on specifications of research technique applied for testing efficiency and productivity. Further, the research uses Malmquist Productivity Index (MPI) as base for calculation of Port Performance Index for the major ports of India.

3.7 Nature of Research Questions:

Both the research questions (RQ – 1 & RQ – 2) are explanatory in nature as they seek to assess the growth patterns in efficiency and productivity at major ports of India. Research questions are aimed to assess the efficiency patterns at all the major ports of India during the period 1995-96 to 2013-14 as this period has seen considerable growth in private investments at different activities of port operations. The study is aimed to assess the level of efficiency and productivity gains at these ports on the basis of published data on their performances. So the temporal focus of this study would be towards backward looking as shown (in Grey Colour) in the following Table 3.1.

Table: 3.1 Temporal Orientation of Research Questions (RQ)			
Type of RQ	**Backward looking**	**Current**	**Forward looking**
Exploratory	Exploratory backward looking	Exploratory Current	Exploratory Forward Looking
Less factual, more oriented towards understanding a trend/pattern	What could have been done? What would have made more effective? Yin (2003) Exploratory what questions	What could be done in this situation? What is the background of this trend? Yin (2003) Exploratory what questions	What will happen? What will be the impact of this initiative? How will people respond? Yin (2003) Exploratory what questions?
Descriptive and predictive	Descriptive backward looking	Descriptive current	Descriptive forward looking
Factual representation or estimation of study object	What were the outcomes of this strategy? How many projects have met expectations? Yin (2003) Inventory what questions, who what where questions	How many firms employ thee processes? Who are currently involved in this project? Yin (2003) Inventory what questions, Who what where questions	What will be the outcome of adopting the processes? Yin (2003) Inventory what questions, who what where questions
Explanatory	**Explanatory backward looking**	**Explanatory current**	**N.A**
Factual, focused on understanding a limited number of events	What happened? Why did it happen? What is the current status? Yin (2003) How, why questions	What happened? Why did it happen? What is the current status? Yin (2003) How, why questions	N.A
(Source: Fenema, 2002; Yin, 2003)			

3.8 Selected Strategies of Inquiry:

The strategies of inquiry relate to the quantitative, qualitative, and mixed methods of study through which the research is actually implemented. The strategies of inquiry have evolved over a period of time and with the availability of numerous computer technologies have push forwarded the ability of data analysis. Ability to analyse complex models have helped researchers to articulate new procedures for conducting social science research.

A paradigm or world view is a "basic set of beliefs that guide action". These beliefs are called as philosophical assumptions, epistemologies, and ontologies (Crotty, 1998); broadly conceived research methodologies (Neuman, 2000); alternative knowledge claims (Creswell, 2003); philosophical worldviews (Guba, 1990); and philosophical paradigms (Lincon & Guba, 2000; Mertens, 1998) by many other researchers. The four philosophical paradigms that inform qualitative research include postpositivism, constructivism, advocacy/participatory, and pragmatism (Creswell, 2003) are further explained as under:

3.8.1 Postpositivist paradigm: This paradigm comes from 19th century writers such as Comte, Mill, Durkheim, Newton, and Locke (Smith, 1983). Assumptions of this paradigm represent the traditional form of research that hold good for quantitative research rather than qualitative research. This is also called scientific method or doing science research. It is also termed as positivist/postpositivist research, empirical science, and postpostivism. Researchers supporting postpositivist approach advance closer to truth while recognising that discoveries as only partial segments or estimates of truth (Clark, 1998). Studies in this paradigm hold a deterministic philosophy that causes probably determine outcomes (Creswell, 2009). Therefore, problems studied reflect the need to identify and assess the causes that influence outcomes. It can also be reductionist with an intention to reduce ideas into small, discrete set of ideas.

3.8.1.1 Postpositivists studies are based on assumptions such as (Phillips & Burbules, 2000):

a. Knowledge is hypothetical and absolute truth can never be found. Thus, researchers instead of proving hypothesis, indicate a failure to reject a hypothesis.
b. Research is a process of making claims followed by refining or deserting some of the claims for others that are more warranted.

c. Data, evidence, and rational considerations carve knowledge. In practice, researchers gather information on instruments based on measures completed by the participants or by observations recorded.
d. Research seeks to devise relevant true statements from the outcome which can serve to explain a situation of concern or describe the casual relationships of interest. Under, quantitative studies, researchers advance these relationships among variables and pose them in terms of questions or hypothesis.

Table: 3.2 Four Paradigms (WorldViews)	
Postpositivism	**Constructivism**
• Determination • Reductionism • Empirical observation and measurement • Theory verification	• Understanding • Multiple participant meaning • Social and historical construction • Theory generation
Advocacy/Participatory	**Pragmatism**
• Political • Empowerment issue-oriented • Collaborative • Change-oriented	• Consequences of action • Problem-centered • Pluralistic • Real-world practice oriented
Source: Adapted from Creswell, Qualitative Inquiry and Research Design, Pg. 19-30, Sage	

3.8.2 Constructive Paradigm:

This has evolved from the works of (Berger & Luckmann, (The social construction of reality) 1967, Lincoln & Guba, 1986). This is based on the assumption that individuals wish to understand the world in which they live and work (Lincon & Guba, 2000; Schwandt & Marquardt 2000; Neuman 2000; Crotty 1998). Individuals develop subjective meaning based on their experiences which are varied and multiple and lead the researcher to look for the complexity of views rather than narrowing meanings into a few categories or ideas. Meaning is derived with an interaction between the interpreter and the interpreted (Crotty, 1998). Researchers aim to depend on participant's view on the situation being studied to the maximum possible level. The questions are broad and general giving an opportunity to the participants to construct the meaning of a situation, typically involved in discussions or

interactions with other persons. Usage of open-ended questions gives ample opportunity to researcher listen carefully to the opinion of participants. The researcher's aim to make sense of the meanings others have about the world rather than starting with a theory that inquirers generate or inductively develop a theory or pattern of meaning.

3.8.2.1 Assumptions of constructive Paradigm (Crotty, 1998):

a. Meanings are constructed by human beings as they get involved with world they interpret. Qualitative researchers tend to employ open-ended questions to facilitate participants share their views.

b. Human beings engage with the world they live and make sense of it based on their historical and social perspectives. Therefore, qualitative researchers wish to understand the context of participants through visiting this context and gathering information personally. They also interpret what they notice which is based on their own experience and background.

c. The basic generation of meaning is often social, budding in and out of interaction with human community. The process of qualitative research is generally inductive, with the inquirer generating meaning from data collected from the field.

3.8.3 Advocacy/Participatory Paradigm:

Researchers (Fay, 1987; Heron & Reason, 1997; Kemmis & Wilkinson, 1998) propounding this paradigm feel that research inquiry needs to be intertwined with politics and political agenda. Therefore, research includes agenda for reform that may change the lives of participants, institutions for which individuals work, and the researcher's life. Some of the writers like have drawn their propositions from the works of Marx, Adorno, Marcuse, Habermas, and Freire (Neuman, 2000). Specific issues addressing prevailing social concerns are addressed. This research assumes that the inquirer will proceed collaboratively so that no further marginalization of the participants happens with the results of the inquiry. This gives a chance for participation of the participants even in designing the questions, collection of

data, analysis of information, or in any other requirement of the research. Thus, this becomes a proactive and participative methodological study.

3.8.3.1 Features of Participatory Paradigm (Kemmis & Wilkinson, 1998):

a. Participative action is recursive and focusses on bringing about change in practices and thus, researchers advance an action agenda for change.

b. This type of inquiry helps individuals to free themselves from constraints found in media, in language, in work procedures, and in the relationships of power in educational settings. These studies are initiated with an important issue concerning the society.

c. These studies are emancipatory and help unshackle people from the constraints of irrational and unjust structures that limit self-development and self-determination. These studies aim to create political debate or discussion for a possible change.

d. It is practical and collaborative as it is done with other rather than on or to others.

3.8.4 Pragmatic Paradigm:

This paradigm has stemmed from actions, situations, and consequences rather than antecedent conditions. Pragmatism is derived from the works of Peirce, James, Mead, and Dewey (Cherryholmes, 1992). Recent research works on pragmatic paradigm include (Rorty, 1990; Murphy, 1990; Patton, 1990; and Cherryholmes, 1992). Instead of focusing on methods, researchers stress on the research problem and use all approaches available to understand the problem (Rossman & Wilson, 1985). This paradigm is not committed to any single system of philosophy and reality. This is applicable to mixed methods research where inquirers draw liberally from both quantitative and qualitative assumptions of the engaged research (Tashakkori & Teddlie, 1998; Patton, 1990).

3.8.4.1 Assumptions of pragmatism studies (Cherryholmes, 1992; Murphy, 1990; Crewsell, 2003):

a. Individual researchers are free to choose the methods, techniques, and procedures of research that suits their needs and purposes.

b. Researchers look to many techniques for collecting and analysing data rather than sticking to one single way.

c. Researchers use both quantitative and qualitative data as they work to provide best understanding of a research problem.

d. Researchers should establish a purpose for their mixing, rationale for the reasons why quantitative and qualitative data need to be mixed in the first place.

3.9 Paradigm Selected for Current Research:

The current research focuses on quantitative data pertaining to 12 major ports of India for a period of 19 years. Therefore, the research is based on Postpositivist Paradigm. The research is aimed to determine the efficiency and productivity gains at these selected ports by collecting data pertaining to various performance indicators. The results derived are verified with the theoretical aspects of '*productivity*'.

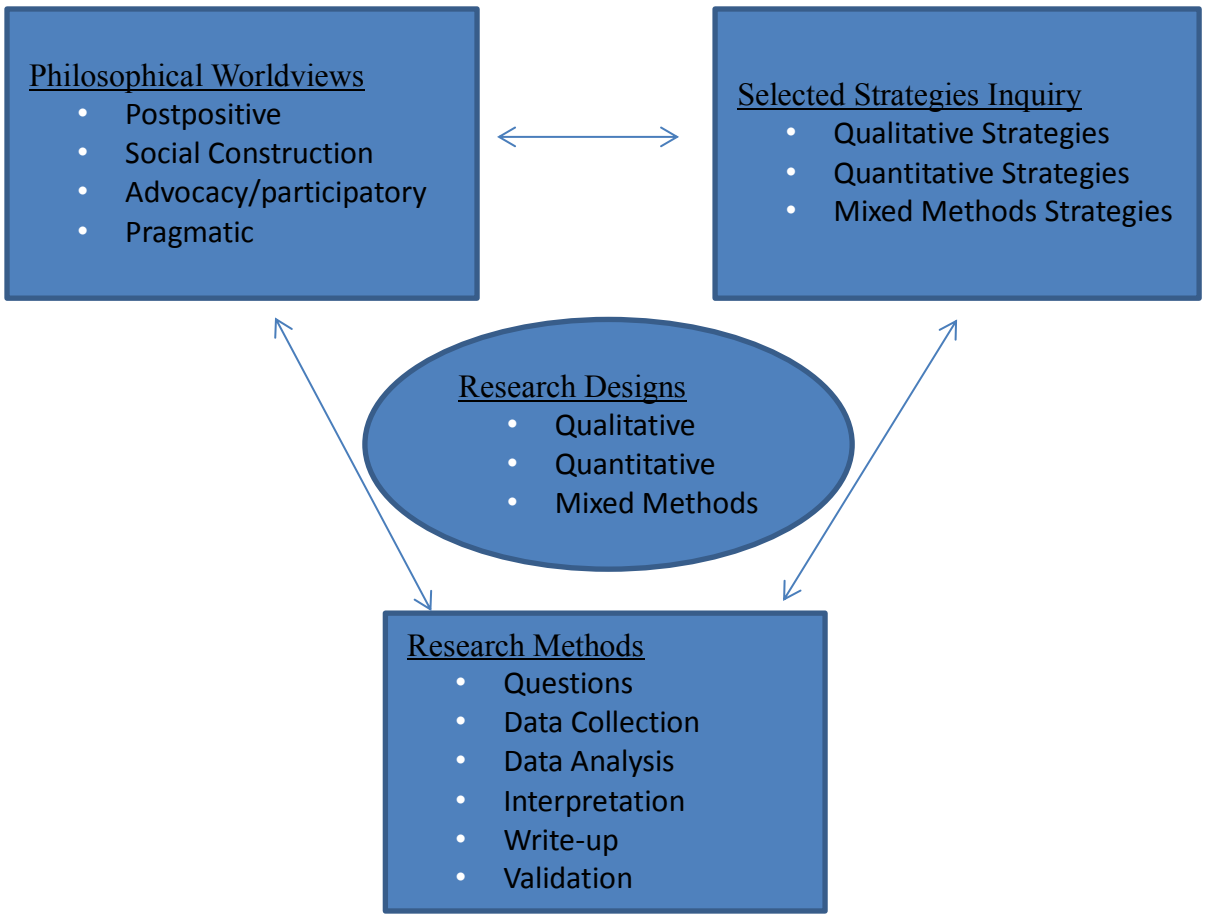
3.10 Framework of Research Design:

Research design is a plan or proposal for conduction of research and involves the intersection of philosophy, strategies of inquiry, and specific methods. While planning a study, researchers think through the philosophical worldview assumptions that they bring to study, the strategy of inquiry that is related to this worldview, and the specific procedures or methods of research that transform the approach into practice. Quality of research design improves trustworthiness of the entire research (Yin, 1994). For being worthwhile a research must maintain "truth value", "applicability", "consistency", and "neutrality", however, nature of knowledge inside the rationalistic (quantitative) paradigm would be different from the

knowledge in naturalistic (qualitative) paradigm is different from knowledge in naturalistic (qualitative) paradigm (Guba & Lincoln 1981).

The framework for research design may be explained in the following manner.

Fig: 3.1 Framework for Design – The Interconnection of Worldviews, Strategies of Inquiry, and Research Methods



Source: John W. Creswell, Research Design, 2003, Sage Publications, Page: 38

3.11 Types of Research Designs:

Research design can be broadly classified as Qualitative Research and Quantitative Research. There is a criticism that research design has been gendered (Oakley, 1997; 1998), with quantitative methods linked with words like positivism, scientific, objectivity, statistics and masculinity. On the other hand, qualitative methods have are generally associated with interpretivism, non-scientific, subjectivity and femininity (Fielding & Schreier, 2001).

Table: 3.3 Alternative strategies of inquiry	
Quantitative	**Qualitative**
• Experimental design • Non-experimental design like surveys	• Narrative research • Phenomenology • Ethnography • Grounded theory studies • Case study
Source: Research Design, Creswell, 2003, pg. 13.	

3.11.1 Quantitative Strategies:

Quantitative Research is an approach with a focus on testing or measuring or examining considerable data. In this approach the investigator uses post-positivist claims for developing knowledge (including cause and effect thinking, reduction to specific variables and hypothesis and questions, use of measurement and observation, and the test of theories) employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data. The research involves establishing relationship between variables and deriving of inferences by comparing these variables (Creswell, 2013; Kleinbau & Kupper, 1982).

- **Experimental design** – it aims to determine if a particular treatment influences an outcome. The impact is assessed by giving a specific treatment to one group and withholding it from other group (Keppal, 1991). Results are derived by checking the difference, if any, in performance of both groups.

- **Survey design** – it provides a numeric or quantitative description of attitudes, trends, or opinions of population by studying a sample of such population. It involves cross-sectional and longitudinal studies using questionnaire or structured interviews for collection of data with an intent to generalise from a sample to a population (Pinsonneault & Kraemer, 1993).

3.11.2 Qualitative research is employed on data which does not indicate any ordinal values (Fraenkel & Wallen, 1993). Qualitative research is a means to explore and understand the meaning individuals or groups attribute to a social or human problem (Creswell, 2013). It also attempts to get an in-depth opinion from participants. The research process includes emerging questions and procedures; data typically collected in the participant's setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data. The final written report has a flexible structure. (Creswell, 2007). Methodologies of qualitative research include:

- **Narrative research –** a researcher works in close collaboration with a group to improve a situation in a particular setting by actually working with them by being a facilitator (Sandelowski, 1991). Therefore, researchers are good at group management and understand group dynamics (Kitzingar, 1995).

- **Phenomenological research -** a strategy of inquiry in which the researcher traces the essence of human experiences regarding a phenomenon described by participants (Groenewald, 2004). Assessing the live experiences makes phenomenology both as a philosophy and also as a method. The process requires the researcher to set aside his or her own experiences in order to understand those of the participants involved in the study (Thompson et. al. 1989).

- **Ethnography** – routed from anthropology (Stocking, 1984; Clifford & Marcus, 1986), a popular mode of inquiry where anthropologists travelled across the remote tribes across the world. Ethnography emphasise on describing and interpreting cultural behavior by mingling with the group being studied to understand their lives and culture (Gregory, 1983).

- **Grounded theory** – often applied in education and health research studies is based on data. It is a method of explication and emergence (Charmaz, 2008).This methodology is depended on generation of theory that is grounded on data. In this theory, methods like focus groups and interview tend to be the choice of data collection method, along with an exhaustive literature review that takes place throughout the data collection process (Eisenhardt & Graebner, 2007). The researcher collects data until a point of '*saturation*' is reached (Suddaby, 2006).

- **Case studies** – a mode of inquiry where the researcher probes in depth a program, event, activity, process, of one or more individuals. These studies are bounded by time and activity, and researchers collect detailed information by applying a wide variety of data collection procedures over a sustained period of time (Baxter & Jack, 2008).

Table: 3.4 Features of Quantitative and Qualitative Methods

Quantitative Methods	Qualitative Methods
• Pre-determined • Instrument based questions • Performance data, attitude data, observational data, and census data • Statistical analysis • Statistical interpretation	• Emerging methods • Open-ended questions • Interview data, observation data, document data, and audio-visual data • Text and image analysis • Themes, patterns, and interpretation

Source: Creswell, 2007

The present study is aimed to assess the efficiency and productivity of major ports of India and thus, demands huge amount of quantitative data for assessment. Therefore, the study is based Quantitative Research with an approach to evaluate the ports being considered.

3.12 Rationale of Study:

Indian economy has been one of the professed destinations of foreign investments and stands at 11th position in confidence index drawn for 25 nations of world (Atkerney, 2015). The improvement in foreign investments mandated better performance of seaport as they act as link for exports and imports. However, the performance of ports in India under public sector has not achieved the standards set (De, 2003; Mohan, 2003). To provide a boost to the improving foreign trade, the government has opted for private sector participation into this core infrastructure segment. This has resulted in higher investments and better performances at the port sector in India. However, there has not been studies that gauged the post privatisation performance of Indian ports. It is important to know the efficiency gains at Indian ports during the period of privatisation so that the government might plan for future requirements and probably address any shortcomings in the existing policies that impact the

growth of port sector. Few of the eminent researchers Rajasekar et. al. (2014); Mokhtar & Shah (2013); Rajasekar & Deo (2012); Rajasekar & Deo (2011); Bhatt & Gaur (2011); Gaur et. al. (2011); Nihar (2011); Ghosh et. al. (2010); Wu & Lin 2008; Chudasama & Pandya (2008); Chudasama & Kota (2007); De & Ghosh (2003) studied port efficiency and productivity at port in India. However, these studies mostly covered the operational aspects and thus, could not provide a holistic perspective of Indian ports with a backdrop of reforms. So the current research attempts to fill this gap and trace out the post reform efficiency and productivity improvements at the major ports of India.

3.13 Data Collection Method:

The data required for the current study is collected from secondary sources based on the publications of Indian Port Association (IPA), New Delhi. 'Yellow Books' displaying 'Profile of Major Ports of India' is published by IPA, the apex authority for Indian major ports that works directly under the Ministry of Shipping, Government of India.

3.14 Data Analysis Strategy:

Data Analysis refers to calculation of certain indices or measures besides searching for patterns of relationship existing among the given data groups (Creswell, 2007). Analysis may be categorised as descriptive and inferential or statistical analysis. Descriptive analysis is the study of distributions of one variable. The study provides researchers with profiles of companies, work groups, persons and other subjects on any of a multiple features like size, composition, efficiency, preferences, and so on. This type of analysis can be in respect of unidimensional or bivariate or even multivariate analysis. In the recent times, with the availability of computer facilities, multivariate analysis has become more popular.

3.15 Efficiency:

Efficiency can be referred as success of a firm in producing as large as possible an output from a given set of inputs where all outputs and inputs are measurable (Farrell, 1957). The payoff from calculating efficiency is that it provides an objective basis to evaluate the performance of a decision making unit (Ray, 2004). Efficiency can be further classified by

economic efficiency, allocative efficiency, productive efficiency, dynamic efficiency, and social efficiency. Port efficiency is an important indicator of port performance; more efficient ports lower transportation costs and facilitate imports and exports of a country (OECD, 2012). Productive port efficiency (OECD, 2012) is defined along *i)* an efficient production frontier that maximises port output at different input levels; *ii)* a benchmark of best practices, on the basis of ports location on efficient production frontier; *iii)* observable gaps between actual current output of port what their optimal ability to produce it they were to be efficient. Efficiency can be described as a distance function between the volume of input and output, and the quantity of input and output defining a frontier, the best possible frontier for a firm in the industry (Daraio & Simar, 2007).

3.16 Data Envelopment Analysis

The present study adopts one of the popular Non-parametric methods, Data Envelopment Analysis (DEA), for analysis of the data collected (Kuosmanen & Johnson, 2010). DEA is considered to be a powerful tool to assess efficiency. Efficiency calculation with DEA is followed by productivity assessment using Malmquist Productivity Index (MPI).

Data Envelopment Analysis (DEA) is a nonparametric method to quantify efficiency of a decision-making unit (DMU) which is an organisation public or private. The concept was initially introduced in the Operations Research (OR) literature by Charnes, Cooper, and Rhodes (CCR) (*European Journal of Operational Research* [EJOR], 1978). The original model of CCR was applicable to technologies characterized by constant returns to scale globally. However, in what turned out to be a significant advancement, Banker, Charnes, and Cooper (BCC) (*Management Science*, 1984) extended the CCR model to accommodate technologies exhibiting variable returns to scale. In subsequent years, methodological contributions by a numerous researchers accumulated into a substantial literature around the CCR–BCC models, and the generic approach of DEA emerged as a reliable alternative to regression analysis for efficiency measurement.

Data Envelopment Analysis (DEA) is a methodology used to measure performance has routed from linear programming. It is a tool being successfully applied to assess relative performance of a set of firms that use multiple of identical inputs to produce multiple of identical outputs. The basic principle of DEA is originated by Farrel (1957). The recent series

of discussions on this topic initiated with the article by Charnes et. al. (1978). A good introduction to DEA is made available by Norman & Stoker (1991). Cooper et al. (2005) updated and comprehended material on DEA. Ji & Lee (2010) developed DEA command that selects chosen variables from Stata data to construct a LP model based on selected DEA options to check efficiency of tested DMUs. Adler et. al. (2002) reviewed research papers that attempted to improve differential capabilities of DEA for ranking efficient and inefficient DMUs. The study has grouped methods applied by different researchers into six broad categories and found that none of the methods could be prescribed as complete to the question of ranking. Banker et. al. (1984) argue that with the adoption of DEA, Mathematical programming is extended for use as a tool for control and evaluation of past accomplishments and as a tool to aid in planning future activities. They have separated efficiency on the basis of technical and scale aspects without altering the basic conditions of DEA on observed data. The study further introduced a variable to determine whether the operations were conducted in regions of increasing, constant, or decreasing returns to scale. Andersen & Petersen (1993) developed extended DEA-measure of technical efficiency that helps in ranking of efficient units. They proposed that the efficiency ranking developed by them would be helpful in comparing ranking derived from parametric methods. Nataraja & Johnson (2011) proposing guidelines for using variable selection techniques in DEA argued that DEA itself has not provided any guidance for specification of production function and inputs and outputs variables. They argue that selection of number of variables is left to user's discretion, judgement, and expertise. They concluded that user must take adequate care by employing best-fit method and identify relevant and irrelevant variables in production process. Charnes et. al. (1981) proposed model for measuring efficiency of Decision Making Units (DMUs) along with methods of implementation and interpretation. Authors suggested that results of the DEA model proposed by them facilitates validation of results and thus, helps in further studies. Charnes et. al. (1991) extended the theory of DEA so as to make it deal with zero inputs and outputs and zero virtual multipliers. They have partitioned DMUs into six classes via primal and dual representation theorems by means of which restrictions to positive observed values for all inputs and outputs can be eliminated along with positivity conditions imposed on the variables that are usually accomplished by recourse to non-archimedian concepts.

DEA is used to measure efficiency of firms that are termed as Decision Making Units (DMU). The technique checks about how efficiently a DMU uses its available resources to

generate its outputs (Charnes et. al. (1978). A DMU can be an organisation that is into production and/or service activities. DEA, as a technique, has successfully measured efficiency of both commercially oriented organisations and also non-profitable organisations where variables for assessment are difficult to capture. DEA uses the concepts of efficiency and productivity, ratio of total outputs to total inputs, to assess performance of selected DMUs. Efficiencies estimated with DEA are relative and thus performance of the best firm/unit is taken as benchmark for comparing efficiency of all other units (Anderson & Peterson, 1993). So, the best performing DMU is assigned an efficiency score of units (100%) and the scores of other DMUs would range between 0 and 100 percent relative to the best performer.

The basic assumption behind computation of relative efficiency is that if one of the firms, efficient firm, is capable of producing the highest level of output(s) at a level of input(s), then other firms being considered should also be able to maintain the same levels if they were to operate efficiently (Charnes et. al. 1981). *Performance Targets* can be set for inefficient firms to enable them to achieve 100 per cent relative efficiency in comparison with the efficient firm. Since all firms operate in the same environment, benchmarking of performance of the efficient firm is realistic.

DEA gathered quick acceptance in management science (Sherman & Zhu, 2006), however, in economics it has to face certain initial skepticism. Three major reasons are quoted for its opposition in economics. Firstly, DEA being nonparametric method; no production, cost, or profit function is estimated from the data. The nonparametric approach does not allow evaluation of marginal products, partial elasticity, marginal costs, or elasticity of substitution from a fitted model (Tridas & Cooper, 1993). As a result, deriving of usual conclusions about the technology, which are possible from a parametric functional form are not possible. Secondly, DEA uses linear programming technique rather than the most used least square regression analysis of that era. Average economist of that time was uncomfortable with shadow prices that become zero at the slightest perturbation of the parameters. Finally, and most important of all, due to their non-statistical nature, LP solution of a DEA problem do not produce standard errors and thus, leaves no room for testing of hypothesis (Ray, 2004). DEA treats any deviation from the frontier as inefficiency and there is no provision for random shocks. However, stochastic frontier models explicitly allow frontiers to move up or

down due to random shocks. At the same time, the parametric frontier gives elasticity and other measures about usefulness of technology for marginal analysis.

3.16.1 Fundamental Concepts in DEA:

DEA is concerned with efficiency of an individual unit, which can be defined as the *Unit of Assessment* (Thanassoulis, 2001) or the *Decision Making Unit* (DMU) (Charnes et al, 1978) that is responsible for controlling the process of production and making decisions at various levels including daily operation, short-term tactics and long-term strategy. DEA is used to measure the relative productivity of DMU by comparing it with other homogenous units transforming the same group of measurable positive inputs into the same types of measurable positive outputs. The following three modes of DEA are generally used for analysis.

$$(FP_0)Max = \frac{u_1 y_{10} + u_2 y_{20} + \ldots + u_n y_{no}}{v_1 x_{10} + v_2 x_{20} + \ldots + v_m x_{mo}}$$

Where:

u – is weight of output y - value of output

v – is weight of input x – is value of input

3.16.2 Charles Cooper Rhodes (CCR) Model (Cooper et. al., 2011) – proposed more scientific approach to measure the efficiencies of DMUs with multiple inputs and outputs. Given the data, the CCR model measures the maximum efficiency of each DMU by solving the fractional programming (FP) problem where input weights and output weights are variable to be obtained. The ratio of 'virtual output' to 'virtual input' cannot exceed 1 for each DMU, which confirms to the economic assumption that the output cannot be more than the input in production.

It may be noted that the computation of DEA CRR model by transforming the FP Model into LP Model has been of great significance for the rapid development and wide application of DEA (Coelli et. al., 1998).

Banker Charnes Cooper (BCC) Model (Cooper et. al., 2011) – assumes constant returns to scale. This model is aimed to decompose the technical efficiency into pure technical

efficiency and scale efficiency. The scale efficiencies can be obtained by dividing overall technical efficiencies by pure technical efficiency.

3.16.3 DEA – Categorisation (Cooper et. al., 2011):

On the basis of *Returns to Scale*

- CCR model proposed efficiency measurement of a DMU for Constant Returns to Scale (CRS) when all DMUs operate at their optimal scale.
- BCC model developed in 1984 presented Variable Returns to Scale allowing breakdown of efficiency as technical and scale efficiencies in DEA.

On the basis of Orientation:

- Input oriented model minimise inputs for a desired level of output.
- Output oriented model maximise the output while input is kept at constant level.
- Both methods seek to maximize output, minimize input to maximise efficiency.
- Input model focus on operational and managerial issues & Output model is oriented towards planning and strategy (Cillinane et al, 2005).
- In a competitive world most ports need to continuously review their productivity and efficiency to make sure that they give better services to society and port users. (Rajasekar et al, 2014).
- The current study follows output oriented model.

3.17 Productivity:

Productivity refers to the relationship between units of output to units of inputs. Productivity of a production unit is the ratio of its output to input (Lovell, 1993). Measuring productivity is easy if only a single input and single output are considered (Farrell, 1957; Banker et. al., 1984; Fare et. al. 1994). However, in modern economic and business environment firms use multiple inputs to produce multiple outputs making the task of gauging productivity complex. Productivity in partial may be measured using partial productivity measures like output per worker, or output per acre, or output per hour (Gronroos & Ojasalso, 2004). But the partial productivity measures tend to mislead and misquote the actual firm performance. This has led to the development of multifactor or total factor productivity (TFP) that can ably check firm

performance using multiple inputs and outputs and help in comparison of multiple firms across a period of time. Thus, TFP can be defined as a ratio of aggregate output produced relative aggregate input used.

3.17.1 Malmquist Productivity Index (Cooper et. al., 2011)**:**

Malmquist TFP was introduced by Caves, Laurits, & Diewart (1982) where they have defined TFP using Malmquist input and output distance functions that has resulted in the development of Malmquist TFP index. The index is developed by measuring the radial distance of observed output and input vectors for two periods relative to reference technology. The Malmquist TFP indices differ based on the output oriented and input oriented distance that is considered. Caves et. al (1982a) proposed and generalised definitions for bilateral input, output, and productivity evaluations for neoclassical structures of production and have proven that a widely used bilateral index to be very attractive for making such comparisons. Caves et. al. (1982b) developed index number procedures to make comparisons under general circumstances. They have proved Tornqvist input index to be line with geometric mean of Malmquist input indexes when two of its underlying functions are translog but with different parameters. They have substituted the technology frontier for the indifference curve to define the productivity index by taking the lead from Malmquist consumer quantity index. Grifell-Tatje & Lovell (1995) argued that Malmquist productivity index does not accurately measure productivity changes under non-constant returns to scale. Malmquist (1953) defined a quantity index as ratios of distances/distance functions were observations are evaluated relative to an indifference curve, as it has working with consumer-based index. Daskovska et. al (2010) proposed and investigated a new working procedure of dynamic forecasting of Malmquist productivity index covering circular and stationary components that allow forecast productivity gains in a better manner. Grifell-Tatje & Lovell (1999) introduced a generalised MPI to overcome the scale-related drawback of existing MPI that was proposed by Caves et. al (1982b). The existing index is multiplied by scale index comprised of distance functions. They have claimed that their index provides an accurate measure of productivity change in the presence of scale economics. They further claim that their index can provide better results even in environment featured by increasing returns to scale. Fare et. al. (1997) Malmquist productivity index can be expressed as the product of technical change and technical efficiency change index.

MPI, a tool for tracing productivity changes observed at a DMU during two periods of time can be calculated in two methods. The first method is using Trans-log Function (Caves et. al., 1982; Liu, 2010) is a parametric approach that requires predefined functional form of distance function to estimate MPI (Yu et. al.2014). The second method using the non-parametric techniques uses DEA function to derive MPI results (Timothy et. al. 2005).

A majority part of Malmquist index estimation comes under the nonparametric DEA approach (Fare et. al., 1998) as it estimates the index and its components by calculation of distance function under both constant and variable returns to scale technologies. The popularity of DEA routs from its advantages of non-parametric approach that helps in easy computation, applicability even with multiple outputs, non-reliance on price related information, non-dependence on economic behavior like cost minimization and profit maximization. It also has the advantage in the form that it neither any particular functional form for estimation nor a large number of observations. These features make the method attractive, especially in cases where price data is not available or cannot be constructed in detail, sample being too small or lack of sufficient understanding of firm behavior. But nonparametric approach does not provide a way to directly test statistical significance or hypothesis regarding the significance of the assembling components or model specification. It fails in separating measurement errors and random noise from technical inefficiency (Yu et. al., 2014).

Under parametric approach, MPI is not directly obtained by estimation of distance functions even with different returns to scale technologies. Instead MPI with its components are calculated based on the fitted distance function along with globally variable returns to scale, assessed at adjacent time periods' input and out-put quantity (Balk et. al. 1997; Fuentes et. al., 2001; Pantzios et. al., 2011; Orea, 2002).

Indexing of Port Performance is developed through Malmquist Productivity Index.

Total Factor Productivity (TFP) – is the ratio between some function that add outputs and some function that adds inputs. Mathematically, the equation to applying the corresponding additions in the productivity ratio, where the following expression is obtained:

$$TFP = \frac{\sum_{m=1}^{M} u'_m y_m}{\sum_{k=1}^{k} v'_k x_k}$$

Where, TFP is total factor productivity for M products employing K inputs and u' and v' weights, since not all inputs or outputs can equally important.

Alternatively, the change in total productivity can be estimated as the ratio of change in TFP over a period of analysis. To clarify this, if a firm produces one output and employs one input for the purpose, the expression that tells us how productivity changed between a starting period (t) and a final period (t+1) is:

$$\frac{y_{t+1}/x_{t+1}}{y_t/x_t}$$

However, this equation represents one output, one input and it only compares productivity levels observed in tow periods, assuming constant technology.
To solve these issues, Malamquist Index is proposed by Caves, Christensen and Diewart (1982).

Malmquist index is a tool that allows changes in total productivity to be determined and decomposed into each of their components. This index employs distance functions and can be represented as:

$$M^{t+1}{}_{OC}(x^t, y^t, x^{t+1}, y^{t+}) = \frac{D^{t+1}{}_{OC}(x^{t+1}, y^{t+1})}{D^{t+1}{}_{oc}(x^t, y^t)}$$

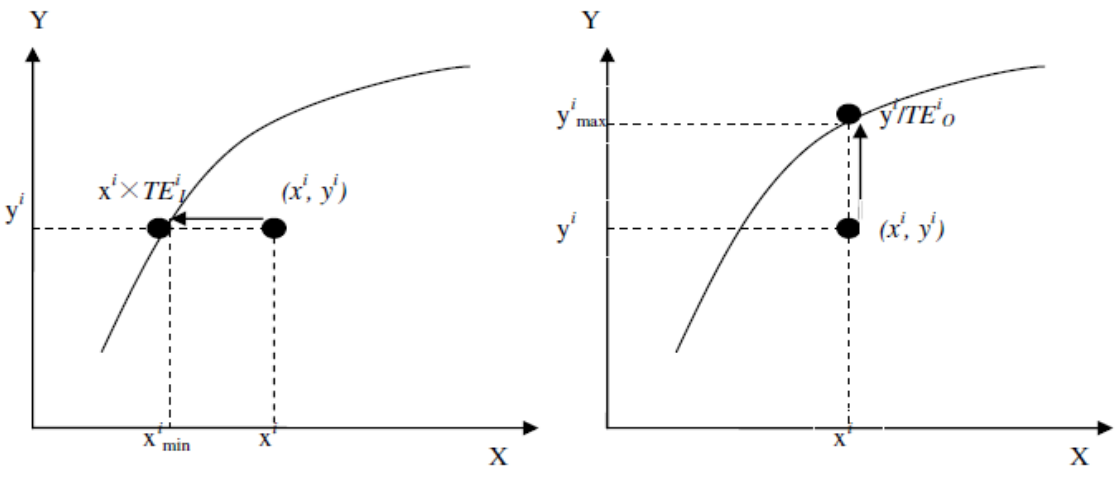
Where, $M^{t+1}{}_{OC}(x^t, y^t, x^{t+1}, y^{t+})$ compares (x^{t+1}, y^{t+1}) withx^t, y^t , obtaining the distance between them and the best possible benchmark given the technology of period t, i.e., $T^t{}_c$. Thus a value greater than 1 in the above equation would indicate that the value of TFP has increased, and if the value is below one, it represents a decrease in TFP.

MPI used in current research to represent productivity gains of the selected 12 major ports of India for 19 years gives results with parameters such as:

- Technical Efficiency Change - (TEC)
  - Pure Technical Efficiency Change - (PEC)
  - Scale Efficiency Change - (SEC)
- Technological Change - (TC)
- Total Factor Productivity (TFP) Change (MI)

- **3.17.1.1 Technical Efficiency (TE)** – it relates to productivity of inputs. TE relates to the productivity of inputs (Sathye, 2001). TE of a firm is a comparative measure of how well a firm processes inputs to achieve its outputs, in comparison to the maximum potential of doing so, as represented by its production possibility frontier (Barros and Mascarenhas, 2005). TE refers to organising the available resources to derive maximum feasible output that no other organisation can derive (Levin et. al. 1976). It is a comparative measure of how well it actually processes inputs to achieve its outputs, as compared to its maximum potential for doing so, as represented by its production possibility frontier. A formal definition for TE, 'TE represents either the ability of a firm to minimise the inputs used in production for a given output vector, or the ability of the firm to maximise the output from a given input vector (Koopmans 1951). This definition leaves two technical efficiency measures of input orientation and output orientation. The following figure depicts both input and output oriented measures of single input and single output cases. The curve depicts ideal performance. (x^i, y^i) is the actual performance of firm *i*; which applies input vector x^i to produce output vector y^i. Technical efficiency of the firm and (x^i, y^i) can be identified by input-oriented measure, $TE_1^i = \frac{x^i min}{x^i}$, or output oriented measure $TE_0^i = \frac{y^i}{y^i{}_{max}}$. The value of TE_0^i and TE_1^i may vary between zero and unity.

Fig: 3.2 Input and output oriented technical efficiency measures



Input-oriented efficiency measurement with single input (input distance function)

Output-oriented efficiency measurement with single output (output distance function)

Source: Ray, Data Envelopment Analysis, 2004.

The choice of measurement technique depends on the type of industry and stage of economy of the country (Rajasekar et. al. 2014). In a developing country like India, the port authority, terminal operator, have the ability to influence the output level. At the same time constant pressure from shippers with cargo can also influence the developments at port facilities and infrastructure. So the current study has checked the efficiency of ports using both input and output orientation.

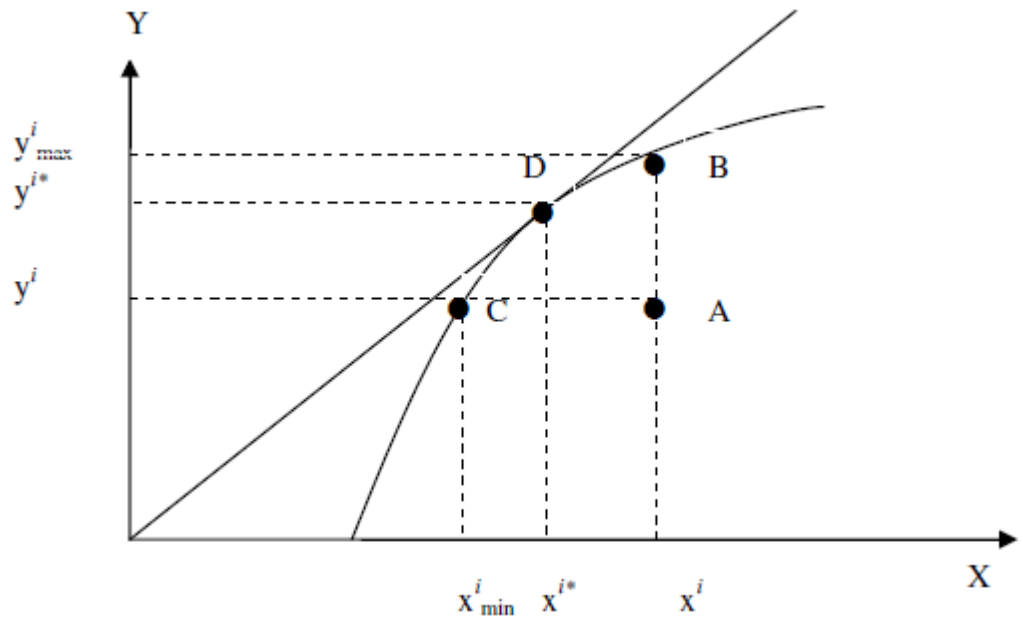
A measure of TE under the assumption of CRS is referred to as a measure *overall technical efficiency (OTE)*. This OTE measure aids in determining inefficiency due to the input/output configuration along with the size of operations. In DEA, OTE measure has been decomposed into two mutually exclusive and non-additive components: 'pure technical efficiency' (PTE) and 'scale efficiency' (SE) (Fare, 1957; Kumar & Gulati, 2008). This decomposition helps in tracing the sources of inefficiencies.

3.17.1.1.1 Pure technical efficiency (PTE) - is a measure of technical efficiency purely reflects the managerial performance to organise the inputs in the production process. It measures about how a DMU utilises its resources under exogenous environments. The PTE measure is derived by estimating the efficient frontier under the assumption of variable returns-to-scale. PTE is a measure of TE without SE and thus, purely represents the managerial performance in organising the inputs in the production process. So, PTE measure is used as an index for capturing managerial performance. A low PTE represents the inefficiency of DMU in managing its resources. The ratio of OTE to PTE gives SE measure.

3.17.1.1.2 Scale Efficiency (SE) - ability of management to choose the optimum size of resources required to attain the expected production level (Kumar & Gulati, 2008). Scale efficiency is the component of technical efficiency that can be attributed to the size of operations. Giving mathematical formula for SE (Balk, 2001) proposed its measurement using both input and output orientation.SE measurement can also be studied through input and output orientation. It indicates the effectiveness of the input (output), for a given output (input) mix. The following figure illustrates both TE and SE measures by considering a firm with single input and single output. While 'A' is actual observation point, 'B' is the output oriented TE optimal for observation 'A', representing the maximum obtainable output, at the same level of input as observation. Point 'C' represents input oriented TE optimal for the

observation ‘A’ representing the minimum input that could be employed for the same level of output as observation ‘A’. Both ‘B’ and ‘C’ are on technical frontier and ‘D’ represents the scale optimal that the firm can achieve with the same level of input and output combination. The output oriented SE can be measured by the slope between OB and OD; the input-oriented SE can be measured by the slope ratio between OC and OD.

Fig: 3.3 Input and output oriented scale efficiency measures



- **3.17.1.2 Technological efficiency** - technological possibilities of transforming inputs into outputs that are available to the organization. Technological efficiency change will impact the level of output an organisation can produce over a period of time due to optimal usage of input and output combinations. So the technological changes result in production possibility frontier to shift upward, as more outputs can be obtained from the same level of inputs. Thus, for a firm productivity improvements over a period of time can be either due to technical efficiency improvement or technological improvements or both. A technological change index represents technical progress (regress) if the output is greater (less) than one (Worthington, 2000).

- **3.17.1.3 Total Factor Productivity (TFP)** – represents the gains in overall aspects of business operations encompassing all inputs and outputs applied in the firm. Partial Factor Productivity (PFP) does not represent all the factors of production but only one or few basing on the requirement in a specific situation. TFP represents a productivity measure involving all factors of production. When multiple input and output factors are considered for calculation of productivity, TFP may be defined as a ratio of aggregate output produced relative to aggregate inputs used (Coelli et. al., 2005). However, calculation of TFP becomes difficult especially, with the complex process of assigning of weights to each of the input and output variables. DEA technique of calculating TFI as suggested under MPI provides a viable opportunity to overcome this difficulty. Thus, the current research attempts to calculate TFP using MPI.

3.18 Conclusions:

This chapter introduced to the concepts of research design and enumerated the research focus for this work. It gave an overall picture of efficiency and productivity and how various authors across the world have actually estimated and studied them in the port sector. Basing on the observations, the statement of problem, research objectives, research questions, along with the scope of the study are discussed. Highlighting the nature of research questions, an in depth note on the various strategies of inquiry is given from where the frame work for the current research is derived.

Then the rationale of the current study is discussed which, is followed by an explanation regarding data collection and validation methods for the current study. Considering the significance of the data analysis strategy, this chapter further, described the techniques of DEA and MPI along with the concepts of efficiency and productivity. The discussions, now, would bestow an opportunity to take-up the actual data analysis.

Chapter 4
Port Sector

4.1 Introduction:

This chapter explains about the progress of world maritime sector and its impact on world economic growth. Patterns of world trade reflected through growth in developing economies. This has originated due to the quest for trade among the European business circles, which has led to the discovery of sea routes. Trade routes and trade links have resulted in development of sea trade and port sector that links sea and land trade. Port and shipping sectors have sustained the political and economic turbulences and evolved as stronger forces of economic development across the world. The culmination of World War II has resulted in new political environment which resulted in economic cooperation among the nations of the world. This has marked the dawn of business prospects of third world nations that have high potentiality of growth. The prospects of cooperation are well cemented with the establishment of UN under which numerous organisations, especially, UNCTAD has supported the world trade including port and shipping sectors. UNCTAD and World Bank have given certain performance indicators to check the performances of ports across the world.

Port sector plays an important role by supporting the shipping industry and ultimately facilitating world trade. To meet the growing demands of international business, numerous ports were established across the world under public and private sector. This growth and development prospects has resulted in competitive spirit among the nations across the world. To make them more vibrant, governments contemplated setting up of ports in different modes which have from time to time evolved. The latter part of 20^{th} century has seen the process of reforms initiated in this sector resulting in huge investments by private sector that gave it greater growth scope for development.

The last part of the chapter highlights the journey of growth experienced by Indian port sector and discusses about the current state of affairs at each of the major ports of India.

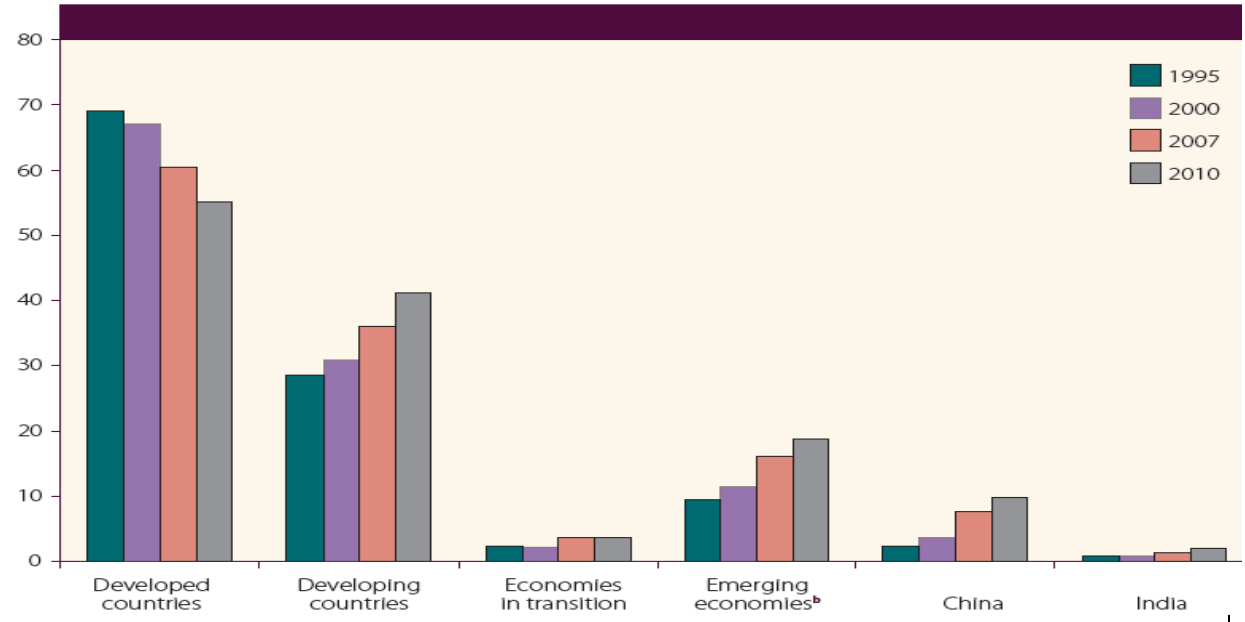
4.2 Background

Structural changes in international trade and evolution of maritime transport directly impact port growth and expansion across the world. Globalisation, expansion of markets and economic prospects of countries, has taken place not just due to the supra-national nature of markets, but also due to free flow of foreign investment and the strategies of multinational enterprises. Both the Asian financial crisis during the year 1997–1998 and the Latin American economic slowdown in year 1999 have jeopardised prospects of the world economy (Nissanke, 2009). However, world economy has seen recovery from late 1999 due to cross border investments in the form of FDI. Macroeconomic reforms, tariff structure and port reforms by governments, have spurred the development of port industry across the world (Carlos M. Gallegos, 2000).

4.3 History of Maritime Trade

The patterns of world trade are shifting towards the developing countries with concentration of economic activity of export and import improving in these countries. During the period of 1995 to 2010, share in world merchandise trade of developed countries declined from 69 to 55 percent (UN Report 2012). While that of developing countries raised from 29 to 41 percent (As given table below). The shifting pattern is associated with rapid industrial growth experienced by the developing economies. These countries are drifting from agriculture and primary production to manufacturing and service sectors resulting in increase of imports and exports. Around 83% of increase in the share of developing countries during 1995-2010 is associated with emerging economies of Brazil, Russia, China, India, South Africa, Mexico and South Korea (Michalopoulos & Ng, 2013).

Figure 4.1: Gains and losses in world market shares of merchandise trade
(share of total exports and imports in total world exports and world imports)



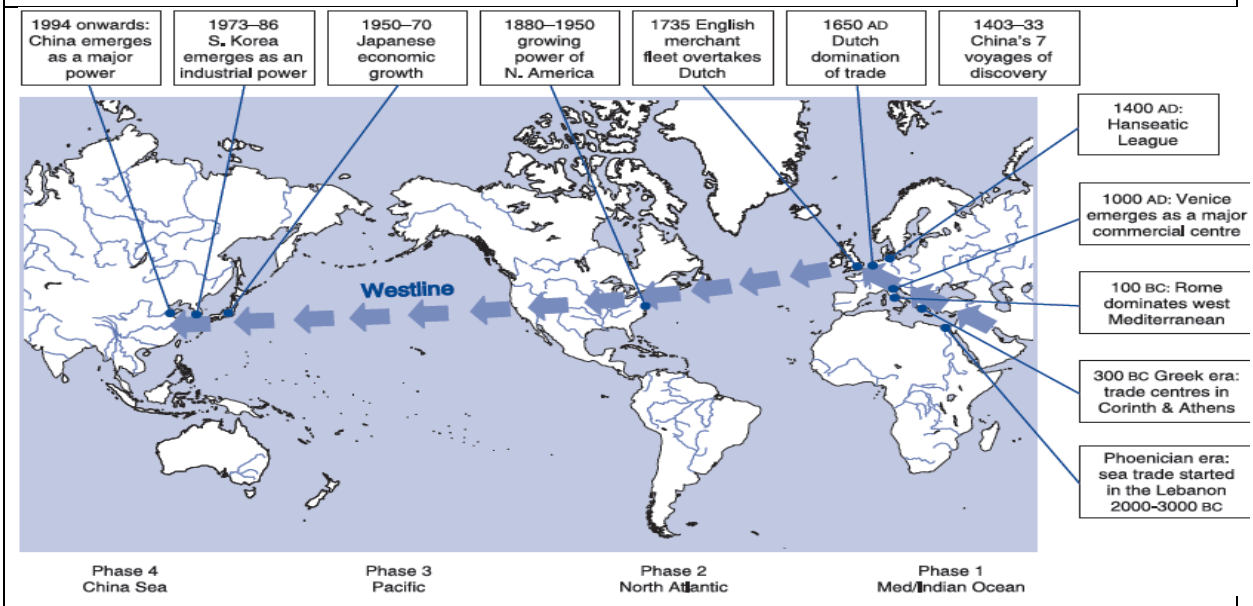
Source: World Economic Situation and Prospects, 2012 Figure II.3, page 43.

[b]Emerging markets include Brazil, China, India, Mexico, South Korea, Russia, & South Africa.

4.4 Growth of ports across the world

The contribution of sea transportation to world economy is immense with maritime trade itself is centuries old. Over a period of 5000 years either by chance or due to unknown economic factors, the commercial center of maritime trade moved towards 'west line' as shown in the following figure. Between 2000-3000 B.C. to 21st Century, sea trade has been dominated by numerous economic and political pressures.

Figure: 4.2 The Westline: 5000 years of Maritime trading centers



Source: Sea Transport and Global Economy, Maritime Economics, Martin Stopford, 2009.

The first sea trade network we know of was developed 5,000 years ago between Mesopotamia, Bahrain and the Indus River in western India (Stopford, 2009). The following figure shows the sea trade links between Mesopotamia and Indus civilisation where Mesopotamia exchanges oil and dates for copper and ivory from Indus.

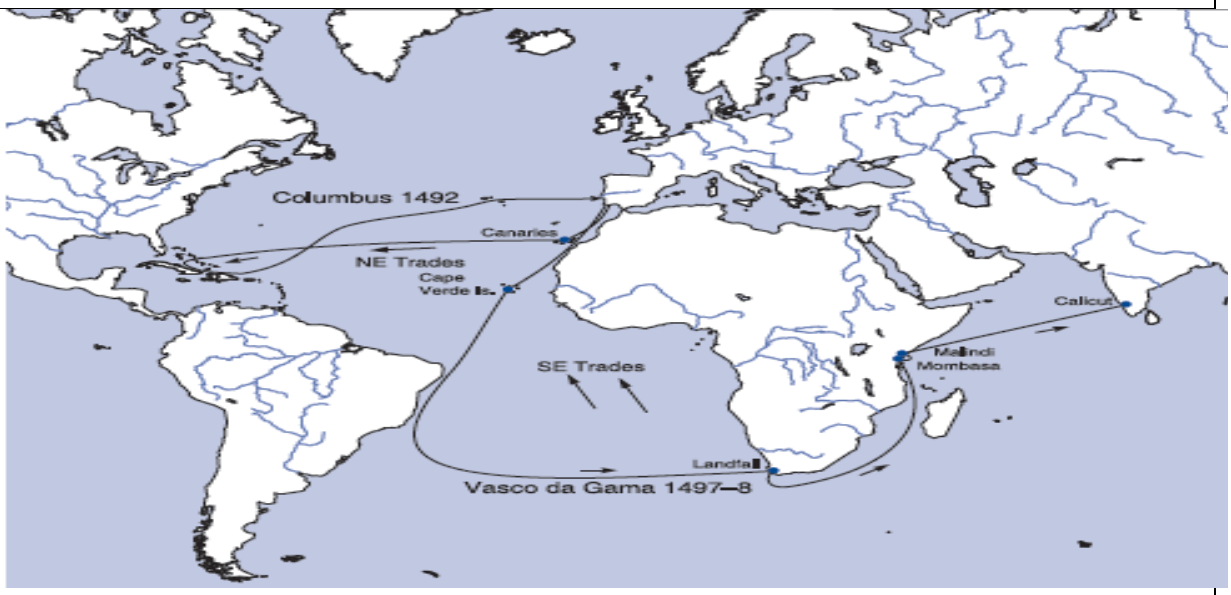
Figure: 4.3 Early Sea Trade, 2000 BC

Source: Sea Transport and Global Economy, Maritime Economics, Martin Stopford, 2009.

4.5 Discovery of sea routes to Asia:

During the 15th century Europe laid foundation for global sea trade network in search of precious spices, silk available in the east. Numerous traders started exploring sea routes towards east and west in search of opportunities for trade.

Figure: 4.4 European Voyages of discovery 1492-98

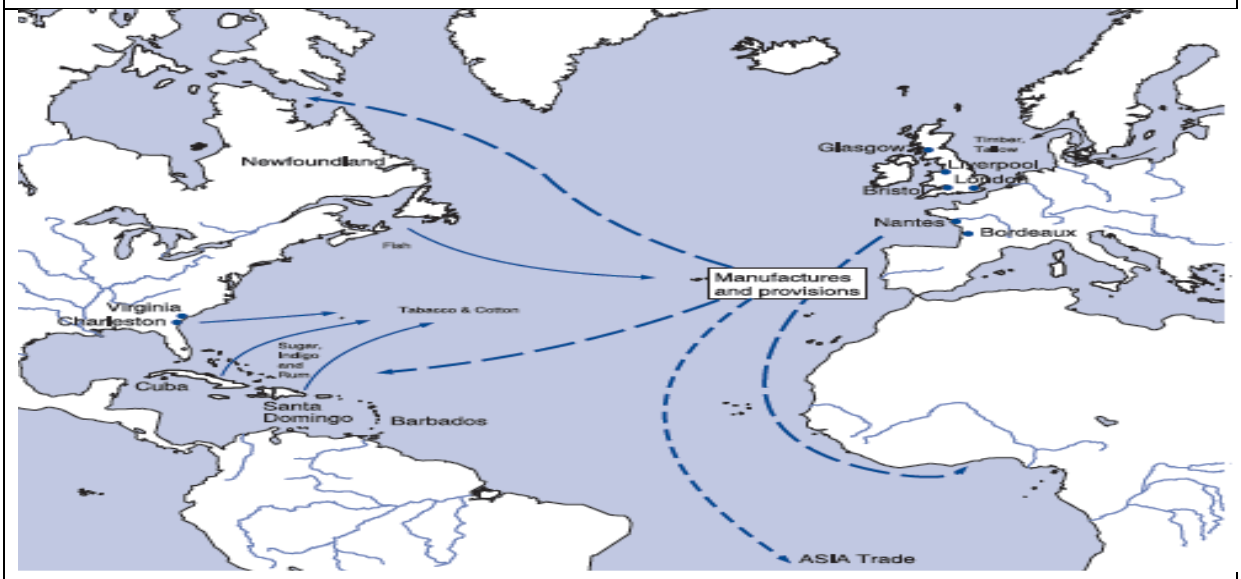


Source: Sea Transport and Global Economy, Maritime Economics, Martin Stopford, 2009.

4.6 Expansion of European Trade:

Within the next decade Europe established trade links and sea routes across the globe with new discovery of new sea routes. The voyages allowed Europe to find new markets for its manufactured finished goods and new sources of raw material like wool, dyestuffs, sugar, cotton, tea, coffee, and spices.

Figure 4.5: Sea trade in the eighteenth century



Source: Sea Transport and Global Economy, Maritime Economics, Martin Stopford, 2009.

Shipping till this period across various countries and ports was predominantly based on colonial rule and dominated by European nations that ruled most countries in of the world. Merchants sailed through countries in search of trade opportunities with the backing of respective rulers of their own countries.

The merchants of ancient times were as aware as current logistics service providers of taking into account the cost of port services and overland transport, as well as cost of maritime transport when selecting a port for discharge or loading of cargo. However, the methods used to make decisions about the port facilities to be provided and the methods of operation have changed significantly over time. (Trevor Heaver, 2006)

However, political struggles during the 19th and 20th century, in a way, destabilised European supremacy (Michael Hefferman, 2002). By the end of World War II, new economic and political environment emerged with an unified approach for development of world economy.

4.7 Aftermath of world war – II: Economic Reorganisation

The United Nations, an organisation of 51 member countries started in 1945 with objectives of peace and security, developing friendly relations among nations and promoting social progress, better living standards and human rights (United Nations, 1945) started as a body for world economy growth. United Nations Conference for Trade and Development (UNCTAD), as a subsidiary of UN, was started in 1964 with an aim for development of international trade among member nations.

To meet the challenging demands of increasing merchandise across the world, ports connecting the countries need to be efficient. Port performance determines its ability to handle ships carrying cargo and thus, a port having better performance standards would be able to attract greater volumes of cargo. In this competitive economic environment, it becomes imperative to quantify ability of a port and qualify it on the basis of its performance. UNCTAD has given certain parameters in this direction that would help countries know the abilities of their ports and plan for their development needs accordingly.

4.8 Performance Indicators

'*Performance*' represents capability of doing some work. Port performance is comparison between port's actual performance vis-à-vis targets. Numerous reports and research works have proposed a variety of methods to measure port performance. However, strangely, none has defined 'port performance'. "Given that robust theory building and accurate interpretation of empirical data cannot take place before formal definitions are established." (Wacker, 2004)

Port performance may be evaluated from the standpoint of technical efficiency, cost efficiency and effectiveness by comparing the port's actual throughput with its economic technically efficient, cost efficient and effectiveness optimum throughput, respectively (Wayne K. Tally, 2007).

4.9 Indicators of Port Performance

United Nations Conference on Trade and Development (UNCTAD), 1976 report on Port Performance Indicators identified two primary reasons for calculation of performance indicators as usage of such data for improving port operations and also as an appropriate basis for planning future port development. The report framed financial indicators and operational indicators providing information on as follows:

Table: 4.1 UNCTAD – Port Performance Indicators

Financial	Operational
1. Tonnage worked	8. Arrival rate
2. Berth occupancy revenue per ton of cargo	9. Waiting time
3. Cargo handling revenue per ton of cargo	10. Service time
4. Labour expenditure per ton of cargo	11. Turn-around time
5. Capital equipment expenditure per ton of cargo	12. Tonnage per ship
6. Total contribution	13. Fraction of time berthed ships worked
7. Contribution per ton of cargo	14. Number of gangs employed per ship per shift
	15. Tons per ship hour in port
	16. Tons per ship hour per berth
	17. Tons per gang hour
	18. Fraction of time gangs idle

The indicators suggested by UNCTAD, 1976 report was followed by suggestions of researchers working for World Bank and other agencies. Kek Choo Chung (1993) suggested, apart from the proposals of UNCTAD, for extensive and intensive utilisation of physical assets and financial benefits of operations as key for port efficiency measurement. The work done on behalf of World Bank, further proposed for bifurcation of ship turnaround time on the basis of type of ships; tonnage per day/hour; congestion status at port; homogeneity of cargo handled; cargo based dwell time; asset utilisation; berth efficiency; and GRT/NRT based financial comparison to trace real efficiency of a port.

Patrick Fourgeaud (2000) proposed customised approach of indicators to monitor port performance, forecast development and set targets in port sector projects. While highlighting need for reliability of data collected, the author suggested that data maintained by port on their operations are reliable in comparison to data on landward operations. Further, based on objective of the individual study, selection of indicators would differ for each of the port being measured. The study found that while the port authorities concentrate on technical efficiency, shipping lines look for schedules of ship handling, costs involved, quality of services, port's adaptability to handle customised cargo, performance standards, and hinterland connectivity.

It may, however, be noted that as the port sector grew as a body of knowledge and as a sector in a competitive business environment over a period of time, new indicators tend to evolve. From the above it is evident that identification of new indicators is still in progress, especially, with the concept of privatisation being taken up seriously around the world.

The indicators so proposed would be useful for policy makers and port authorities to assess and understand the working of their ports and formulate policies and measures to streamline the developments in this vibrant sector of economy. The indicators are useful for checking the performance of both publicly owned and privately owned ports.

4.10 Port Administration Models

Port Administration refers to the manner in which a port is developed, maintained, and operated so as to provide the best possible services to different stakeholders depended on it. A port is generally managed by a 'Port Authority' which is responsible for its performance.

Commission of European Union defines 'Port Authority' as a "State, Municipal, public or private body, which is largely responsible for the tasks of construction, administration and sometimes the operation of port facilities and, in certain circumstances, for security."

The United Nations Conference on Trade and Development (UNCTAD) handbook for Port Planners in Developing Countries has listed the statutory powers of a National Port Authority as follows (on the postulation that operational decisions will be taken locally):

a. Investment: Power to approve proposal for port investments in amounts above a certain figure. The criterion for approval would be that the proposal was broadly in accordance with a national plan, which the authority would maintain.
b. Financial policy: Power to set common financial objectives for ports, with a common policy on what infrastructure will be funded centrally versus locally, and advising the government on loan applications.
c. Tariff policy: Power to regulate rates and charges as required toprotect the public interest.
d. Labour policy: Power to set common recruitment standards, a common wage structure, and common qualifications for promotion; and the power to approve common labor union procedures.
e. Licensing: When appropriate, power to establish principles for licensing of port employees or agents.
f. Information and research: Power to collect, collate, analyse, and disseminate statistical information on port activity for general use, and to sponsor research into port matters as required.
g. Legal: Power to act as legal advisor to local port authorities.

Central governments implement seaport policies through the allocation of resources rather than through the exercise of wide-ranging regulatory powers. While the central governments pursue macroeconomic objectives, the seaport authorities should be focused on port finances and operations. Port authorities need to objectively work for full recovery of all port-related costs, including capital costs, plus an adequate return on capital. Approach of full recovery of costs helps a port authority to:

a. Preserve internal cost discipline.
b. Attract outside investment and establish ensure long-term cash flows.
c. Stimulate innovation in the various functional areas that guarantee a long-term equilibrium between costs and revenues.
d. Generate internal cash flows required to replace and expand port infrastructure and superstructure.
e. Compete as per the rules of the market system, without excessive distortions of competition.

f. Put limits on cross-subsidisation, which would be rational from a marketing point of view, but which can undermine financial performance.
g. Avoid dissipation of the port authority's asset base to satisfy objectives of third parties.

4.11 Port Management Models

Port administration refers to the manner in which a port is established and maintained. Factors such as socio-economic structure of a country, historical developments, location, and type of cargo handled by the port influence the port organisation. Port administration may be broadly categorised into four models namely: Service Port; Tool Port; Landlord Port; and Private Service Port. The following table encapsulates the sectors with their different responsibilities under each of these models.

Table: 4.2 Basic Port Management Models

Type	Infrastructure	Superstructure	Port Labour	Other Functions
Public Service Port	Public	Public	Public	Majority Public
Tool Port	Public	Public	Private	Public/Private
Landlord Port	Public	Private	Private	Public/Private
Private Service Port	Private	Private	Private	Majority Private

Service Ports observed in developing countries are public in character where port authority offers a complete range of services required for functioning. The port owns, maintains, and operates all assets and cargo handling services are performed by port employed workforce. These ports are generally owned by ministry of the union.

Under **Tool Port** model, the port authority owns, develops, and maintains the port infrastructure as well as the superstructure, including cargo handling equipment. Staff appointed by the port authority usually operates all equipment owned by port authority. Other cargo handling on board vessels as well as on the apron and on the quay is generally carried out by private cargo handling firms contracted by shipping agents or other principals licensed by the port authority.

Landlord Ports are established under public-private orientation where the port authority acts as regulator and as landlord and port operations are taken-up by private companies. Infrastructure is leased to private operating companies or to industries such as refineries, tank terminals, and chemical plants. A fixed lease rent that would be adjusted to measure of inflation is agreed upon. The level of lease amount is related to initial preparation and construction costs. Private operators entering into lease agreement would provide and own their own superstructure, purchase and install their own equipment that is required at the terminal ground. The required dock labor is employed by private terminal operators. Of late, the port authority have started taking a share in the revenue earned by operation in the form of 'royalty' which is mutually beneficial in comparison to lease rents.

Under **Fully Privatised Port** model, the state does not have any meaningful involvement or public policy interest in the port sector. Port land is privately owned and in some cases the government may transfer even the regulatory functions to the private operator. The risk in this type of arrangement is that port land can be sold or resold for non-port facilities. There is also the possibility of land speculation, especially when port land is in or near a major city. Further, sale of land to private ports may also sometimes raise a national security issue.

4.12 Port Sector Reforms

During the entire 19th and first half of 20th century ports treated to be instruments of state or colonial powers with port access and control considered as means of market control (Port Reform Toolkit, 2007). With minimal competition, port-related costs became insignificant in comparison to high cost of ocean and inland transport. Most socialist countries ports were considered as part of national state structure and so were controlled by national shipping companies. All policies on maritime development were decided centrally, with port authorities carrying out the different day-to-day nautical and operational functions. Therefore, improvement of port efficiency was not taken seriously. However, the change in world economic scenario and with improved trade flows, port efficiency became a significant factor in the competitive environment. Reforms in port sector, the feature of 1990's, connotes the changing institutional structure of the port business and the much greater involvement of the private sector in the exploitation and financing of port facilities, terminals, and services. The phenomena of reforms in port sector gaining momentum in industrilised and developing countries alike (Dirk Sommer 1999). Port reform, thus, results in changing relationships

between the public and private sectors. Involvement of huge capital investments in port infrastructure generated drive to unbind ports from bureaucratic control of public entities and bring-in private investments into wide range of port operations.

By the turn of 1980's, the belief in the management and operating capacities of national governments faded in most market economy countries. The concept of privatisation crept into port sector as in any other public sector. This has resulted in the reassessment of the role of the government and private enterprise. Argument favouring privatisation initiated due to multiple motives such as efficiency, cost reductions, improvement in service quality, reduction of bottlenecks in decision making, etc. All these different reasons for opting port reforms are depicted in the following table 3.3.

Table 4.3: Reasons for World Port Reforms

General Reasons	Administrative and Managerial Reasons
• Improve port efficiency. • Decrease costs and prices. • Improve service quality. • Increase competitive power • Change the attitude with respect to port clients	• Depoliticise the public port administration. • Reduce bureaucracy. • Introduce performance-based management. • Avoid government monopolies.
Financial Reasons	**Employment Reasons for Change**
• Reduce public expenditure. • Attract foreign investment • Reduce commercial risks for the public sector. • Increase private sector participation in the regional or national economy.	• Reduce the size of the public administration. • Restructure and retrain the port labor force. • Eliminate restrictive labor practices. • Increase private sector employment.

Source: Various World Bank surveys from 1990 – 2000. Port Performance Tool Kit (2007)

World Bank's Port Reform Toolkit (2007) identified five forces of Competitive Landscape facing port authorities in the 21st Century as 1) rivalry among existing competitors; 2) threat from new competitors; 3) potential for global substitutes; 4) bargaining power of port users; and 5) bargaining power of port service providers. These forces are expected to impact all the

ports, irrespective of their size, and push them towards expansion, service improvement, pricing decisions, and improved management.

Port operations in the 21st century are expected to see radical changes (Port Reform Toolkit, 2007). Intense global competition offers for innovative systems and technological up-gradation of port infrastructure leading to high degree of specialisation, rising of financial stakes of port investments, and demand for specialisation in workforce.

Containerisation of world trade has put more pressure on port to improve throughput and reduce their turnaround time. Container traffic has consistently increased over a period of time and is expected to dominate the future cargo structure. Containerisation dramatically reduces the personnel requirement and ship's stay at the port and berth. It has also improved cargo handling and berth productivity but increased capital intensity of port operations.

4.13 Constraints and emerging concerns in port development

A port traditionally has been a node for transferring goods from one mode of transport to another. In this age of economic liberalisation ports are quickly transforming from traditional land/sea interfaces to providers of a comprehensive logistics network units. The dynamic market environments after initiation of globalisation across the world pose numerous challenges to port performance. Some of such emerging issues (Rodrigue, 2010; CRISIL 2010; UNESCAP 2005) include:

a. Globalisation of manufacturing and outsourcing of products and services;

b. Restructuring and reposition of distribution centers at both regional and/or local logistics networks across liberalised economies of the world;

c. Change in volume and mode of cargo composition;

d. Increasing size of ships and their carrying capacities;

e. Greater transshipment cargos and higher competition among ports;

f. Transformation towards hub port concept;

g. One stop shopping concept and multi-model transport systems lining ocean, railways, roadways, and inland waterway transportation;

h. Ever increasing efficiency and productivity of ports across the world;

i. Capital intensity and risks involved in developing port facilities;

j. Environmental clearances for both starting and expanding ports.

All these developments put pressure on ports in to handle higher volumes of cargo with greater efficiency. To stay in the competition, ports are compelled to review their performances and strive for improving productivity for long-term sustenance.

Having understood the world port scenario, it is ideal to have a thorough understanding the growth trends of Indian ports. The following section addresses this key requirement of probing into the maritime developments of Indian sub-continent.

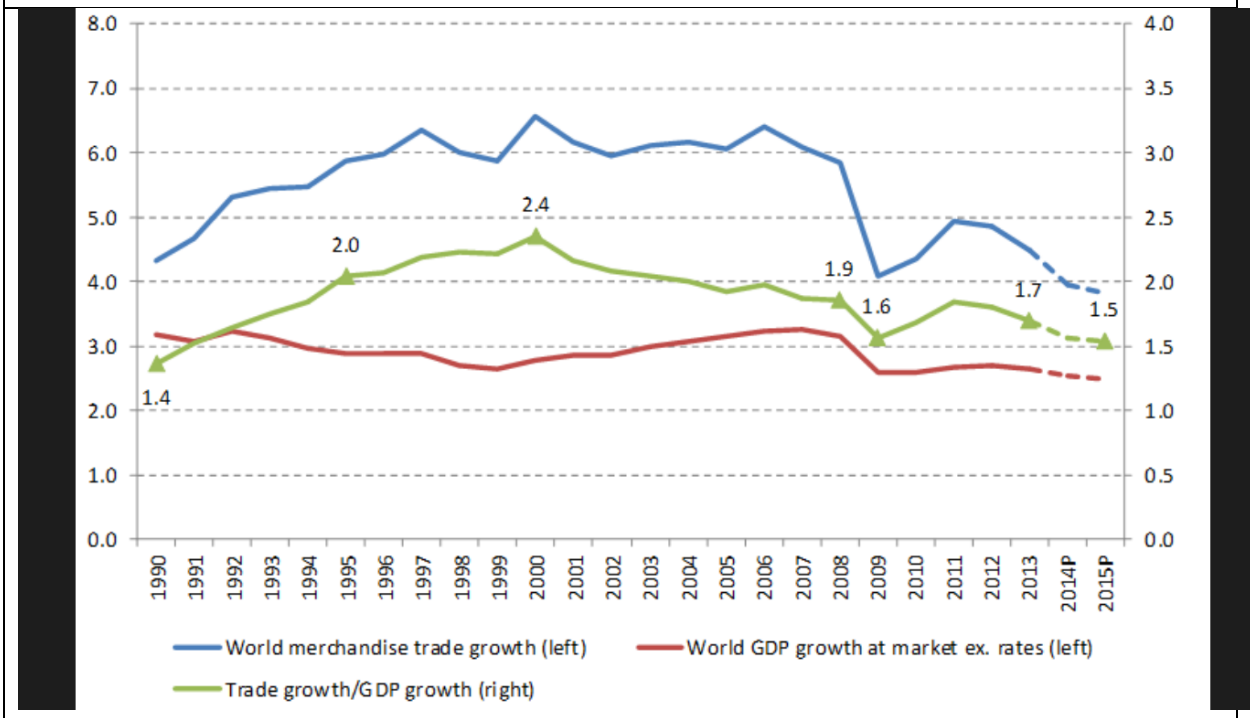
International merchandise trade after the World War II progressed at a remarkably dynamic rate due to dismantling of national trade barriers across the world. Between 1950 and 2000, world trade volume increased at an average of 6% annually (HWWI Report 2006). At a multilateral level, efforts of liberalisation have concentrated on tariff reductions for some period of time. Significant successes have been achieved in tariff reduction and reduction of entry barriers due to the negotiations of General Agreement on Tariffs and Trade (GATT). The Uruguay Round of GATT, lasting from 1986 to 1993, has led to the setting up of World Trade Organisation (WTO) in 1995. Formation of WTO has resulted in comprehensive renewal and extension of international trade regulations.

Establishment of WTO has accelerated economic reforms across the world to facilitate smooth and speedy movement of foreign investments (WTO, 2015). Countries, especially the developing, went on with reform process and opened their markets to private and FDI investors (WTO, 2014). This has led to a spurt in business activity and cross border investments. Investments in the form of financial, technological, and managerial dimensions

have enhanced business opportunities. With the improvement of international business a strong demand for viable sea transportation to move both raw material and finished goods from one destination to another has cropped. Growth in shipping business and sea transport have mandated for existence of ports that provide faster and reliable services to handling the incoming and outgoing cargo. Issues like Mechanisation of cargo handling facilities, robust hinterland connectivity, containerisation, technological advancements in cargo handling procedures, etc., have made reforms in port ownership and operations (Maritime Agenda, 2009). Attempts to make ports that are under the control of public sector, especially in socialistic economies, to perform in tandem with changing economic environment are initiated across the world.

The growth in world merchandise trade has been higher than the world GDP growth as depicted in the following figure.

Figure 4.6: World Merchandise Trade Growth, World GDP growth, & Trade growth/GDP growth



Source: WTO, 2014.

4.14 World Merchandise trade during 2010-2013:

Maritime transport, enabled by, inter alia, technological developments and competitive transport costs, is estimated to handle over 80% world trade by volume and over 70% by value (Maritime Agenda 2020). At the same time, technological advancements in bulk and container transport have made maritime transport cheaper and cost effective. The Volume of world exports expanded by 2.2% during the year 2013-14 vis-à-vis 2.3% in 2012-13. However, developing economies it is 5.1% in 2013-14 from 4.6% recorded in 2012-13. Like same, even imports developing economies showed a growth from 5.3% to 5.5% percent when the world average was constant at 2.1% during the period 2012-13 to 2013-14. In the developing regions Asia, led by China, has shown greater growth levels.

Table 4.4: Growth in volume of merchandise trade, 2010-13 (Annual percentage change)

Exports				Countries/regions	Imports			
2010	2011	2012	2013		2010	2011	2012	2013
13.9	5.5	2.3	2.2	**WORLD**	13.8	5.4	2.1	2.1
12.9	4.9	0.5	1.3	**Developed economies**	10.8	3.4	-0.4	-0.4
				of which:				
11.6	5.5	-0.1	1.4	European Union (EU-28)	9.4	2.8	-2.5	-1.2
27.5	-0.6	-1.0	-1.8	Japan	10.1	4.2	3.8	0.5
15.4	7.2	4.0	2.6	United States	14.8	3.8	2.8	0.9
16.0	6.7	4.6	5.1	**Developing economies**	18.5	7.7	5.3	5.5
				of which:				
10.3	-6.8	7.8	-1.8	**Africa**	6.5	3.9	11.8	5.6
8.1	5.1	3.1	1.5	**Developing America**	22.3	11.3	3.1	2.4
18.2	8.5	4.5	4.3	**Asia**	19.3	7.3	5.1	6.1
				of which:				
29.5	13.4	7.4	4.8	China	25.0	10.7	6.1	8.8
14.0	15.0	-1.8	7.6	India	13.8	9.7	5.5	0.1
4.2	9.1	9.8	2.2	Western Asia	8.6	8.2	8.7	8.6
11.4	4.1	1.3	1.0	**Transition economies**	17.6	16.8	5.0	2.7

Source: UNCTAD, Trade and Development Report, 2014, table 1.2

Note: Data on trade volumes are derived from international trade values deflated by UNCTAD unit value indices.

4.15 Indian Maritime Sector

Ports in India have been the gateway for foreign trade from time immemorial. The existence of foreign trade and usage of ports to reach key international destinations are traced in the pre early stages of human developments itself. India, ruled by different rulers at different times

has maintained relations with different countries and export and import trade has flourished with these nations. Indian ports and shippers were respected for their abilities and expertise over the sea trade.

The Maritime trade from India to Southeast Asia was seasonal phenomenon (Sila Trapati, 2011). The distribution of Buddhist settlements, discovery of variety of pottery, beads and inscriptions along the ports and trade centers point to active maritime trade between India and South East Asia. The eastern coast of India is well known for its several seaports located at river mouths or outlets of sea. Typical stupas, monasteries, and vihars that existed at close proximity to ports and trade centers indicated that Buddhism had played a significant role in maritime trade since the beginning of the Christian era to a later period. Mariners of the east coast might have felt of the force of wind and currents which assisted in driving the ships faster than the regular speed. This knowledge was probably confined to mariners; hence no reference is available prior to 6^{th} century BC. The ports of embarkation on the east coast were Tamralipti, Palur, Kalingapatnam, Dharinakota, Arikamedu, Poompuhar, etc. from where ships sailed to northern coast of Sri Lanka before crossing the Bay of Bengal into the 100 channel aided by favorable winds and current. From there, ships sailed towards the east of Sumatra and reached Java, Bali Island and crossed the Malacca Strait. Over a period of time, ancient methods of maritime trade disappeared, and now are only remembered and celebrated as rituals and social events along the east coast of India. It may be concluded from various articles that Maritime trade was well developed in India and Indian Mariners had a great expertise in international cargo handling.

However, the modern port operations started during the Mughal where international connections with Central Asia and Islamic World were maintained (Spodek 2007) and during British rule when Indian private businesses shouldered responsibility and contributed to the economy through business with many of the East Asian and European countries (Singhal & Tagore 2002).

Ports in India, after Independence, were managed by the Union of India as this sector is considered of national importance. The classification of ports is not on the basis of capacity or cargo handled but on the basis of control. India port sector is dominated by the Major Ports that work under the Ministry of Shipping, Government of India. The ministry of shipping was formed in 2009 by bifurcating the erstwhile Ministry of Shipping, Road Transport and

Highways into two independent Ministries. The ministry encompasses within its fold major ports and inland water transport. India has 12 Major ports that are governed by the Major Ports Trust Act 1963. The provisions of The Companies Act 1956 administer Ennore Port. The Government of India, State Governments and private port developers have administrative control over 187 non-major or intermediate ports. Tariff Authority for Major Ports, an independent authority regulates the tariff charged by Major Ports. It regulates all the tariff charges relating to vessel, cargo, and lease rates of properties in Major Ports Trusts and private operations located therein.

Entry number 27 of Union list of 7th schedule of 'The Constitution of India' reads "*ports declared by or under law by parliament or existing law to be Major Ports, including their delimitation, and the constitution and powers of Port authorizes therein.*"

Entry number 31 of Concurrent List 7th Schedule of 'The Constitution of India' reads "*Ports other than those declared by or under law made by Parliament or existing law to be major ports"*

By late 1980's major ports of India, just as most other public sector enterprises, proved to be inefficiency with multiple constraints. With the initiation of reform process in 1991, Indian became an attractive destination for foreign investments and investments in port sector became imperative to catch up with flow of foreign trade. This has led to allowance of private investments in port and shipping sectors.

Indian economy is one of the most vibrant economies of the modern day with greater scope for development. There is a lot of untapped potential for trade growth, and consequently the demands on the country's ports are trade infrastructure will continue to mount as trade diversifies and grows. The term 'maritime' refers to ports and shipping activity.

Sea ports are a link between maritime and inlands modes of transport for movement of good and passengers. Ports are single organizational units with multi-dimensional activities integrated within the logistics chain for providing services to maritime trade. Seaports operate with the prime objective of providing fast and safe transit of good and passengers through its facilities at minimal costs. At a global level, seaborne trade is handled through

more than 2000 ports, from single berth locations handling a few hundred tons to multipurpose facilities handling up to 300 million tons per annum.

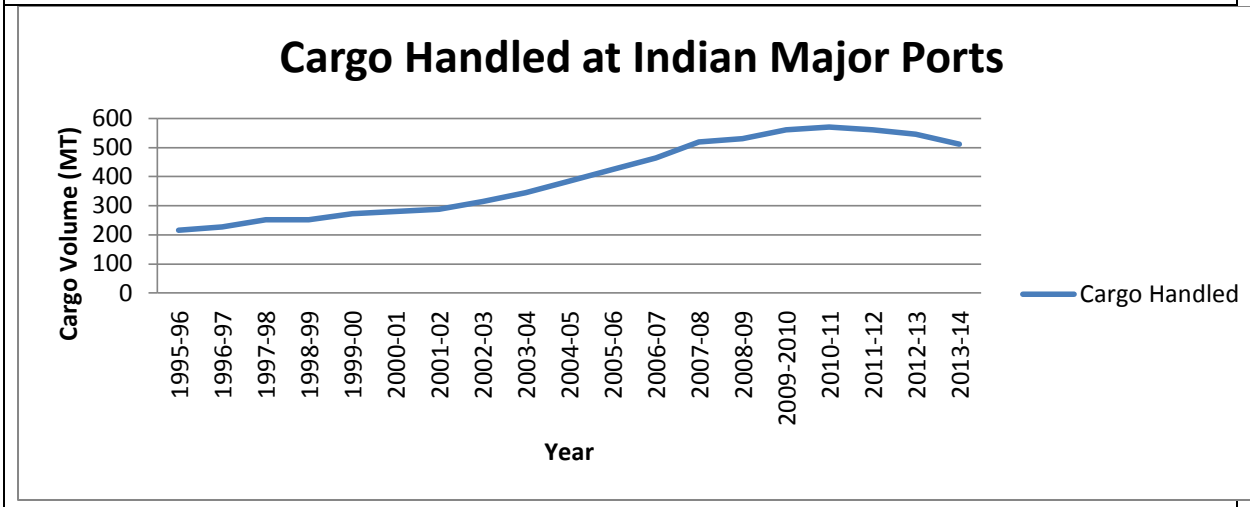
4.16 Major Ports of India:

Sea ports have played a key role in export of various precious goods from India to different locations. Presently India has got 13 major ports (including Andaman & Nicobar Port) and over 200 non-major ports.

Ports in Indian economy hold a special status as they handle over 95 percent of international trade by volume and 70 percent by value. In all, 12 Major ports in India were established on the east and west coast of India spread across 7517 KMS and covering nine Indian states of West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Goa, and Gujarat. Each of these ports, initially, was setup to deal with a single dedicated cargo. Out of the 12 Major Ports 11 ports were established as Trusts and Ennore Port is, however, established as a Corporation. The first six autonomous port trusts were set up under the MPT Act 1963 included the three legacy ports of Chennai, Kolkata, and Mumbai along with the ports of Cochin, Tuticorin, and Visakhapatnam. Subsequently, five other Ports Jawaharlal Nehru Port (JNP), Kandla, Mormugao, New Mangalore, and Paradip were added to the list. Ennore Port Corporation is the only major port which is not registered as a trust.

Best-in-class ports help India to become a transshipment hub, and superior port infrastructure ensures quicker and reliable shipping. All major ports of India, except Ennore port, are established under Major Ports Act, 1963 and function as semi-autonomously bodies under administrative preview of Ministry of Shipping. Cargo handling at these major ports has recorded consistent increase ever since their establishment. The growth in cargo volumes since the initiation of privatisation at major ports is shown in the following table. The figures in the table depict a two and half time growth in traffic handled during this reform phase.

Table: 4.5 Cargo Volume Handled at Major Ports of India during 1995-96 to 2013-14



Source: Compiled from publications of Indian Port Association, New Delhi 1995-2014

While there has been a consistent growth in overall cargo handled by Indian ports, the challenge is the wide range of cargo composition.

4.17 Problems faced by Indian Ports:

Indian major ports have numerous shortcomings in their performance levels in comparison to most of the international ports. (India Transport Report 2014) "India's ports are highly constrained for capacity and are expected to remain so in near future." In spite of recession across the world India his reported a growth in both exports and imports and are set for growth in future. Therefore, considering the long-term implications, it is extremely important to review current constraints to ensure the facilitating environment, consisting of both physical infrastructure and government policy, evolve in a desired manner. Cargo traffic at Indian ports is expected to grow at a CAGR of over 6 percent to reach 3068 MT by the end of 15^{th} plan (2031-32) from the current level of 914 MT. To meet the projected traffic growth needs, a capacity requirement of around 4000 MT at both Major and Non-Major Ports by the year 2031-32.

4.17.1 Problems faced by Indian Ports (Consolidated Port Development Plan 2007):

The primary problem faced by Indian ports is low productivity. The major reasons that have led to this drawback are:

a. Operational constraints like frequent breakdown of cargo-handling equipment due to obsolescence or wrong specification of equipment, poor maintenance and so on.
b. Inadequate facilities for dredging of berth and channels at certain ports and insufficient container handling facilities.
c. Inefficient and redundant deployment of port equipment.
d. Labor intensive methods of bulk handling of sensitive commodities.
e. Poor inter-departmental communication flows especially between Customs and Port Authorities.

4.18 Cargo related Problems at ports in India

Indian ports handle various types of cargo to serve the economic needs of the nation. Each of the ports has evolved certain degree of competence in handling certain ports. But if we are to consider the overall performance of the ports, all of them are constrained by certain problems in handling the cargo. In the following sections we shall see the problems faced by different ports in handling different cargo.

To overcome the constraints faced by major ports of India, government of India asked the Port of Rotterdam to assess current position and suggest pertinent measures to resolve the bottlenecks at major ports of India.

The study in its first report proposed a few suggestions to make Indian major ports competitive which include existence of incentives for competition among major ports, delegations of powers and responsibilities, autonomy in tariff setting and investing, speedy decision making, operational freedom, and professionalism.

The study further suggested for five options for port reforms such as improvement of port organisation, liberalisation, commercialisation, corporatisation and privatisation.

4.19 Indian port reforms:

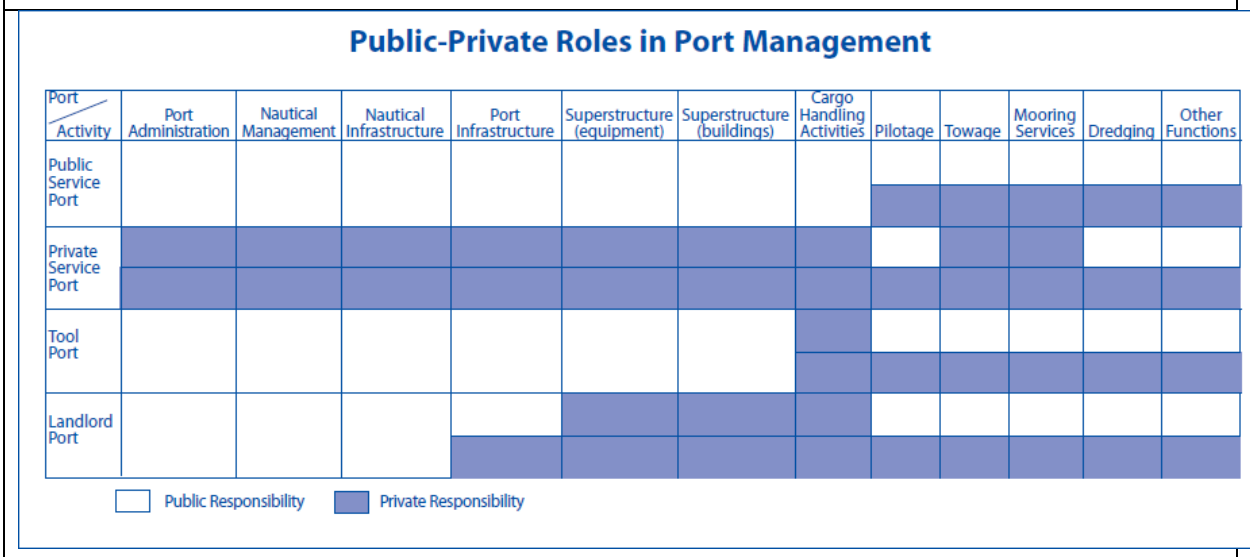
Although the economic reforms in India started in 1991, reforms allowing private investments at major ports were initiated only in 1995 (Maritime Agenda, 2020). Government of India, has, in phased manner allowed private sector in port operations. Currently, Foreign

Direct Investments (FDI) up to 100% through automatic route are allowed in port infrastructure investments.

With most nations opting to privatization of ports, the traditional service port model is slowing being overtaken by the landlord port model. Under the landlord model, the port authority retains the port infrastructure and fulfills its regulatory functions, and port services are provided by private operators that own the assets conforming to port superstructure and equipments required for service provision.

Indian government is promoting both Fully Privatised Ports as well as private participation at major ports in the form of Land Lord Port model. Projects are awarded under Public Private Partnership mode under Build Operate and Lease (BOT) scheme for periods ranging from 15 to 30 years.

Table: 4.6 Roles of Public-Private Parties in Port Management



Source: Module 1 – Framework for Port Reforms, Port Reform Toolkit, World Bank

Researchers (Ian O'Boyle, David Hassan 2014; Kwee Kwong Choong 2013; Claire Moxham 2013; Xiao Hong et. al. 2013; Striteska & Spickova 2012; Michal Hammer 2007; Langen et. al. 2007; Ruel P.E. 2003; Baird (1999); & Neely et. al. 1997) studying on basics performance using variables such as raw material, volume of output, expenses, and revenues found a few astonishing that include facts such as performance measurement in public sector to be for statutory compliance but not service improvement; identification of unstructured performance

indicators. These studies, often times, ignored numerous relevant indicators including financial and thus, could not provide holistic picture for performance levels.

International developments in port and shipping sectors bestowed both opportunities and threats to ports in India. Demands from vast markets in India have made Indian ports more competitive among themselves and abroad. To develop the port sector in India numerous initiatives were taken by the government of India. Policy measures to improve infrastructure, modernisation of facilities, robust logistic chain, abolition of licenses, opening of retail markets for foreign investments, opening of newer Special Economic Zones for newer projects etc. were taken. To stay competitive, port authorities had to modernize and upgrade port facilities to meet the needs of port users (Maritime Agenda 2020).

To augment the performance of ports, government envisaged National Maritime Development Program (NMDP) through which private parties were allowed to own and operate at major ports. Private investment, through Build Operate and Transfer (BOT) mode were thrown open on revenue sharing mechanism include construction of container handling berths, container terminals, and warehousing facilities, installation of cargo handling equipment, construction of dry-docks and ship repair facilities, etc. through open competitive bidding. Foreign Direct Investment (FDI) up to 100% is allowed through open bidding in port projects.

Under NMDP program 276 projects to be taken up for implementation over the years 2005 to 2012 with a total investment of Rs. 55, 804 crores (at 2004-05 prices) for port development were proposed. The NMDP program aimed to take cargo handling capacity of major ports to 616.73 MT by the year 2010.

Maritime Agenda 2020 unveiled by Ministry of shipping, Government of India, targeted traffic at major ports of India from 561.09 MT in 2009-10 to 1214.82 MT by 2019-20. Major port are posed to bring in structural changes in administration to improve organizational effectiveness. Major port are slowly drifting towards ‘Land Lord Port Model’ limiting their role to maintenance of channels and basic infrastructure leaving development of operational terminal management and cargo handling facilities to private operators. The capacity estimation as per Maritime Agenda 2020 is given as under:

Table: 4.7 Targeted capacity additions at major ports (In million tons)

Ports	Existing level 2009-10	Projections			CAGR (%) between 2009-10 & 2019-20		
		2011-12	2016-17	2019-20	2011-12	2016-17	2019-20
Major Ports	616.73	741.36	1328.26	1459.53	9.64	11.58	9.00
Non-Major Ports	346.31	498.68	1263.86	1670.51	20.00	20.31	17.04
Overall	963.04	1240.04	2592.12	3130.04	13.47	15.19	18.34

Source: Maritime Agenda – 2020, Ministry of Shipping, Government of India 2011.

Traffic Projections corresponding to the capacity projections during the same period are given as under.

Table: 4.8 Targeted capacity additions at major ports (In million tons)

Ports	Existing level 2009-10	Projections			CAGR (%) between 2009-10 & 2019-20		
		2011-12	2016-17	2019-20	2011-12	2016-17	2019-20
Major Ports	561.09	629.64	1031.50	1214.82	5.93	9.09	8.03
Non-Major Ports	288.80	402.50	987.81	1280.13	18.05	19.21	16.06
Overall	849.89	1032.14	2019.31	2494.95	10.20	13.16	11.37

Source: Maritime Agenda – 2020, Ministry of Shipping, Government of India 2011.

To maintain the above levels of capacity addition and traffic handling, the ministry has set some priorities that include:

1. Major port to be made land lord ports
2. Vibrant land policy allowing port to lease their unused land
3. Policy preventing monopoly of major ports
4. Corporatisation and commercialisation of major ports
5. Traffic regulation at major ports
6. Port regulator to facilitate level playing field for all ports in India
7. Open environment clearance mechanism
12. Dredging
13. Rail-Road Connectivity
14. Hub Ports
15. Tax regime
16. Cruise shipping
17. Pilots pool
18. Corporate social responsibility

8. Environment policy and green ports
9. Capacity building and human resource development
10. Competition and cooperation among ports
11. Indian Maritime Finance Corporation
19. Approach to International Cooperation
20. Indian Maritime Cadre
21. Legislative Framework
22. Indian Ports' Global

4.20 DETAILS OF MAJOR PORTS OF INDIA:

Indian peninsula has around 7517 Kms of coast spread across 10 maritime states of West Bengal, Odissa, Andhra Pradesh, Puducherry, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra, and Gujarat. 12 major ports of Indian operating in these states support the exports and imports. Each of the ports has got its own unique advantage and at the same time work under varied constraints. While some of the ports are gifted with natural advantage such as draft, better hinterland connectivity, access to international routes, etc., some of them are still striving in many aspects required to for attracting business. Therefore, working and performance of Major Ports of India is not uniform. The existence of numerous constraints is hampering their development of the major ports in India. Ports vary widely based on the type of cargo handled at the port. In the following sections the research would highlight the inception, growth, advantages & disadvantages, and the growth plans relating to each of the major ports of India.

As per government of India's estimate, total investment as proposed in the eleventh five year plan for port development stood at 869.9 Billion INR (at 2006-07 price level), with 552 Billion INR being invested in major ports and 317.4 Billion INR in minor ports. Of the total amount about 640.9 Billion INR is expected to come from private investment and the remaining 229 Billion INR from public sector.

India's Maritime Transport growth is driven by developments in the world economy viz. growth in world output & trade as well as in Indian economy. Thus volume of seaborne cargo traffic is essentially in the nature of derived demand and is mainly shaped by the levels and changes in both the global and domestic activity.

Measures for increasing the capacity of Major Ports which are under the control of Central Government are taken as part of an ongoing process, keeping in view the demands of maritime trade through implementation of development plans for the ports, improvement in productivity, etc. At the end of March 2014 the cargo handling capacity of Major Ports was 800.52 MT.

Maritime Agenda 2020 has set a target of 3130 MT Port capacity by the year 2020 with more than 50% of this capacity to be created under Non-Major Ports segment. By 2020, Non-Major Ports are expected to play a greater role and are targeted to handle 1280 MT of cargo traffic. The agenda aims to enhance port capacity and transform Indian ports competitive to match with international ports.

On the other hand by infusing and improving port infrastructure, transaction costs can be reduced considerable to make Indian ports globally competitive. A total investment of 2960 Billion INR is envisaged for Major and Non-major Ports of India by the year 2020. A lion's share of this investment is expected to come from private sector. Deployment of public funds will be for common user infrastructure facilities such as deepening of port channels, rail and road connectivity between ports and hinterland etc. FDI to the tune of 100% under automatic route is permitted for construction and maintenance of Ports.

The following sections explain about the details of each of the major ports India including their history, infrastructural details, and capabilities.

4.20.1 Kolkata Port Trust:

Kolkata is the oldest major port in the country serving the foreign trade from the times of Aurangzeb and the British Settlement in Eastern India. As the British Crown took over the power to rule India, the affairs of the Port were brought under the administrative control of the Government with the appointment of a Port Commission in 1870.

The present day port has a long channel of 232 km with multi-cargo facilities. The port is well connected to the hinterland with road and rail. The port is catering to the entire Eastern India and two landlocked neighboring countries, Nepal and Bhutan. Kolkata Port Trust (KPT)

has twin dock system, i.e. Kolkata Dock System (KDS) on Eastern bank of river Hoogly and Haldia Dock Complex (HDC) started in 1971 on the Western bank of the river Hoogly.

Table: 4.9 Features of Kolkata – Haldia Port **(2013 – 2014)**

	Capacity	Traffic Handled	Draft		Total Berths
			Max.	Min.	
KPT	21.66 MT	12.87 MT	8.4	4.8	33
HDC	49.75 MT	28.51 MT	8.4	6.7	17

The Traffic at these ports is mainly Coal (Thermal and Coking), Iron ore, Metallurgical coke, Ferro-Chrome, Mica etc.

4.20.2 Paradip Port Trust:

Paradip Port, commissioned in 1966, is the only major sea port in Odisha that serves eastern and central part of the country. The port majorly handles dry bulk. The port is near mineral rich hinterland, but need to work on improving connectivity, mechanization, and labor productivity. The port targets to achieve 70 MT by March 2012.

Table: 4.10 Features of Paradip Port **(2009 – 2010)**

	Capacity	Traffic Handled	Draft		Total Berths
			Max.	Min.	
PPT	108.80 MT	68 MT	13	11	15

Development Projects carried out at this port include:

1. Deepening of Channel - Paradip Port is undertaking the work of 'Deepening of Channel' at a cost of Rs.253.36 crores. After deepening of channel, Port will be in a position to handle Cape size vessels (i.e. up to 1, 25,000 DWT). On completion of the

project, the depth of the entrance channel and approach channel will be increased from 13.00 mtrs to 17.00 mtrs and 15.00 mtrs to 18.70 mtrs respectively.

2. Construction of New Berths – one Iron Ore Berth, one berth for handling Coal, one oil berth, one Ro-Ro Jetty are planned for construction. All the projects are on PPP basis.

3. Connectivity Projects – Railway line connecting Haridaspur to Paradip is in progress. At the same time for better road connectivity, Four lining of Chandikhole to Paradip on NH 5A is in full swing.

4.20.3 Visakhapatnam Port Trust:

Visakhapatnam Port has got three harbors viz., outer harbor, inner harbor, and fishing harbor. The outer harbor has water spread of 200 hectares with 6 berths and the inner harbor has a water spread of 100 hectars with 18 berths. Blessed with natural deep water basins, the outer harbor is capable of accommodating 150,000 DWT vessels and draft to the extent of 17 meters. The inner harbor is capable of accommodating vessels to the tune of 230 meters LOA and draft up to 11 meters. The anchorage at the port can handle Very Large Crude Carriers (VLCC) meant for transshipment of 3 to 4 lakh dwt.

The port has the following distinctions:

- ISO 14001; 2004 (EMS)/OHSAS/8001 and ISO 9001:2000 (QMS).
- An **ISPS compliant** Port.
- Complimented by the Ministry of Shipping, Government of India as the **BRIGHTEST JEWEL** among all the major ports of India
- **NATIONAL SAFETY AWARD** for outstanding performance in industrial safety winners for the year 2002, 2006, 2007 runner-up for the years 1999, 2000, 2001, and 2003.
- **GREENTECH SAFETY AWARD** in service sector for outstanding achievement in Safety management Silver - 2008, 2010.
- **GREENTECH GOLD AWARD** for Environment Management for the year 2007

- **GREENTECH ENVIRONMENT EXCELLENT AWARD**
  in Service Sector for outstanding achievement in Environment Management Gold – 2007, 2009

The port is prominent for its mechanized handling systems, efficient pilot services. However, the port has problem of draft mismatch between channel and berths. The commissioning of Gangavaram Port (a non-major port in PPP mode) is a major threat to this port as Gangavaram has better natural draft.

Table: 4.11 Features of Visakhapatnam Port **(2009 – 2010)**

	Capacity	Traffic Handled	Draft		Total Berths
			Max.	Min.	
PPT	88.92 MT	58.50 MT	17	9.75	22

The port handles commodities ranging from coal, crude, iron ore, POL, chrome ore,

The Port has ambitious plans for modernization of its operations to be the most preferred Port in South Asian Region. Substantial investments through PPP mode are on the cards envisaging deepening of channels and berths, construction of new berths, installation of state of art mechanized handling facilities and other logistics.

Projects in pipeline:

a) Strengthening and mechanization of the General-cum-bulk Cargo Berth (GCB) in the outer harbor to accommodate 2 lakh DWT coal vessels (DBFOT).
b) Mechanized handling facilities for fertilizer at EQ7 berth (DBFOT) at a targeted output of 28,000TPD with storage sheds, silos and bagging plant.
c) Development of EQ1 and EQ1A berths in the inner harbor with mechanized handling facilities (DBFOT) at a targeted output of 15,000TPD and 27,000TPD for Handymax and Panamax vessels respectively for steam coal and thermal coal
d) Installation of mechanized iron ore handling facilities at WQ1 berth in the inner harbour (DBFOT) at a targeted output of 25,000TPD and 43,200TPD for Handymax and Panamax vessels respectively

e) Development of EQ10 berth in the inner harbour (DBFOT) for handling liquid cargo and chemicals including Bio-diesel at a targeted handling rate of 7,200TPD
f) Development of WQ6 berth in the inner harbor for handling multi commodities in DBFOT mode has started.
g) Development of WQ7 and WQ8 berths in the inner harbor in DBFOT mode for handling alumina and other dry bulk.

4.20.4 Ennore Port Corporation:

Ennore port is situated on the coromandal coast about 24 kms north of Chennai Port along the coast line in Tamil Nadu. The port was originally conceived as a satellite port for the Chennai port, primarily to handle thermal coal to meet the requirement of Tamil Nadu Electricity Board (TNEB). The scope was expanded to set up (i) 1880 MW LNG Power Project; (ii) a large Petro Chem Park and (iii) A Naphtha Cracker Plant. Commissioned on 1st February, 2001, it is the 12th Major Port and the first corporatized port in India.

Table: 4.12 Features of Ennore Port

(2009 – 2010)

	Capacity	Traffic Handled	Draft		Total Berths
			Max.	Min.	
EP Corp.	31 MT	27.33 MT	16		6

The projects at Ennore Port completed during 2010 – 11.

1. Iron ore terminal of 6 million tpy capacity each in Phase I and II, respectively, with jetty length of 347.5 m completed.
2. Coal terminal of 8 million tpy capacity with jetty length of 325 m completed.
3. General Cargo Berth of 0.5 million tpy capacity plus 2000,000 cars per annum, with quay length of 250 m completed.
4. One project is ongoing. One Container Terminal (Phase I) of 18 million tpy capacity (1.5 million TEUs), with quay length of 1000m.
5. Marine Liquid Terminal with capacity 3.0 million tpy with Jetty length 360 m completed by Ennore Tank Terminal Pvt. Ltd.

4.20.5 Chennai Port Trust:

Chennai Port, the third oldest port among the 12 major ports, is fast emerging as a hub port in the East Coast of India. This gateway port has completed over 130 years of service. During the first couple of years the port registered traffic of 3 lakh tonnes of cargo handling 600 ships.

India's Independence gave a great momentum for the development of this port. The topography of the Port changed in 1964 when the Jawahar dock with capacity to berth 6 vessels and to handle Dry Bulk cargoes such as Coal, Iron ore, Fertilizer and non-hazardous liquid cargoes was commissioned out on the southern side. In line with the international maritime developments, the port developed the Outer Harbor, named Bharathi Dock for handling Petroleum in 1972 and for mechanized handling of Iron Ore in 1974. In 1983, the port conceived the country's first dedicated container terminal facility. The Port privatized this terminal and is now operated by Chennai Container Terminal Private Limited. Having the capability of handling fourth generation vessels, the terminal, today, is ranked in the top 100 container ports in the world. Witnessing a phenomenal growth in container handling year after year the port is added with the Second Container Terminal with a capacity to handle 1.5 M TEUs to meet the ever growing demand. To cater to the latest generation of vessels and to exploit the steep increase in containerized cargo the port is contemplating to welcome the future with a Mega Container Terminal, capable of handling 5 Million TEUs expected to be operational from 2013.

Chennai Port is an artificial harbor situated on the coromandal coast in south-east India. The largest size of the vessel that can be received at the port is 175,000 dwt, having a maximum 17.4 m draft and maximum 280 m overall length. The port has advantage of better hinterland connectivity and has the constraint of dust pollution. The port has also severe problem of depth mismatch between channel and berths, handling inefficiency and road traffic restrictions.

Chennai port trust is one of the few major ports having Terminal Shunting Yard and running its own railway operations inside the harbor on its East Coast. The port has railway lines running up to 68 kms and handles 25% of its total cargo volumes. The port equipped with 3

docks, 24 berths, and its draft ranges between 12 meters to 16.5 meters and it has also become a hub port for Containers, Cars and Project Cargo in the East Coast.

Ongoing Projects:

Development of Second Container Terminal on BOT Basis was completed including dedicated elevated Port Link road, expressway from Chennai port to Maduravoyal up to NH 4, modernization of the Chennai Port, additional open storage area by reclamation, development of additional open storage yard, Chennai Ennore Port road connectivity, development of Chennai Mega Terminal, deepening of channels, basins and berths, etc.

Future Plans

- Master plan for Port Railway, Realigning Rail and Road network.
- Dedicated Elevated Expressway from Chennai Port to Maduravoyal up to NH4 is approved by the Government to enhance the hinterland connectivity.
- Development of Ro-Ro Terminal and a Multi-level car parking facility with a capacity extending to handle 5000 cars.
- Chennai Mega Container Terminal with a continuous quay length of 2 km with 18-22m side along draft. Capable of handling ultra large container ships carrying over 15000 TEU's is conceptualized.
- The break water extension from existing outer arm is proposed to be utilized to develop deep draft oil berth for handling VLCCs.

Table: 4.13 Features of Chennai Port

(2009 – 2010)

	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
CPT	86.04 MT	51.05 MT	17.4	8.5	24

The port mainly handles Barytes, Coal, Coke & briquettes, Fluorspar, Iron ore, Iron ore pellets, Iron ore lumps, manganes ore, non-ferrous metals, bauxite.

4.20.6 Chidambaranar Port Trust:

ISO 9001:2008 and ISO 14001:2004 Certified, Tuticorin port is situated on the eastern coast in Tamil Nadu. It has two operating wings viz, Zone A, comprising new major port, and Zone B, representing old anchorage port. The largest size of vessel that can be received at the port is 65,000 dwt with length 245 m. The port is very near to international shipping route and is good in handling container traffic. One other advantage for the port is that it does not need to expend on dredging activity due to rocky bed. However, the port has the problem of rail connectivity.

ADVANTAGES:

- Strategically located very close to the East- West International sea-route.
- Well connected by broad gauge rail & road with all Major cities and all ICDs.

Table: 4.14 Features of Chidambaranar Port

(2009 – 2010)

	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
TPT	42.06 MT	28.64 MT	10.70	5.85	15

Ongoing Projects: Development projects undertaken by the Tuticorin port during 2009-10.

1. Deepening of approach channel to enhance the draft to 12.8 mts helping to handle vessels of size 65,00 DWT. The expected cost for this project is Rs. 450 crore.

2. Outer harbor development – to develop the port as an international transshipment hub port with a proposed cost of over Rs. 3100 crores as the outer harbor construction involved Break Water Dredging & Reclamation; construction of 6 container berths and construction of industrial coal jetty.

3. Conversion of Berth No. 8 into Container Terminal – the present multipurpose berth is proposed to be converted as dedicated berth to handle containers with an proposed cost of 150 crores.

4. Construction of North Cargo Berth, Berth No.9 – estimated investment is Rs. 50 crores and would help to handle coal imports for the proposed thermal plant of Neyveli Lignite Corporation.

5. Construction of Ship Building Yard – investment involved is Rs. 200 crores

4.20.7 Cochin Port Trust:

Cochin port is situated on Willingdon islands with berths on two backwater channels. The port is ISO 9001:2008 certified ISPS compliant. The port is very near to the international shipping route and plans to become a major international trans-shipment hum. It is the first e-port in India. The largest size vessel that can be received by at this port is 300,000 dwt. It lacks depth, has outdated equipment, and is not well connected with rail links.

The key inward shipping channel of the port divides in to the Ernakulam and Mattancherry channels .The Ernakulum Channel is 4.90 Km long, with the width varying from 250m to 500 m and has a draft of 12.5 m up to the Oil Terminal and RGCT and a draft of 9.14 m up to the wharves and the north and south tanker berths.. The 1024 m long Ernakulam Wharf has six alongside berths. Of these three are utilized as a full-fledged container terminal, two for general cargo and a fertilizer berth. The Mattancherry channel is 4.08 Km long, with the width varying from 180 to 250 m and a draft of 9.14 m except at Boat Train Pier where the draft is around 10.0 m. On the Mattancherry Channel there exists four alongside berths, for general cargo, one Boat Train Pier and two jetties for miscellaneous cargo.

Table: 4.15 Features of Cochin Port **(2009 – 2010)**

	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
CPT	49.66 MT	20.88 MT	12.5	9.14	19

The port handles commodities such as coal, crude, zinc, clay, gypsum, river sand, sulphur, rock phosphate, salt, iron ore, slag, lignite sand, granite, LPG.

4.20.8 New Mangalore Port Trust:

The Mangalore Harbor Projects Started in 1962 and was completed in May 1974 and was formally inaugurated on 11th January, 1095. Being a strategic port, it was always under conflict in the past swarmed over by several varied dynasties. Chroniclers disclose that vessels from Mangalore port touched the shores of Persia, Greece, Rome etc. Lying south, the Indian Ocean offers major sea routes connecting the Middle East, Africa, and East Asia with Europe and the Americas.

Over the years the Port has grown from the level of handling less than a lakh tonnes of cargo to 39.36 MT handled during the year 2013-14. The Port facilities provided are to face the growing challenges and emerging needs of the 21st century. The ports are famous for being congestion free with ability to deliver break bulk cargo directly from hook point.

The port provides a railway siding to Mangalore and the railway links spread into the neighboring states of Maharashtra, Kerala and Tamil Nadu besides the hinterland. The rail network extends to major industrial cities like Chennai, Bangalore Coimbatore and Mumbai in addition to many other commercially important cities.

The Konkan Railway has given a great boost to the port / rail interface and thereby to industrial development in the adjoining regions and direct connection to Goa and Mumbai.

The Port is connected with 3 National Highways with the national highway NH 17 passing near the Port. This highway stretches from Kochi to Mumbai linking many key cities and towns in its route. The NH 48 connects directly Mangalore to Bangalore and NH 13 Mangalore-Sholapur.

The port facilities provided are to face the growing challenges and emerging needs of the 21st century. The Port is well equipped to handle bulk, liquid chemicals, hazardous cargoes, crude and POL products, heavy lifts, machinery, containers.

Mangalore Port has a modern all weather artificial lagoons situated at panombur, Mangalore in Karnataka. The port is ISO 9001:2008 certified. It is a deep water port with a capacity to handle 77.78 MT. The problem for this port is with high turnaround time and non-

mechanized mode in handling dry bulk cargo. The largest vessel that can be received by this port is 90,000 tonnes. The port handles commodities that include Bentonite, Bauxite, Coal, Granite, Crude Oil, Iron ore, Limestone, Slag, Gypsum, Rock Powder.

Table: 4.16 Features of Mangalore Port **(2009 – 2010)**

	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
MPT	77.77 MT	39.36 MT	14.0	7.0	15

Ongoing Developments:

1. Additional Oil Berth – Work under progress
2. Coal handling berth – Work under progress
3. Mechanised Iron Ore handling facilities at Berth No. 14

Future Projects:

1. Container Terminal at the Western Dock Arm
2. Deep draft general cargo berth
3. SPM by MRPL
4. Deepening of lagoon
5. Procurement of mobile cranes
6. Port based SEZ

4.20.9 Mormugao Port Trust:

The port was commissioned in 1888 with 3 berths along with a breakwater having a length of 358 meters. By 1922, two new berths 4 and 5 were built and the breakwater was extended to its present length of 522.40 meters. A mole of 270 meters was added. With the emergence of mining as a major industry in Goa, a Master Plan was developed by the Portuguese for the development of **Mormugao Port** as an iron ore terminal, envisaging "dedicated berth fitted with Mechanical Ore Loading Plants, provided and financed by various iron ore exporters." In line with this, Asia's very first Mechanical Ore Handling Plant at Berth No.6, with a capacity of 1000 tph. Berth 7 was constructed as an adjunct to it.

In the year 1961, Goa became an integral part of Government of India and from then a fair amount of change as the emphasis shifted to development of infrastructure. A couple of years after liberation, the port got delinked from the Railway management. The main railway section from Vasco da Gama to the border of Goa was transferred to the Southern Railways. The Port however, operated its own railway system between Vasco da Gama interchange point and the harbor area.

The declaration of **Mormugao as a Major Port** in 1964 was a milestone in the port's journey to success as it joined the ranks of the country's ten major Ports. The Port administration could now concentrate upon a sustained development program as its newly formed Board of Trustees was empowered to take major decisions financial or otherwise.

In 1965, therefore, a Perspective Plan was evolved up by a reputed firm of consulting engineers, seeking to develop Mormugao Port systematically. The aim was to provide deep waters and high capacity loading, particularly in relation to iron ore exports, which needed to be competitive in the international arena by reducing the transportation cost.

As a stepping stone in that direction, a 20-year perspective plan for the port development was prepared in February 1965, by the consulting engineering firm of Randal, Palmer & Tritton. Major developments of the Port were taken up only after it became a Major Port with a number of developmental projects conceived and implemented under the various Five Year Plans of the Government of India.

Mormugao Port occupies a prominent position as India's premier iron ore exporting port. This accounts for about 46% of the total iron ore export from India. During the financial year 2010-2011 the port handled a traffic of 50.02 million tonnes which is 9% of the total traffic of 569.92 million tonnes handled by all the twelve major ports of India.

The largest vessel that can be received by this port is about 275,000 dwt. The demand for Mooring Dolphins particularly during monsoon period is heavy and also for export of iron ore through this facility. Ore ships are loaded in mid-stream by tran-shippers.

The commodities handled by the port include Iron ore, Iron ore pellets, Bauxite, Coke, Coal.

Table 4.17 Features of Mormugao Port **(2009 – 2010)**					
	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
MPT	36.65 MT	11.74 MT	14.4	13.1	6

Developments at this port include:

a. Construction of 4 lane road from port to verma junction on NH-17 including flyover from Gate No.9 to NH 17B near Baina Bay.
b. Construction of additional 3 numbers of Mooring Dolphin.
c. Construction of a jetty for relocation of ports crafts and small boats.
d. Strengthening of the Break water mole.
e. Development of coal import Terminal at Berth No. 7 of Mormugao on DBFOT basis.

4.20.10 Jawaharlal Nehru Port Trust:

Commissioned in 1989, Jawaharlal Nehru Port (JNPT) does not have any facility to handle ore/minerals, separately. The port is dedicated facility to handle container cargo. JNPT has become a world class international container handling port. The largest size of the vessel that can be received at the port is 100,000 dwt. It handles around 60% of the total container traffic handled by all the major ports in India. JNPT also, like many other major ports, lacks depth.

Ever since its inception in 1989, JNP has charted India's international trade to a glorious course of success and achievements by breaking all records and setting new benchmarks. JNP is the biggest container handling Port in India, handling around 60% of the country's containerized cargo. In its coveted role as the Hub Port on the Western Coast of India, JNP, today, is ranked 24th among the top 100 Container Ports in the World. JNP has set a goal of handling 10 million TEU's by the year 2014-15.

The port is ably supported by world class infrastructure with impeccable technological standards facilitates full-fledged Customs House, over 23 Container Freight Stations and a

large number of ICD's across the country. Excellent hinterland connectivity both by road and rail as well as proximity to Airports, Hotels etc., give the Port an extra edge to cater to the needs of the shippers, efficiently and promptly.

Table: 4.18 Features of JNPT Port **(2009 – 2010)**

	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
CPT	65.88 MT	62.33 MT	12.5	NA	12

Abundance trade and resource avenues in India have made it an important destination for most of the foreign traders. In the following centuries the same avenues coupled with disintegrated independent small kingdoms has given an opportunity for the foreign invasions. India has seen numerous attacks and the subsequent destruction of its trade and industry abilities have crippled its ability to develop and have negatively impacted its foreign trade prospects through port and shipping.

India is among the 20 leading merchant fleets all over the world. The Gross Tonnage (GT) under Indian flag was 9.47 million as on 31st December, 2009. All the major ports in the country are at present having both rail and road connectivity.

The total amount of traffic handled by all the Indian Ports during 2009-10 was 849.9 Million Tonnes. Non-Major Ports account for around one-third of the seaborne trade. The growth in cargo handled by Major Ports in 2009-10 was 5.8% and 35.4% respectively as compared to 2.2% and 3.3% in 2008-09.

4.20.11 Mumbai Port Trust:

Established in 1873, Mumbai Port has long been the principal gateway of India and carved a niche for itself in the Indian commercial geography. The Port has played a crucial role in the development of national economy, trade, and commerce. Mumbai Port remained India's premier port by virtue of being at the commercial capital of India.

Mumbai Port lies midway along the West Coast of India and is gifted with a natural deep-water harbor. The port is protected by mainland of Konkan on its east and island of Mumbai on its west. The deep waters in the harbor offer secure and ample shelter for shipping throughout the year. This gift of nature coupled with the enterprise of men with vision and purpose made Mumbai Port is one of the most fortunate amongst the World Ports.

The port has three enclosed wet docks namely, Prince's, Victoria and Indira Dock, having a total area of 46.30 hectares and quayage of 7,776 meters inside the wet basin and 853 meters along the harbor wall. Mumbai Port is ISO 9001:2008 certified, and is ISPS code complaint. Mumbai port is a natural deep water multipurpose port handling all types of cargo-liquid bulk, dry bulk, break bulk, and container. The port has three docks with locks and also is one of the largest holders of property. The port is well connectivity with mainland. However, it suffers from depth limitation and outdated equipment.

Table: 4.19 Features of Mumbai Port **(2009 – 2010)**

	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
MPT	50.53 MT	59.18 MT	10.5	3.6	31

4.20.12 Kandla Port Trust:

Kandla port situated in the Gulf of Kutch, is a natural harbor situated on the western coast of Gujarat. This is one of the cash rich ports in India and is ISO 9001:2008 certified. The largest size of vessel that can be received at this port is 74,099 dwt. It has 12 berths of which 2 are operated by private operators. The port handled commodities like Bentonite, Fertilizer, Rock Phospate, Salt, Sulphur, Zinc conc., Copper conc., Lead, Crude oil etc. The port has ample amount of land available for expansion. The major concern for the port is regarding the lack of depth. The port faces problems with the numerous non-major ports in the state.

Table 4.20 Features of Kandla Port **(2009 – 2010)**

	Capacity	Traffic Handled	Draft (in meters)		Total Berths
			Max.	Min.	
KPT	102.40 MT	87.00 MT	12.00	10.00	24

Storage Facilities:

a. Twelve Dry Cargo berths with a Quay Length of 2532 mtrs
b. Six Oil Jetties
c. Total custom bonded port area within the custom fencing of 253 hectars
d. Four cargo mooring and one deep draft mooring within inner harbour area for stream handling

Container Handling Facilities:

a. Quay Length 545 meters
b. 4 RMQCs; 2 Harbour Mobile Cranes; 4 RTGC, 4 Reach Stackers, 18 Prime Movers
c. 40 hectares for container storage; 6 Container Freight Stations; Reefer Plug Points
d. Regular feeder service to JNPT, Mumbai, UAE, Colombo, Bunder Abbas, Muscat, Korea, Cochin Tuticorin, Pipavav, Mangalore and many other destinations
e. Affordable handling charges and concessional TAMP tariff for costal vessels
f. Railway line adjacent to container yard

4.21 Post Reform Initiatives in Indian Port Sector:

Port of Rotterdam was asked to develop a comprehensive business plan with an objective "to transform Indian ports into world class facilities suited to requirements of the future economy of India." The report prepared a general SWOT analysis of Indian ports as follows:

Table: 4.21 SWOT Analysis of Indian Port Sector

Strengths	Weaknesses
• High Growth • High Market Share • Most ports located at strategic locations	• Old Infrastructure • Limited water depth • Old and inefficient cargo handling systems • Poor hinterland connectivity • Rigid institutional framework • High tariffs • Poor quality of services/business attitude • Overstaffing • Lack of capacity • Lack of extension possibilities

Opportunities	Threats
• Introduce competition • Huge Indian markets, and landlocked countries in the North • Improve organisation: training, IT, downsizing, • Port reform – more autonomy • PPP other than BOT • Invest in infrastructure, lower costs for port users • Invest in total transport chain	• Private ports • Minor ports • Bureaucracy • Time
Source: IPA Coordination of business plans for major ports of India, 2007	

4.22 Non-Major Ports of India:

Privatisation has helped in the formation of a competitive segment in port sector which has grown at a faster pace in India. Non-major ports come under the preview of the respective states in which they are setup. Strong potential for growth, buoyant investment climate, and support given by government have made investments in this segment more attractive to both domestic and foreign investors. Green field projects by both foreign investors like DP World, APM, PSA and Indian private sector like Jindal, Adani, Gangavaram, etc. are established and have brought in tough competition in the sector. Increasing demand for coal imports, containerisation of cargo, growing POL trade etc., have given ample opportunity to these non-major ports to capture markets and flourish. Proactive policies of government like de-licensing and tax holidays, tariff flexibility, model concession agreements, etc., have also made the sector lucrative for private investments. (Dama & Zawar, 2013) expected non-major ports to sustain strong momentum, given their robust infrastructure, strong revenue assurance due to captive cargo, shorter turnaround time and more planned investments. Most of the non-major ports are well connected to manufacturing hubs of India.

At the same time major ports have reached their high saturation levels giving ample opportunity of growth to the non-major ports. With major ports falling short of meeting the

growing demands, private ports got the opportunity to serve the spill-off demand from major ports.

4.23 Conclusions

This chapter discussed about how the world maritime development his over a period of time evolved and influenced the world economies. It explained about the way in which sea routes helped in development of sea ports across the world and how sea ports have developed over the centuries. The growth story of Indian port sector is along with the challenges that it faced during the course of its development are also discussed. The current stage of Indian port sector covering information about developments happening at individual ports along with the reform program initiated by government are also deliberated. Thus, the chapter gives an overview of the world and Indian port sectors.

Chapter – 5

Data Analysis–I – Data Envelopment Analysis

5.1 Introduction:

This chapter is an attempt to assess efficiency gains at 12 of the major ports of India during for assessment period 1995-96 to 2013-14.

The chapter introduces to the basics of production function, productivity, and efficiency followed by information regarding the sources and selection of data. It also details about the way selected data is validated and subsequently the process of data analysis discussed. Finally the identified findings and interpretations are presented for discussion.

Nye (2009), defines *efficiency* as "encompassing capacity (TEU per hectare, annual TEU), productivity, (containers per hour, man-hours per move), and terminal cost (land, infrastructure, equipment, systems and labor)". Efficiency determines productivity and profitability of a port and identification of inefficiency helps in deciding course of control action.

Efficiency is represented by linking output with inputs. More output per unit of input represents better efficiency. Firm efficiency represents a relationship between output units that the firm produced with a given set of inputs. Full efficiency is attained by a firm if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs.

5.2 Sources of Data:

Sourcing of data from a reliable avenue is determinant to arrive at robust analysis and subsequent results. The present study has collected required data on performance of all the 12 major ports from the publications of Indian Port Association (IPA), New Delhi. IPA, working under direct control of Ministry of Shipping, is the apex authority controlling the activities of major ports of India. It publishes 'Major Ports of Indian – A Profile' also called as 'Yellow Books' every year representing a complete details of all major ports of India. The

report publishes annual operational and financial details along with physical infrastructural facilities at all the ports. To ensure confidence in the data, details given in these yellow books are cross-checked with the publications of Ministry of Shipping and IndiaStat.com.

5.3 Selection of Data:

Identification of variables representing true and fair picture of holistic performance of ports holds key in maintaining the quality of a study. A total of 133 variables used by different authors were derived through literature review. However, considering the constraints posed by Data Envelopment Analysis that is applied in this study, all these variables cannot be put to test. So to select just and suitable variables the current study depended on correlation analysis and expert opinion. Industry experts from Indian Port Association, senior executives from the ports of Visakhapatnam port trust and Kandla port trust, and researchers from Indian Maritime University were approached for arriving at variables.

5.4 Correlation Analysis:

Correlation is a powerful tool to measure association between two variables. Correlation coefficient provides two inferences regarding the strength of relationship between variables and the type of relationship between the tested data sets (Taylor, 1990). If both data sets increase or vice-versa, they may be referred to having direct relationship. If values of one set of data increase and that of the other set decrease, then they are referred to be having inverse relationship (Berenson et. al., 2012). Based on the data relevance, availability, and as suggested by industry experts a total of 10 input and 16 output variables were considered for correlation analysis. The results of Correlation Analysis are given in table .

5.5 Validation of Data Variables:

The results of correlation analysis were again referred to the industry experts for suggestions. Based on the recommendations of all the experts' 4 input variables and 6 input variables totaling 10 variables were selected for DEA and MPI tests. Considering the dynamic business environment and port operations, industry experts have suggested for inclusion for few variables. Subsequent to the unanimous and strong recommendations of all the experts a couple of variables having high degree of correlation were also selected. The selected inputs

include Operating Expenses to Total Expenses (OETTE), Number of Berths (NoB), Number of Vessel Calls (NoV), and Number of Cranes (NoC). The output variables include Throughput (Tp), Average Turnaround Time (ATAT), Berth Throughput (BTO), Operating Income to Total Income (OITTI), Operating Revenue (OR), Revenue Per Employee (RPE).

Upon the selection of variables for the study, data analysis is initiated with the assessment of efficiency. The following sections introduce to the basics of efficiency followed by efficiency check using DEA for all the selected DMUs for the period 1995-96 to 2013-14.

5.6 Basics of Efficiency

Efficiency is a measure of ratio between outputs and inputs. It compares the number of outputs produced to the number of input units and a higher ratio represents better performance and vise-versa.

$$Efficiency = \frac{Output}{Input}$$

If a firm uses two inputs to produce one output then efficiency is calculated through ratios, which can be graphically assessed through efficiency frontiers, often called as Frontier Analysis (Farrell 1957).

However, graphical assessment is not possible with an increase in the number of input and output variables. Firms, practically, consume multiple inputs to produce multiple outputs which are to be considered for efficiency check. Usage of multiple input and output for efficiency check mandates the usage of mathematical formulation. The mathematical framework to handle frontier analysis is described by Charnes et. al. (1978) in their seminal paper and coined the term Data Envelopment Analysis (DEA).

Efficiency can be broadly classified as Technical Efficiency (TE) and Scale Efficiency (SE). Koopmans (1951) has defined Technical Efficiency (TE). TE refers to ability of a firm to either minimise the inputs used in the production for a given output vector, or its ability to maximise the output from a given input vector. Thus, technical efficiency is measured with input and/or output measure.

5.7 Constant Returns to Scale (CRS):

DEA uses linear programming methods to build non-parametric piece-wise surface (or frontier) over the data considered. The surface is then used to calculate relative efficiency.

5.8 Fractional DEA Programs:

Each of the 12 major ports of India is taken as an independent DMU and their efficiency is assessed with a mathematical model. The following section depicts the efficiency of

$$\max E_m = \frac{\sum_{j=1}^{J} v_{jm} y_{jm}}{\sum_{i=1}^{I} u_{im} x_{im}}$$

Subjected to:

$$0 \leq \frac{\sum_{j=1}^{J} v_{jm} y_{jn}}{\sum_{i=1}^{I} u_{im} x_{in}} \leq 1; \quad n = 1, 2, K, N$$

$v_{jm}, \ u_{im} \geq 0; \quad i = 1, 2, K, I; \quad j = 1, 2, K, J$

(5.1)

where

E_m is the efficiency of the m^{th} DMU

y_{jm} is j^{th} output of the mth DMU

v_{jm} is the weight of that output

x_{im} is i^{th} input of the mth DMU

u_{im} is the weight of that input, and

y_{jn} and x_{jn} are j^{th} output and i^{th} input, respectively, of the nth DMU, $n = 1, 2, \ldots, N$

Note that here n includes m.

Considering the 12 DMUs KHPT, PPT, VSPT, EPC, ChPT, CbPT, CPT, NMPT, MGPT, MbPT, JNPT, KPT. Let $v_j, \ j = 1(1)12$, represent weight associated with six outputs considered namely Tp, ATAT, BTO, OITTO, OR, RPE with JNPT being the considered DMU to solve the model for data pertaining to the year 2013-2014.

Table: 5.1 Input & Output Variables for 12 DMUs, 2013-14										
Variable/ DMU	**INPUT**				**OUTPUT**					
	NOB	NOV	NOC	WF	Tp	ATAT	BTO	OITTO	OR	RPE
KHPT	52	3225	15	7008	41.39	96.24	0.8	83.06	82.41	2.71
PPT	18	1443	7	2017	68	110.9	3.78	85.62	60.1	5.3
VSPT	23	2005	20	4618	58.5	113.5	2.54	80.56	66.04	2.07
EPC	6	689	0	102	27.34	101.8	4.56	96.4	30.45	51.05
ChPT	24	1804	63	5979	51.11	59.04	2.13	73.95	98.97	1.36
CbPT	15	1159	16	1645	28.64	94.08	1.91	88.91	61.37	2.58
CPT	20	1426	22	2544	20.89	42.24	1.04	79.06	105.6	1.8
NMPT	16	1075	1	1335	39.37	76.32	2.46	90.06	64.57	3.04
MGPT	6	414	1	2330	34.05	104.2	5.68	97.12	114	0.93
MbPT	31	1847	21	12042	29.5	127.4	0.95	79.69	85.71	1.42
JNPT	12	2526	127	1697	44.38	58.56	3.7	79.24	45.42	10
KPT	25	2304	16	3299	68.82	135.8	2.75	75.46	74.85	3.27

The input and output variables listed in this above table representing values for different ports can be explained as follows. For example, for the port KHPT, a value of 52 against NOB represents number of berths at the port which facilitate loading and unloading process at the port. A value of 3225 for NOV represents the number of calls made by ships and each call gives a chance of business for the port. NOC with 15 represents the number of cranes that the port is equipped with for cargo handling. 7008 of WF represents the number of workforce available with the port.

The output variable Tp represents throughput at 41.34 MT that the port has handled. ATAT represents average ship turnaround time representing the time taken to handle cargo onboard at 96.24 hours. 0.8 of BTO represents berth wise throughput in MT. A value of 83.06 against OITTO represents the ratio of Operating Income to Total Income. OR represent Operating Revenue at 82.41 Million INR earned by a port. A value of 2.71 Million RPE shows the revenue earned by the port per employee.

The linear programming equations representing these values is shown as under:

$$Max.E_{JNPT} = \frac{44.38v_1 + 58.56v_2 + 3.7v_3 + 79.24v_4 + 45.42v_5 + 10v_6}{12u_1 + 2526u_2 + 127u_3 + 1697u_4}$$

Subjected to:

$$0 \leq \frac{41.39v_1 + 96.24v_2 + 0.8v_3 + 83.06v_4 + 82.41v_5 + 2.71v_6}{52u_1 + 3225u_2 + 15u_3 + 7008u_4} \leq 1$$

$$0 \leq \frac{68v_1 + 110.9v_2 + 3.78v_3 + 85.62v_4 + 60.1v_5 + 5.3v_6}{18u_1 + 1443u_2 + 7u_3 + 2017u_4} \leq 1$$

$$0 \leq \frac{58.5v_1 + 113.5v_2 + 2.54v_3 + 80.56v_4 + 66.04v_5 + 2.07v_6}{23u_1 + 2005u_2 + 20u_3 + 4618u_4} \leq 1$$

$$0 \leq \frac{27.34v_1 + 101.8v_2 + 4.56v_3 + 96.4v_4 + 30.45v_5 + 51.05v_6}{6u_1 + 689u_2 + 0.u_3 + 102u_4} \leq 1$$

$$0 \leq \frac{51.11v_1 + 59.04v_2 + 2.13v_3 + 73.95v_4 + 98.97v_5 + 1.36v_6}{24u_1 + 1804u_2 + 63u_3 + 5979u_4} \leq 1$$

$$0 \leq \frac{28.64v_1 + 94.08v_2 + 1.91v_3 + 88.91v_4 + 61.37v_5 + 2.58v_6}{15u_1 + 1159u_2 + 16u_3 + 1645u_4} \leq 1$$

$$0 \leq \frac{20.89v_1 + 42.24v_2 + 1.04v_3 + 79.06v_4 + 105.6v_5 + 1.8v_6}{20u_1 + 1426u_2 + 22u_3 + 2544u_4} \leq 1$$

$$0 \leq \frac{39.37v_1 + 76.32v_2 + 2.46v_3 + 90.06v_4 + 64.57v_5 + 3.04v_6}{16u_1 + 1075u_2 + 1.u_3 + 1335u_4} \leq 1$$

$$0 \leq \frac{34.05v_1 + 104.2v_2 + 5.68v_3 + 97.12v_4 + 114v_5 + 0.93v_6}{6u_1 + 414u_2 + 1.u_3 + 2330u_4} \leq 1$$

$$0 \leq \frac{29.5v_1 + 127.4v_2 + 0.95v_3 + 79.69v_4 + 85.71v_5 + 1.42v_6}{31u_1 + 1847u_2 + 21u_3 + 12042u_4} \leq 1$$

$$0 \leq \frac{44.38v_1 + 58.56v_2 + 3.7v_3 + 79.24v_4 + 45.42v_5 + 10v_6}{12u_1 + 2526u_2 + 127u_3 + 1697u_4} \leq 1$$

$$0 \leq \frac{68.82v_1 + 135.8v_2 + 2.75v_3 + 75.46v_4 + 74.85v_5 + 3.27v_6}{25u_1 + 2304u_2 + 16u_3 + 3299u_4} \leq 1$$

$v_j \geq 0,\ j = 1(1)6; \qquad u_i \geq 0, \qquad i = 1(1)4$

(5.2)

By solving the above mathematical program, values of weights *u* and *v* for maximizing efficiency of DMU named JNPT are derived. If the value of efficiency comes out to be unity, then the DMU is said to be efficient and will lie on the frontier. If the value is less than unity, the firm is said to be relatively inefficient. To get the efficiency of the other DMUs, mathematical programs pertaining to their objective functions need to be derived. However, the constraints for each of such mathematical programs are same.

5.9 Output Maximization and Input Minimization DEA Programs:

It may be noted that these mathematical programs are fractional in nature and thus, are difficult to solve. To solve them with ease they are converted into simpler formulations like linear programming (LP) formats. The easiest method to convert these fractional programs to linear programs is to normalize either the numerator or the denominator of the fractional programming objective function.

The denominator of objective function of fractional program of JNPT is normalized to estimate its efficiency. This gives the linear program (LP) for maximizing the efficiency of JNPT.

$$Max.E_{JNPT}\ 44.38v_1 + 58.56v_2 + 3.7v_3 + 79.24v_4 + 45.42v_5 + 10v_6$$

Subjected to:

$$12u_1 + 2526u_2 + 127u_3 + 1697u_4 = 1$$

$$41.39v_1 + 96.24v_2 + 0.8v_3 + 83.06v_4 + 82.41v_5 + 2.71v_6 - [52u_1 + 3225u_2 + 15u_3 + 7008u_4] \leq 0$$

$$68v_1 + 110.9v_2 + 3.78v_3 + 85.62v_4 + 60.1v_5 + 5.3v_6 - [18u_1 + 1443u_2 + 7u_3 + 2017u_4] \leq 0$$

$$58.5v_1 + 113.5v_2 + 2.54v_3 + 80.56v_4 + 66.04v_5 + 2.07v_6 - [23u_1 + 2005u_2 + 20u_3 + 4618u_4] \leq 0$$

$$27.34v_1 + 101.8v_2 + 4.56v_3 + 96.4v_4 + 30.45v_5 + 51.05v_6 - [6u_1 + 689u_2 + 0.u_3 + 102u_4] \leq 0$$

$$51.11v_1 + 59.04v_2 + 2.13v_3 + 73.95v_4 + 98.97v_5 + 1.36v_6 - [24u_1 + 1804u_2 + 63u_3 + 5979u_4] \leq 0$$
$$28.64v_1 + 94.08v_2 + 1.91v_3 + 88.91v_4 + 61.37v_5 + 2.58v_6 - [15u_1 + 1159u_2 + 16u_3 + 1645u_4] \leq 0$$
$$20.89v_1 + 42.24v_2 + 1.04v_3 + 79.06v_4 + 105.6v_5 + 1.8v_6 - [20u_1 + 1426u_2 + 22u_3 + 2544u_4] \leq 0$$
$$39.37v_1 + 76.32v_2 + 2.46v_3 + 90.06v_4 + 64.57v_5 + 3.04v_6 - [16u_1 + 1075u_2 + 1.u_3 + 1335u_4] \leq 0$$
$$34.05v_1 + 104.2v_2 + 5.68v_3 + 97.12v_4 + 114v_5 + 0.93v_6 - [6u_1 + 414u_2 + 1.u_3 + 2330u_4] \leq 0$$
$$29.5v_1 + 127.4v_2 + 0.95v_3 + 79.69v_4 + 85.71v_5 + 1.42v_6 - [31u_1 + 1847u_2 + 21u_3 + 12042u_4] \leq 0$$
$$44.38v_1 + 58.56v_2 + 3.7v_3 + 79.24v_4 + 45.42v_5 + 10v_6 - [12u_1 + 2526u_2 + 127u_3 + 1697u_4] \leq 0$$
$$68.82v_1 + 135.8v_2 + 2.75v_3 + 75.46v_4 + 74.85v_5 + 3.27v_6 - [25u_1 + 2304u_2 + 16u_3 + 3299u_4] \leq 0$$
$$v_j \geq 0,\ j = 1(1)6; \qquad u_i \geq 0, \qquad i = 1(1)4$$

(5.3)

Weighted sum of the inputs is constrained to be unity in the above linear program. Since the objective function is the weighted sum of outputs that is to be maximized, this formulation is stated as *Output Maximization* DEA program.

Similarly LP formulation is possible by minimizing the weighted sum of inputs by setting the weighted sum of outputs equal to unity. This is called as *Input Minimization* DEA program.

Input Minimization DEA program for the DMU – JNPT is as under:

$$Min.\, E_{JNPT}\ \ 12u_1' + 2526u_2' + 127u_3' + 1697u_4'$$

Subjected to:

$$44.38v_1' + 58.56v_2' + 3.7v_3' + 79.24v_4' + 45.42v_5' + 10v_6' = 1$$
$$41.39v_1' + 96.24v_2' + 0.8v_3' + 83.06v_4' + 82.41v_5' + 2.71v_6' - [52u_1' + 3225u_2' + 15u_3' + 7008u_4'] \leq 0$$

$68v_1' + 110.9v_2' + 3.78v_3' + 85.62v_4' + 60.1v_5' + 5.3v_6' - [18u_1' + 1443u_2' + 7u_3' + 2017u_4'] \leq 0$

$58.5v_1' + 113.5v_2' + 2.54v_3' + 80.56v_4' + 66.04v_5' + 2.07v_6' - [23u_1' + 2005u_2' + 20u_3' + 4618u_4'] \leq 0$

$27.34v_1' + 101.8v_2' + 4.56v_3' + 96.4v_4' + 30.45v_5' + 51.05v_6' - [6u_1' + 689u_2' + 0.u_3' + 102u_4'] \leq 0$

$51.11v_1' + 59.04v_2' + 2.13v_3' + 73.95v_4' + 98.97v_5' + 1.36v_6' - [24u_1' + 1804u_2' + 63u_3' + 5979u_4'] \leq 0$

$28.64v_1' + 94.08v_2' + 1.91v_3' + 88.91v_4' + 61.37v_5' + 2.58v_6' - [15u_1' + 1159u_2' + 16u_3' + 1645u_4'] \leq 0$

$20.89v_1' + 42.24v_2' + 1.04v_3' + 79.06v_4' + 105.6v_5' + 1.8v_6' - [20u_1' + 1426u_2' + 22u_3' + 2544u_4'] \leq 0$

$39.37v_1' + 76.32v_2' + 2.46v_3' + 90.06v_4' + 64.57v_5' + 3.04v_6' - [16u_1' + 1075u_2' + 1.u_3' + 1335u_4'] \leq 0$

$34.05v_1' + 104.2v_2' + 5.68v_3' + 97.12v_4' + 114v_5' + 0.93v_6' - [6u_1' + 414u_2' + 1.u_3' + 2330u_4'] \leq 0$

$29.5v_1' + 127.4v_2' + 0.95v_3' + 79.69v_4' + 85.71v_5' + 1.42v_6' - [31u_1' + 1847u_2' + 21u_3' + 12042u_4'] \leq 0$

$44.38v_1' + 58.56v_2' + 3.7v_3' + 79.24v_4' + 45.42v_5' + 10v_6' - [12u_1' + 2526u_2' + 127u_3' + 1697u_4'] \leq 0$

$68.82v_1' + 135.8v_2' + 2.75v_3' + 75.46v_4' + 74.85v_5' + 3.27v_6' - [25u_1' + 2304u_2' + 16u_3' + 3299u_4'] \leq 0$

$v_j' \geq 0,\ j = 1(1)6; \quad u_i' \geq 0,\ \ i = 1(1)4$

(5.4)

5.10 Dual of O/P Maximization of DEA program

The basic theory of linear programing propounds that for every primal problem there would be a dual problem and for every dual problem there exists a primal problem. While constraints of primal problem are depended on the number of DMUs, the constraints of dual problem are depended on the number of input and output variables. The computational efficiency of LP codes is highly depended on the number constraints rather than the number of variables. In a DEA exercise, the numbers of variables are lesser than the number of

DMUs considered. Therefore, dual formation is computationally efficient than the primal. For the primal problem of output maximizing DEA program of JNPT for the year 2013-14, the following dual problem can be written. The dual problem is written as per the rules specified by Taha (1997).

$$Min.\ y_1 - y_2$$

Subjected to:

$41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12} \geq 44.38$

$96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12} \geq 58.56$

$0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12} \geq 3.7$

$83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12} \geq 79.24$

$82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12} \geq 45.42$

$2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12} \geq 10$

$-[52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12}] + 12y_1 - 12y_2 \geq 0$

$-[3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12}] + 2526y_1 - 2526y_2 \geq 0$

$-[15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0.\lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1.\lambda_8 + 1.\lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12}] + 127y_1 - 127y_2 \geq 0$

$-[7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12}] + 1697y_1 - 1697y_2 \geq 0$

where $\lambda_i \geq 0,\ i = 1(1)12;$ $(y_1 - y_2)$ is unrestricted

(5.5)

$$Min. \qquad \theta_{JNPT}$$

Subjected to:

$41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12} \geq 44.38$

$96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12} \geq 58.56$

$0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12} \geq 3.7$

$83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12} \geq 79.24$

$82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12} \geq 45.42$

$2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12} \geq 10$

$52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12} \leq 12\theta_{JNPT}$

$3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12} \leq 2526\theta_{JNPT}$

$15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0.\lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1.\lambda_8 + 1.\lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12} \leq 127\theta_{JNPT}$

$7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12} \leq 1697\theta_{JNPT}$

where $\lambda_i \geq 0,\ i = 1(1)12;\quad \theta_{JNPT} = y_1 - y_2$ is unrestricted

(5.6)

$$Max.\quad y_1 - y_2$$

Subjected to:

$52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12} \leq 12$

$3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12} \leq 2526$

$15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0.\lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1.\lambda_8 + 1.\lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12} \leq 127$

$7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12} \leq 1697$

$-[41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12}] + 44.38y_1 - 44.38y_2 \leq 0$

$-[96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12}] + 58.56y_1 - 58.56y_2 \leq 0$

$-[0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12}] + 3.7y_1 - 3.7y_2 \leq 0$

$-[83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12}] + 79.24y_1 - 79.24y_2 \leq 0$

$-[82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12}] + 45.42y_1 - 45.42y_2 \leq 0$

$-[2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12}] + 10y_1 - 10y_2 \leq 0$

where $\lambda_i \geq 0, \quad i = 1(1)12; \qquad (y_1 - y_2)$ is unrestricted (5.7)

$$Max. \quad \phi_{JNPT}$$

Subjected to:

$52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12} \leq 12$

$3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12} \leq 2526$

$15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0.\lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1.\lambda_8 + 1.\lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12} \leq 127$

$7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12} \leq 1697$

$41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12} \geq 44.38\phi_{JNPT}$

$96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12} \geq 58.56\phi_{JNPT}$

$0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12} \geq 3.7\phi_{JNPT}$

$83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12} \geq 79.24\phi_{JNPT}$

$82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12} \geq 45.42\phi_{JNPT}$

$2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12} \geq 10\phi_{JNPT}$

where $\lambda_i \geq 0, \quad i = 1(1)12; \quad \phi_{JNPT} = y_1 - y_2$ is unrestricted

(5.8)

It may be noted that dual of a dual is primal and therefore, primal DEA program and dual DEA program are relative. New terms are being popularly used to represent DEA formulations. DEA programs linking weights of inputs and outputs (u and v) are called Multiplier DEA programs.

5.11 CRS – Input and Output Oriented Program

The dual of output maximizing multiplier programs becomes input oriented enveloped program (5.6). Like same, the dual of the input minimising multiplier program becomes output oriented envelopment program (5.8). Both (5.6) and (5.8) represent CRS-Input and CRS-Output oriented programs respectively.

5.12 VRS – Input and Output Oriented Program

The Input oriented VRS DEA program for DMU-JNPT is discussed as follows.

$$Min. \qquad \theta_{JNPT}$$

Subjected to:

$41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12} \geq 44.38$

$96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12} \geq 58.56$

$0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12} \geq 3.7$

$83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12} \geq 79.24$

$82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12} \geq 45.42$

$2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12} \geq 10$

$52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12} \leq 12\theta_{JNPT}$

$3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12} \leq 2526\theta_{JNPT}$

$15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0.\lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1.\lambda_8 + 1.\lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12} \leq 127\theta_{JNPT}$

$7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12} \leq 1697\theta_{JNPT}$

$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 + \lambda_8 + \lambda_9 + \lambda_{10} + \lambda_{11} + \lambda_{12} = 1$ (Convexity constraint)

where $\lambda_i \geq 0,\ i = 1(1)12;\quad \theta_{JNPT} = y_1 - y_2$ is unrestricted (5.9)

The Dual of the above problem (5.9) is called Primal and is given as follows:

$$Max.E_{JNPT}\ 44.38v_1 + 58.56v_2 + 3.7v_3 + 79.24v_4 + 45.42v_5 + 10v_6 + w$$

Subjected to:

$$12u_1 + 2526u_2 + 127u_3 + 1697u_4 = 1$$

$41.39v_1 + 96.24v_2 + 0.8v_3 + 83.06v_4 + 82.41v_5 + 2.71v_6 - [52u_1 + 3225u_2 + 15u_3 + 7008u_4] + w \leq 0$

$68v_1 + 110.9v_2 + 3.78v_3 + 85.62v_4 + 60.1v_5 + 5.3v_6 - [18u_1 + 1443u_2 + 7u_3 + 2017u_4] + w \leq 0$

$58.5v_1 + 113.5v_2 + 2.54v_3 + 80.56v_4 + 66.04v_5 + 2.07v_6 - [23u_1 + 2005u_2 + 20u_3 + 4618u_4] + w \leq 0$

$27.34v_1 + 101.8v_2 + 4.56v_3 + 96.4v_4 + 30.45v_5 + 51.05v_6 - [6u_1 + 689u_2 + 0.u_3 + 102u_4] + w \leq 0$

$51.11v_1 + 59.04v_2 + 2.13v_3 + 73.95v_4 + 98.97v_5 + 1.36v_6 - [24u_1 + 1804u_2 + 63u_3 + 5979u_4] + w \leq 0$

$28.64v_1 + 94.08v_2 + 1.91v_3 + 88.91v_4 + 61.37v_5 + 2.58v_6 - [15u_1 + 1159u_2 + 16u_3 + 1645u_4] + w \leq 0$

$20.89v_1 + 42.24v_2 + 1.04v_3 + 79.06v_4 + 105.6v_5 + 1.8v_6 - [20u_1 + 1426u_2 + 22u_3 + 2544u_4] + w \leq 0$

$39.37v_1 + 76.32v_2 + 2.46v_3 + 90.06v_4 + 64.57v_5 + 3.04v_6 - [16u_1 + 1075u_2 + 1.u_3 + 1335u_4] + w \leq 0$

$34.05v_1 + 104.2v_2 + 5.68v_3 + 97.12v_4 + 114v_5 + 0.93v_6 - [6u_1 + 414u_2 + 1.u_3 + 2330u_4] + w \leq 0$

$29.5v_1 + 127.4v_2 + 0.95v_3 + 79.69v_4 + 85.71v_5 + 1.42v_6 - [31u_1 + 1847u_2 + 21u_3 + 12042u_4] + w \leq 0$

$44.38v_1 + 58.56v_2 + 3.7v_3 + 79.24v_4 + 45.42v_5 + 10v_6 - [12u_1 + 2526u_2 + 127u_3 + 1697u_4] + w \leq 0$

$68.82v_1 + 135.8v_2 + 2.75v_3 + 75.46v_4 + 74.85v_5 + 3.27v_6 - [25u_1 + 2304u_2 + 16u_3 + 3299u_4] + w \leq 0$

$v_j \geq 0,\ j = 1(1)6; \quad u_i \geq 0, \quad i = 1(1)4; \quad w$ is free (Convexity constraint) (5.10)

Similarly, we can write the Primal and Dual of the Output oriented VRS DEA program for the same DMU

$$Max. \quad \phi_{JNPT}$$

Subjected to:

$52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12} \leq 12$

$3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12} \leq 2526$

$15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0.\lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1.\lambda_8 + 1.\lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12} \leq 127$

$7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12} \leq 1697$

$41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12} \geq 44.38\phi_{JNPT}$

$96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12} \geq 58.56\phi_{JNPT}$

$0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12} \geq 3.7\phi_{JNPT}$

$83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12} \geq 79.24\phi_{JNPT}$

$82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12} \geq 45.42\phi_{JNPT}$

$2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12} \geq 10\phi_{JNPT}$

$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 + \lambda_8 + \lambda_9 + \lambda_{10} + \lambda_{11} + \lambda_{12} = 1$ (Convexity constraint)

where $\lambda_i \geq 0, \quad i = 1(1)12; \quad \phi_{JNPT} = y_1 - y_2$ is unrestricted

(5.11)

The Dual of the above problem (5.11) is called Primal and is given as follows:

$$Min.\, E_{JNPT} \;\; 12u_1' + 2526u_2' + 127u_3' + 1697u_4' + w$$

Subjected to:

$$44.38v_1' + 58.56v_2' + 3.7v_3' + 79.24v_4' + 45.42v_5' + 10v_6' = 1$$

$41.39v_1' + 96.24v_2' + 0.8v_3' + 83.06v_4' + 82.41v_5' + 2.71v_6' - [52u_1' + 3225u_2' + 15u_3' + 7008u_4'] + w \leq 0$

$68v_1' + 110.9v_2' + 3.78v_3' + 85.62v_4' + 60.1v_5' + 5.3v_6' - [18u_1' + 1443u_2' + 7u_3' + 2017u_4'] + w \leq 0$

$58.5v_1' + 113.5v_2' + 2.54v_3' + 80.56v_4' + 66.04v_5' + 2.07v_6' - [23u_1' + 2005u_2' + 20u_3' + 4618u_4'] + w \leq 0$

$27.34v_1' + 101.8v_2' + 4.56v_3' + 96.4v_4' + 30.45v_5' + 51.05v_6' - [6u_1' + 689u_2' + 0.u_3' + 102u_4'] + w \leq 0$

$51.11v_1' + 59.04v_2' + 2.13v_3' + 73.95v_4' + 98.97v_5' + 1.36v_6' - [24u_1' + 1804u_2' + 63u_3' + 5979u_4'] + w \leq 0$

$$28.64v_1' + 94.08v_2' + 1.91v_3' + 88.91v_4' + 61.37v_5' + 2.58v_6' - [15u_1' + 1159u_2' + 16u_3' + 1645u_4'] + w \leq 0$$

$$20.89v_1' + 42.24v_2' + 1.04v_3' + 79.06v_4' + 105.6v_5' + 1.8v_6' - [20u_1' + 1426u_2' + 22u_3' + 2544u_4'] + w \leq 0$$

$$39.37v_1' + 76.32v_2' + 2.46v_3' + 90.06v_4' + 64.57v_5' + 3.04v_6' - [16u_1' + 1075u_2' + 1.u_3' + 1335u_4'] + w \leq 0$$

$$34.05v_1' + 104.2v_2' + 5.68v_3' + 97.12v_4' + 114v_5' + 0.93v_6' - [6u_1' + 414u_2' + 1.u_3' + 2330u_4'] + w \leq 0$$

$$29.5v_1' + 127.4v_2' + 0.95v_3' + 79.69v_4' + 85.71v_5' + 1.42v_6' - [31u_1' + 1847u_2' + 21u_3' + 12042u_4'] + w \leq 0$$

$$44.38v_1' + 58.56v_2' + 3.7v_3' + 79.24v_4' + 45.42v_5' + 10v_6' - [12u_1' + 2526u_2' + 127u_3' + 1697u_4'] + w \leq 0$$

$$68.82v_1' + 135.8v_2' + 2.75v_3' + 75.46v_4' + 74.85v_5' + 3.27v_6' - [25u_1' + 2304u_2' + 16u_3' + 3299u_4'] + w \leq 0$$

$v_j' \geq 0,\ j = 1(1)6; \quad u_i' \geq 0,\ \ i = 1(1)4; \quad$ w is free (Convexity constraint)

(5.12)

The above mathematical formulation is developed on the input and output variables of JNPT for the year 2013-14.Same formulations are to be done for all the 19 years being considered for all of the 12 ports that are DMUs for this study. Like same, Mathematical program (5.8) represents CRS-Output Oriented and (5.11) represents VRS-Output oriented on which the study is made. Like same programs are to be written for all the DMUs for all years. To arrive at the results, the current study depended on reliable software from online developers www.deaos.org to solve these formulations and results derived are assessed and interpreted. Complete details of the data are given in appendix.

The efficiency results of DEA – CCR and VRS model for the years 1995-96 to 2013-14 covering all the 12 major ports of India are shown in the following tables. Table NNNN shown

Table 5.2 DEA (CCR) - Efficiency Results for Major Ports from 1995-96 to 2013-14																			
Port/ Year	**1995-96**	**1996-97**	**1997-98**	**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**
KHPT	0.473	0.384	0.364	0.387	0.432	0.423	0.381	0.410	0.399	0.391	0.417	0.425	0.313	0.304	0.258	0.271	0.291	0.303	0.232
PPT	1.000	0.981	1.000	0.969	0.895	0.981	0.896	1.000	0.968	0.983	0.917	1.000	0.522	0.625	0.779	0.870	0.918	1.000	0.954
VSPT	0.856	0.710	0.677	0.765	0.810	0.976	0.953	0.924	0.804	0.731	0.740	0.766	0.507	0.558	0.531	0.581	0.657	0.777	0.517
EPC	***	***	***	***	***	***	***	***	***	***	***	***	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ChPT	0.669	0.559	0.581	0.650	0.680	0.767	0.586	0.560	0.538	0.568	0.531	0.558	0.513	0.534	0.525	0.544	0.549	0.686	0.441
CbPT	0.755	0.721	1.000	1.000	1.000	1.000	0.974	1.000	0.832	0.864	0.807	0.950	0.286	0.351	0.370	0.485	0.689	0.600	0.541
CPT	0.609	0.596	0.669	0.692	0.790	0.702	0.842	0.822	0.798	0.889	0.868	0.857	0.399	0.630	0.705	0.808	0.816	0.640	0.654
NMPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.569	0.639	0.658	0.707	0.706	0.872	0.760
MGPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MbPT	0.482	0.389	0.392	0.374	0.412	0.401	0.484	0.558	0.571	0.470	0.416	0.478	0.491	0.503	0.485	0.523	0.550	0.689	0.275
JNPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.802	1.000	1.000	1.000	1.000	1.000	0.750
KPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.827	0.814	0.532	0.643	0.667	0.857	0.893	1.000	0.602

Table 5.3 DEA (VRS) – Efficiency Results for Major Ports from 1995-96 to 2013-14																			
Port /Year	**1995-96**	**1996-97**	**1997-98**	**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**
KHPT	0.997	0.972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.992	1.000	0.990	1.000	0.896
PPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
VSPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.892	0.959	0.956
EPC	***	***	***	***	***	***	***	***	***	***	***	***	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ChPT	0.987	0.975	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.944	0.956	1.000	1.000	0.985	1.000
CbPT	0.982	0.973	1.000	1.000	1.000	1.000	1.000	1.000	0.900	0.887	0.938	0.980	0.938	0.930	0.881	0.856	1.000	0.990	0.918
CPT	1.000	0.995	1.000	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.940
NMPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MGPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MbPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
JNPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.895
KPT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

5.13 Findings & Interpretations

5.13.1 CCR Model – Constant Returns to Scale

- The first table given in above represent constant returns to scale (CCR) and ranking ports assessed.
- Ports that register exactly 1.000 are treated as efficient and that which are less than 1.000 are inefficient.
- From the tables it is evident that Ennore Port Corporation and Murmogao Port Trust are efficient. While Mumbai Port Trust and Kolkata Port Trust are most inefficient.
- Interestingly Ennor port has maintained efficiency of 1.000 from the year of its inception.
- New Mangalore Port that maintained 1.000 till 2006-07 but from then its performance has been fluctuating.
- Two of the older and bigger ports of India, Mumbai and Kolkata have, unfortunately, been most inefficient throughout the assessment period.
- Paradip, Chidambaramnar, and Kandla ports have registered efficiency level of 1.000 during few years of assessment but on a whole reported fluctuations in efficiency.
- Finally, it may be concluded that the notion ‘bigger ports perform better’ no longer is relevant.

5.13.2 BCC Model – Variable Returns to Scale

- The second tables, given above, represent variable returns to scale (VRS) and its ranking for ports assessed.
- Ports that register exactly 1.000 are treated as efficient and that which are less than 1.000 are inefficient.
- Efficiency level of 1.000 is attained by Paradip, Ennore, New Mangalore, Mormugao, Mumbai, and Kandla ports.
- Chidambaranar port has been most inefficient.
- Results obtained under BCC Model are better as it works on Variable Returns to Scale.

From the results given above it may be noted that a DMU that is CCR efficient is also a BCC efficient but the opposite is not true.

5.14 Overall Findings of Research Objective (RO) 1

- Considering results of both Constant Returns to Scale and Variable Returns to Scale, it is evident that smaller ports have shown better performances.
- Both EPC and MGPT have maintained efficiency under both methods.
- EPC port maintained best efficiency right from year one of its operations due to its size and technological advancement in its operations.
- Under constant returns to scale method, ranks from 1 to 5 are maintained by smaller and technologically advanced ports.
- Under variable returns to scale the last 5 positions are acquired by bigger ports.
- Oldest ports of Mumbai and Kolkata are found inefficient.

5.15 Conclusions:

This chapter assessed the efficiencies at the major ports during the post reform a period of 19 years. Considering performance indicators relating to operational, financial, and physical aspects of the ports, the study used DEA technique to assess the efficiency levels. The entire period of 19 years is divided into two parts, pre and post commencement of Ennore port, with the first part assessing 11 ports during the period between the years 1995-96 to 2006-07 and the second part with 12 ports for the period 2007-08 to 2013-14. Efficiencies of ports with both the constant returns to scale and variable returns to scale are calculated. The results show that ports that maintain high level of mechanisation are highly efficient. Older ports that are not able to invest in mechanisation and that are depended on manual working face problems in maintaining efficiency. The results also show that ports that have started to invest in technological aspects are slowly improving in their efficiency.

Chapter – 6

Data Analysis–II – MALMQUIST PRODUCTIVITY INDEX

6.1 Introduction:

The emphasis of this chapter is to build as index representing the productivity of major ports of India for the period 1995-1996 to 2013-2014. Encouraged by the results of DEA, where Ennore port has shown highest efficiency right from its year of inception, the productivity index is calculated in two chunks. The first chunk for the period from 1995-96 to 2006-07 represents 11 ports and the second for the period from 2007-08 to 2013-14 represents 12 ports. To build the index, the study relied on the existing technique of Malmquist Productivity Index (MPI).

6.2 Productivity:

Productivity is a descriptive measure of performance while efficiency is a normative measure performance. Productivity fundamentally refers to a level concept and measures of productivity could be used to compare performance of firms at a given point of time. Productivity change denotes the movements in productivity performance of a firm or an industry over a period of time. Productivity can be *partial productivity* or *total productivity*. Partial productivity considers a relationship between single output with single input factor and total productivity considers all output factors to all input factors of production. Measuring productivity is simple for a business unit with single input and single output. However, multiple inputs and multiple outputs make productivity measurement complex. Thus, TFP can be defined as aggregate output produced relative to aggregate input used.

Total Factor Productivity (TFP) – is the ratio between some function that add outputs and some function that adds inputs. Mathematically, the equation to applying the corresponding additions in the productivity ratio, where the following expression is obtained:

$$TFP = \frac{\sum_{m=1}^{M} u'_m y_m}{\sum_{k=1}^{k} v'_k x_k}$$

Where, TFP is Total Factor Productivity for *M* products employing *K* inputs and *u*' and *v*' weights, since not all inputs or outputs can equally important.

Alternatively, the change in total productivity can be estimated as the ratio of change in TFP over a period of analysis. To clarify this, if a firm produces one output and employs one input for the

purpose, the expression that tells us how productivity changed between a starting period (t) and a final period (t+1) is:

$$\frac{y_{t+1}/x_{t+1}}{y_t/x_t}$$

However, this equation represents one output, one input and it only compares productivity levels observed in tow periods, assuming constant technology.

6.3 Malmquist Productivity Index:

MPI is one of the most reliable techniques to measure productivity changes over a period of time. Malmquist Productivity Index was proposed by Caves, Christensen and Diewart (1982), also termed as CCD is a normative measure to construct a production frontier that represents the technology and uses corresponding distance functions evaluated at different input-output combinations for productivity comparisons. The CCD Malmquist index is also known as Total Factor Productivity (TFP) and measures the TFP change between two data points by calculating the ratio of distance of each data point relative to common technology. Researchers in the following years have decomposed Malmquist index into separate factors representing technical changes, technical efficiency change, and scale efficiency change.

Malmquist index is a tool that allows changes in total productivity to be determined and decomposed into each of their components. This index employs distance functions and can be represented as:

$$M^{t+1}{}_{OC}(x^t, y^t, x^{t+1}, y^{t+}) = \frac{D^{t+1}{}_{OC}(x^{t+1}, y^{t+1})}{D^{t+1}{}_{oc}(x^t, y^t)}$$

Where, $M^{t+1}{}_{OC}(x^t, y^t, x^{t+1}, y^{t+})$ compares (x^{t+1}, y^{t+1}) withx^t, y^t , obtaining the distance between them and the best possible benchmark given the technology of period t, i.e., $T^t{}_c$. Thus a value greater than 1 in the above equation would indicate that the value of TFP has increased, and if the value is below one, it represents a decrease in TFP.

MPI results are shown on the following parameters:

- Technical Efficiency Change - (TEC)
  - Pure Technical Efficiency Change - (PEC)
  - Scale Efficiency Change - (SEC)
- Technological Change - (TC)
- Total Factor Productivity (TFP) Change (MI)

- **6.3.1 Technical Efficiency** – it relates to productivity of inputs. Koopmans (1951) defines Technical Efficiency as either the ability of a firm to minimise the inputs used in the production for a given output vector, or the ability of the firm to maximise the output from the given input. It is a comparative measure of how well it actually processes inputs to achieve its outputs, as compared to its maximum potential for doing so, as represented by its production possibility frontier.

- **6.3.2 Pure technical efficiency** - is a measure of technical efficiency purely reflects the managerial performance to organize the inputs in the production process.

- **6.3.3 Scale Efficiency** - ability of management to choose the optimum size of resources required to attain the expected production level. SE measurement can be input-oriented or output-oriented. SE indicates how effective the input (output) level is, for a given output (input) mix.

6.4 Technological efficiency - technological possibilities of transforming inputs into outputs that are available to the organization.

Motivated with the trends in efficiency shown by EPC, MPI for Major Ports of India is constructed from 1995-96 to 2006-07 and 2007-08 to 2013-14. Since EPC started its full-fledged operations from the year 2007-08 it is felt that bifurcation of MPI into two parts gives a better picture covering two scenarios (before and after entry of EPC).

Table: 6.1 Linear Programing Equations

LP-1(CRS- Output Oriented)	LP-2 (CRS- Output Oriented)
$[d_{0c}^{t}(y_t, x_t)]^{-1} = \max_{\phi,\ \lambda} \phi$	$[d_{0c}^{t+1}(y_{t+1}, x_{t+1})]^{-1} = \max_{\phi,\ \lambda} \phi$
Subjected to:	Subjected to:
$-\phi\, y_{i\,t} + Y_t\, \lambda \geq 0$	$-\phi\, y_{i\,t+1} + Y_{t+1}\, \lambda \geq 0$
$x_{i\,t} - X_t\, \lambda \geq 0$	$x_{i\,t+1} - X_{t+1}\, \lambda \geq 0$
$\lambda \geq 0$	$\lambda \geq 0$

LP-3 (CRS- Output Oriented)	LP-4 (CRS- Output Oriented)
$[d_{0c}^{t}(y_{t+1}, x_{t+1})]^{-1} = \max_{\phi,\ \lambda} \phi$ Subjected to: $-\phi\ y_{i\ t+1} + Y_t\ \lambda \geq 0$ $x_{i\ t+1} - X_t\ \lambda \geq 0$ $\lambda \geq 0$	$[d_{0c}^{t+1}(y_t, x_t)]^{-1} = \max_{\phi,\ \lambda} \phi$ Subjected to: $-\phi\ y_{i\ t} + Y_{t+1}\ \lambda \geq 0$ $x_{i\ t} - X_{t+1}\ \lambda \geq 0$ $\lambda \geq 0$
LP-5 (Output - VRS)	LP-6 (Output - VRS)
$[d_{0v}^{t}(y_t, x_t)]^{-1} = \max_{\phi,\ \lambda} \phi$ Subjected to: $-\phi\ y_{it} + Y_t\ \lambda \geq 0$ $x_{it} - X_t\ \lambda \geq 0$ $\sum \lambda = 1$ (Convexity constraint) $\lambda \geq 0$	$[d_{0v}^{t+1}(y_{t+1}, x_{t+1})]^{-1} = \max_{\phi,\ \lambda} \phi$ Subjected to: $-\phi\ y_{it+1} + Y_{t+1}\ \lambda \geq 0$ $x_{it+1} - X_{t+1}\ \lambda \geq 0$ $\sum \lambda = 1$ (Convexity constraint) $\lambda \geq 0$

Where,

y_i is $N \times 1$ vector of output for i^{th} DMU (N represents number of output variables)

x_i is $K \times 1$ vector of input for i^{th} DMU (K represents number of input variables)

Y is $N \times M$ vector of output for all M-DMUs

X is $K \times M$ vector of input for all M-DMUs

λ is $M \times 1$ vector provides information on the peers of i^{th} DMU

ϕ is scalar, gives information on the TE score for i^{th} DMU

On solving the above four LPs we obtain ϕ and λ

Malmquist Productivity Index $m_0(y_{t+1}, x_{x+1}, y_t, x_t) = \sqrt{\left[\frac{d_{0c}^{t+1}(y_t,x_t)}{d_{0c}^{t+1}(y_{t+1},x_{t+1})} \times \frac{d_{0c}^{t}(y_t,x_t)}{d_{0c}^{t}(y_{t+1},x_{t+1})}\right]}$

Technical Efficiency Change $(TEC) = \frac{d_{0c}^{t}(y_t,x_t)}{d_{0c}^{t+1}(y_{t+1},x_{t+1})}$

Pure Efficiency Change $(PEC) = \frac{d_{0v}^{t}(y_t,x_t)}{d_{0v}^{t+1}(y_{t+1},x_{t+1})}$

Scale Efficiency Change (SEC) $= \frac{TEC}{PEC}$

Technological Change $(TC) = \left[\frac{d_{0c}^{t+1}(y_{t+1},x_{t+1})}{d_{0c}^{t}(y_{t+1},x_{t+1})} \times \frac{d_{0c}^{t+1}(y_t,x_t)}{d_{0c}^{t}(y_t,x_t)}\right]^{\frac{1}{2}}$

In the above formula

$d_{0c}^{t+1}(y_t, x_t)$ represents distance from period "t" observations to period "$(t+1)$" technology calculated in output oriented CRS

$d_{0v}^{t+1}(y_t, x_t)$ represents distance from period "t" observations to period "$(t+1)$" technology calculated in output oriented VRS

m_0 is known as TFP change between two time periods (MPI) for this we need to calculate all the above four LPs for each DMU.

The current mathematical formulation represents the index for JNPT for the year 2012-13. To perform this formulation data pertaining to the year 2012-13 (t) and 2013-14 ($t+1$) of JNPT are considered. LP for the same figures is solved to arrive at distance function.

Table 6.2 Input & Output Variables with values for the year 2012-13

	INPUT				**OUTPUT**					
DMU	NOB	NOV	NOC	WF	Tp	ATAT	BTO	OITTO	OR	RPE
KHPT	52	3155	18	7534	39.93	101.76	0.7678	88.5922	94.34	1.8612
PPT	18	1279	7	2234	56.55	105.36	3.1418	85.4532	64.52	3.5732
VSPT	22	2066	21	4941	59.04	129.36	2.6836	79.0089	69.63	1.8003
EPC	6	475	0	100	17.89	70.8	2.9808	98.3114	34.48	32.571
ChPT	24	1928	63	6481	53.4	77.76	2.2252	71.3878	93.01	1.3635
CbPT	15	1292	16	1812	28.26	103.44	1.884	88.9568	57.97	2.2583
CPT	19	1367	22	2793	19.85	37.92	1.0445	69.8614	117.9	1.597
NMPT	16	1096	1	1441	37.04	78.96	2.3148	79.491	58.93	2.9915
MGPT	6	473	1	2538	17.69	94.32	2.9488	90.176	117.08	0.9696
MbPT	31	1949	21	15931	58.04	133.92	1.8722	73.0738	94.15	1.0543
JNPT	12	2588	114	1706	64.49	60.96	5.3742	73.1665	55.44	8.7681
KPT	25	2734	16	3521	93.62	153.6	3.7448	78.4864	65.99	2.7916

Table 6.3 Input & Output Variables with values for the year 2013-14										
Year 2013-14	**INPUT**				**OUTPUT**					
DMU	NOB	NOV	NOC	WF	Tp	ATAT	BTO	OITTO	OR	RPE
KHPT	52	3225	15	7008	41.39	96.24	0.8	83.06	82.41	2.71
PPT	18	1443	7	2017	68	110.9	3.78	85.62	60.1	5.3
VSPT	23	2005	20	4618	58.5	113.5	2.54	80.56	66.04	2.07
EPC	6	689	0	102	27.34	101.8	4.56	96.4	30.45	51.05
ChPT	24	1804	63	5979	51.11	59.04	2.13	73.95	98.97	1.36
CbPT	15	1159	16	1645	28.64	94.08	1.91	88.91	61.37	2.58
CPT	20	1426	22	2544	20.89	42.24	1.04	79.06	105.6	1.8
NMPT	16	1075	1	1335	39.37	76.32	2.46	90.06	64.57	3.04
MGPT	6	414	1	2330	34.05	104.2	5.68	97.12	114	0.93
MbPT	31	1847	21	12042	29.5	127.4	0.95	79.69	85.71	1.42
JNPT	12	2526	127	1697	44.38	58.56	3.7	79.24	45.42	10
KPT	25	2304	16	3299	68.82	135.8	2.75	75.46	74.85	3.27

LP-1:

$$[d_{0c}^{2012-13}(y_{2012-13}, x_{2012-13})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ y_{JNPT,\ 2012-13} + Y_{2012-13}\ \lambda \geq 0$$

$$x_{JNPT,\ 2012-13} - X_{2012-13}\ \lambda \geq 0$$

$$\lambda \geq 0$$

The above mathematical formulation LP-1 is discussed as follows:

$$[d_{0c}^{2012-13}(y_{2012-13}, x_{2012-13})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ 64.49 + (39.93\lambda_1 + 56.55\lambda_2 + 59.04\lambda_3 + 17.89\lambda_4 + 53.4\lambda_5 + 28.26\lambda_6 + 19.85\lambda_7 + 37.04\lambda_8 + 17.69\lambda_9 + 58.04\lambda_{10} + 64.49\lambda_{11} + 93.62\lambda_{12}) \geq 0$$

$$-\phi\ 60.96 + (101.76\lambda_1 + 105.36\lambda_2 + 129.36\lambda_3 + 70.8\lambda_4 + 77.76\lambda_5 + 103.44\lambda_6 + 37.92\lambda_7 + 78.96\lambda_8 + 94.32\lambda_9 + 133.92\lambda_{10} + 60.96\lambda_{11} + 153.6\lambda_{12}) \geq 0$$

$$-\phi\ 5.3742 + (0.7678\lambda_1 + 3.1418\lambda_2 + 2.6836\lambda_3 + 2.9808\lambda_4 + 2.2252\lambda_5 + 1.884\lambda_6 + 1.0445\lambda_7 + 2.3148\lambda_8 + 2.9488\lambda_9 + 1.8722\lambda_{10} + 5.3742\lambda_{11} + 3.7448\lambda_{12}) \geq 0$$

$$-\phi\ 73.1665 + (88.5922\lambda_1 + 85.4532\lambda_2 + 79.0089\lambda_3 + 98.3114\lambda_4 + 71.3878\lambda_5 + 88.9568\lambda_6 + 69.8614\lambda_7 + 79.491\lambda_8 + 90.176\lambda_9 + 73.0738\lambda_{10} + 73.1665\lambda_{11} + 78.4864\lambda_{12}) \geq 0$$

$$-\phi\ 55.44 + (94.34\lambda_1 + 64.52\lambda_2 + 69.63\lambda_3 + 34.48\lambda_4 + 93.01\lambda_5 + 57.97\lambda_6 + 117.9\lambda_7 + 58.93\lambda_8 + 117.08\lambda_9 + 94.15\lambda_{10} + 55.44\lambda_{11} + 65.99\lambda_{12}) \geq 0$$

$$-\phi\ 8.7681 + (1.8612\lambda_1 + 3.5732\lambda_2 + 1.8003\lambda_3 + 32.571\lambda_4 + 1.3635\lambda_5 + 2.2583\lambda_6 + 1.597\lambda_7 + 2.9915\lambda_8 + 0.9696\lambda_9 + 1.0543\lambda_{10} + 8.7681\lambda_{11} + 2.7916\lambda_{12}) \geq 0$$

$$12 - (52\lambda_1 + 18\lambda_2 + 22\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 19\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12}) \geq 0$$

$$2588 - (3155\lambda_1 + 1279\lambda_2 + 2066\lambda_3 + 475\lambda_4 + 1928\lambda_5 + 1292\lambda_6 + 1367\lambda_7 + 1096\lambda_8 + 473\lambda_9 + 1949\lambda_{10} + 2588\lambda_{11} + 2734\lambda_{12}) \geq 0$$

$$114 - (18\lambda_1 + 7\lambda_2 + 21\lambda_3 + 0\ \lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1\ \lambda_8 + 1\ \lambda_9 + 21\lambda_{10} + 114\lambda_{11} + 16\lambda_{12}) \geq 0$$

$$1706 - (7534\lambda_1 + 2234\lambda_2 + 4941\lambda_3 + 100\lambda_4 + 6481\lambda_5 + 1812\lambda_6 + 2793\lambda_7 + 1441\lambda_8 + 2538\lambda_9 + 15931\lambda_{10} + 1706\lambda_{11} + 3521\lambda_{12}) \geq 0$$

$$\lambda_i \geq 0; \quad i = 1(1)12$$

LP-2:

$$[d_{0c}^{2013-14}(y_{2013-14}, x_{2013-14})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ y_{JNPT,\ 2013-14} + Y_{2013-14}\ \lambda \geq 0$$

$$x_{JNPT,\ 2013-14} - X_{2013-14}\ \lambda \geq 0$$

$$\lambda \geq 0$$

The above mathematical formulation LP-2 is discussed as follows:

$$[d_{0c}^{2013-14}(y_{2013-14}, x_{2013-14})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ 44.38 + (41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12}) \geq 0$$

$$-\phi\ 58.56 + (96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12}) \geq 0$$

$$-\phi\ 3.7 + (0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\ \lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\ \lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12}) \geq 0$$

$$-\phi\ 79.24 + (83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12}) \geq 0$$

$$-\phi\ 45.42 + (82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12}) \geq 0$$

$$-\phi\ 10 + (2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12}) \geq 0$$

$$12 - (52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12}) \geq 0$$

$$2526 - (3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12}) \geq 0$$

$$127 - (15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0\ \lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1\ \lambda_8 + 1\ \lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12}) \geq 0$$

$$1697 - (7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12}) \geq 0$$

$$\lambda_i \geq 0; \quad i = 1(1)12$$

LP-3:

$$[d_{0c}^{2012-13}(y_{2013-14}, x_{2013-14})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ y_{JNPT,\ 2013-14} + Y_{2012-13}\ \lambda \geq 0$$

$$x_{JNPT,\ 2013-14} - X_{2012-13}\ \lambda \geq 0$$

$$\lambda \geq 0$$

The above mathematical formulation LP-3 is discussed as follows:

$$[d_{0c}^{2012-13}(y_{2013-14}, x_{2013-14})]^{-1} = \max_{\phi,\ \lambda} \phi$$

$$-\phi\ 44.38 + (39.93\lambda_1 + 56.55\lambda_2 + 59.04\lambda_3 + 17.89\lambda_4 + 53.4\lambda_5 + 28.26\lambda_6 + 19.85\lambda_7 + 37.04\lambda_8 + 17.69\lambda_9 + 58.04\lambda_{10} + 64.49\lambda_{11} + 93.62\lambda_{12}) \geq 0$$

$$-\phi\ 58.56 + (101.76\lambda_1 + 105.36\lambda_2 + 129.36\lambda_3 + 70.8\lambda_4 + 77.76\lambda_5 + 103.44\lambda_6 + 37.92\lambda_7 + 78.96\lambda_8 + 94.32\lambda_9 + 133.92\lambda_{10} + 60.96\lambda_{11} + 153.6\lambda_{12}) \geq 0$$

$$-\phi\ 3.7 + (0.7678\lambda_1 + 3.1418\lambda_2 + 2.6836\lambda_3 + 2.9808\lambda_4 + 2.2252\lambda_5 + 1.884\lambda_6 + 1.0445\lambda_7 + 2.3148\lambda_8 + 2.9488\lambda_9 + 1.8722\lambda_{10} + 5.3742\lambda_{11} + 3.7448\lambda_{12}) \geq 0$$

$$-\phi\ 79.24 + (88.5922\lambda_1 + 85.4532\lambda_2 + 79.0089\lambda_3 + 98.3114\lambda_4 + 71.3878\lambda_5 + 88.9568\lambda_6 + 69.8614\lambda_7 + 79.491\lambda_8 + 90.176\lambda_9 + 73.0738\lambda_{10} + 73.1665\lambda_{11} + 78.4864\lambda_{12}) \geq 0$$

$$-\phi\ 45.42 + (94.34\lambda_1 + 64.52\lambda_2 + 69.63\lambda_3 + 34.48\lambda_4 + 93.01\lambda_5 + 57.97\lambda_6 + 117.9\lambda_7 + 58.93\lambda_8 + 117.08\lambda_9 + 94.15\lambda_{10} + 55.44\lambda_{11} + 65.99\lambda_{12}) \geq 0$$

$$-\phi\ 10 + (1.8612\lambda_1 + 3.5732\lambda_2 + 1.8003\lambda_3 + 32.571\lambda_4 + 1.3635\lambda_5 + 2.2583\lambda_6 + 1.597\lambda_7 + 2.9915\lambda_8 + 0.9696\lambda_9 + 1.0543\lambda_{10} + 8.7681\lambda_{11} + 2.7916\lambda_{12}) \geq 0$$

$$12 - (52\lambda_1 + 18\lambda_2 + 22\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 19\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12}) \geq 0$$

$$2526 - (3155\lambda_1 + 1279\lambda_2 + 2066\lambda_3 + 475\lambda_4 + 1928\lambda_5 + 1292\lambda_6 + 1367\lambda_7 + 1096\lambda_8 + 473\lambda_9 + 1949\lambda_{10} + 2588\lambda_{11} + 2734\lambda_{12}) \geq 0$$

$$127 - (18\lambda_1 + 7\lambda_2 + 21\lambda_3 + 0\ \lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1\ \lambda_8 + 1\ \lambda_9 + 21\lambda_{10} + 114\lambda_{11} + 16\lambda_{12}) \geq 0$$

$$1697 - (7534\lambda_1 + 2234\lambda_2 + 4941\lambda_3 + 100\lambda_4 + 6481\lambda_5 + 1812\lambda_6 + 2793\lambda_7 + 1441\lambda_8 + 2538\lambda_9 + 15931\lambda_{10} + 1706\lambda_{11} + 3521\lambda_{12}) \geq 0$$

$$\lambda_i \geq 0; \quad i = 1(1)12$$

LP-4:

$$[d_{0c}^{2013-14}(y_{2012-13}, x_{2012-13})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ y_{JNPT,\ 2012-13} + Y_{2013-14}\ \lambda \geq 0$$

$$x_{JNPT,\ 2012-13} - X_{2013-14}\ \lambda \geq 0$$

$$\lambda \geq 0$$

The above mathematical formulation LP-4 is discussed as follows:

$$[d_{0c}^{2013-14}(y_{2012-13}, x_{2012-13})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ 64.49 + (41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12}) \geq 0$$

$$-\phi\ 60.96 + (96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12}) \geq 0$$

$$-\phi\ 5.3742 + (0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\ \lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\ \lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12}) \geq 0$$

$$-\phi\ 73.1665 + (83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12}) \geq 0$$

$$-\phi\ 55.44 + (82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12}) \geq 0$$

$$-\phi\ 8.7681 + (2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12}) \geq 0$$

$$12 - (52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12}) \geq 0$$

$$2588 - (3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12}) \geq 0$$

$$114 - (15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0\ \lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1\ \lambda_8 + 1\ \lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12}) \geq 0$$

$$1706 - (7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12}) \geq 0$$

$$\lambda_i \geq 0; \quad i = 1(1)12$$

Pure Efficiency Change (PEC) is derived by solving LP–5 and LP–6.

LP-5 (VRS):

$$[d_{0v}^{2012-13}(y_{2012-13}, x_{2012-13})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ y_{JNPT,\ 2012-13} + Y_{2012-13}\ \lambda \geq 0$$

$$x_{JNPT,\ 2012-13} - X_{2012-13}\ \lambda \geq 0$$

$$\sum \lambda = 1 \ \text{(Convexity constraint)}$$

$$\lambda \geq 0$$

The above mathematical formulation LP-5 is discussed as follows:

$$[d_{0v}^{2012-13}(y_{2012-13}, x_{2012-13})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$-\phi\ 64.49 + (39.93\lambda_1 + 56.55\lambda_2 + 59.04\lambda_3 + 17.89\lambda_4 + 53.4\lambda_5 + 28.26\lambda_6 + 19.85\lambda_7 + 37.04\lambda_8 + 17.69\lambda_9 + 58.04\lambda_{10} + 64.49\lambda_{11} + 93.62\lambda_{12}) \geq 0$

$-\phi\ 60.96 + (101.76\lambda_1 + 105.36\lambda_2 + 129.36\lambda_3 + 70.8\lambda_4 + 77.76\lambda_5 + 103.44\lambda_6 + 37.92\lambda_7 + 78.96\lambda_8 + 94.32\lambda_9 + 133.92\lambda_{10} + 60.96\lambda_{11} + 153.6\lambda_{12}) \geq 0$

$-\phi\ 5.3742 + (0.7678\lambda_1 + 3.1418\lambda_2 + 2.6836\lambda_3 + 2.9808\lambda_4 + 2.2252\lambda_5 + 1.884\lambda_6 + 1.0445\lambda_7 + 2.3148\lambda_8 + 2.9488\lambda_9 + 1.8722\lambda_{10} + 5.3742\lambda_{11} + 3.7448\lambda_{12}) \geq 0$

$-\phi\ 73.1665 + (88.5922\lambda_1 + 85.4532\lambda_2 + 79.0089\lambda_3 + 98.3114\lambda_4 + 71.3878\lambda_5 + 88.9568\lambda_6 + 69.8614\lambda_7 + 79.491\lambda_8 + 90.176\lambda_9 + 73.0738\lambda_{10} + 73.1665\lambda_{11} + 78.4864\lambda_{12}) \geq 0$

$-\phi\ 55.44 + (94.34\lambda_1 + 64.52\lambda_2 + 69.63\lambda_3 + 34.48\lambda_4 + 93.01\lambda_5 + 57.97\lambda_6 + 117.9\lambda_7 + 58.93\lambda_8 + 117.08\lambda_9 + 94.15\lambda_{10} + 55.44\lambda_{11} + 65.99\lambda_{12}) \geq 0$

$-\phi\ 8.7681 + (1.8612\lambda_1 + 3.5732\lambda_2 + 1.8003\lambda_3 + 32.571\lambda_4 + 1.3635\lambda_5 + 2.2583\lambda_6 + 1.597\lambda_7 + 2.9915\lambda_8 + 0.9696\lambda_9 + 1.0543\lambda_{10} + 8.7681\lambda_{11} + 2.7916\lambda_{12}) \geq 0$

$12 - (52\lambda_1 + 18\lambda_2 + 22\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 19\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12}) \geq 0$

$2588 - (3155\lambda_1 + 1279\lambda_2 + 2066\lambda_3 + 475\lambda_4 + 1928\lambda_5 + 1292\lambda_6 + 1367\lambda_7 + 1096\lambda_8 + 473\lambda_9 + 1949\lambda_{10} + 2588\lambda_{11} + 2734\lambda_{12}) \geq 0$

$114 - (18\lambda_1 + 7\lambda_2 + 21\lambda_3 + 0\ \lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1\ \lambda_8 + 1\ \lambda_9 + 21\lambda_{10} + 114\lambda_{11} + 16\lambda_{12}) \geq 0$

$1706 - (7534\lambda_1 + 2234\lambda_2 + 4941\lambda_3 + 100\lambda_4 + 6481\lambda_5 + 1812\lambda_6 + 2793\lambda_7 + 1441\lambda_8 + 2538\lambda_9 + 15931\lambda_{10} + 1706\lambda_{11} + 3521\lambda_{12}) \geq 0$

$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 + \lambda_8 + \lambda_9 + \lambda_{10} + \lambda_{11} + \lambda_{12} = 1$ (Convexity constraint)

$$\lambda_i \geq 0; \quad i = 1(1)12$$

LP-6 (VRS):

$$[d_{0v}^{2013-14}(y_{2013-14}, x_{2013-14})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$$-\phi\ y_{JNPT,\ 2013-14} + Y_{2013-14}\ \lambda \geq 0$$

$$x_{JNPT,\ 2013-14} - X_{2013-14}\,\lambda \geq 0$$

$$\sum \lambda = 1 \ \text{(Convexity constraint)}$$

$$\lambda \geq 0$$

The above mathematical formulation LP-6 is discussed as follows:

$$[d_{0v}^{2013-14}(y_{2013-14}, x_{2013-14})]^{-1} = \max_{\phi,\ \lambda} \phi$$

Subjected to:

$-\phi\ 44.38 + (41.39\lambda_1 + 68\lambda_2 + 58.5\lambda_3 + 27.34\lambda_4 + 51.11\lambda_5 + 28.64\lambda_6 + 20.89\lambda_7 + 39.37\lambda_8 + 34.05\lambda_9 + 29.5\lambda_{10} + 44.38\lambda_{11} + 68.82\lambda_{12}) \geq 0$

$-\phi\ 58.56 + (96.24\lambda_1 + 110.9\lambda_2 + 113.5\lambda_3 + 101.8\lambda_4 + 59.04\lambda_5 + 94.08\lambda_6 + 42.24\lambda_7 + 76.32\lambda_8 + 104.2\lambda_9 + 127.4\lambda_{10} + 58.56\lambda_{11} + 135.8\lambda_{12}) \geq 0$

$-\phi\ 3.7 + (0.8\lambda_1 + 3.78\lambda_2 + 2.54\lambda_3 + 4.56\lambda_4 + 2.13\lambda_5 + 1.91\lambda_6 + 1.04\ \lambda_7 + 2.46\lambda_8 + 5.68\lambda_9 + 0.95\ \lambda_{10} + 3.7\lambda_{11} + 2.75\lambda_{12}) \geq 0$

$-\phi\ 79.24 + (83.06\lambda_1 + 85.62\lambda_2 + 80.56\lambda_3 + 96.4\lambda_4 + 73.95\lambda_5 + 88.91\lambda_6 + 79.06\lambda_7 + 90.06\lambda_8 + 97.12\lambda_9 + 79.69\lambda_{10} + 79.24\lambda_{11} + 75.46\lambda_{12}) \geq 0$

$-\phi\ 45.42 + (82.41\lambda_1 + 60.1\lambda_2 + 66.04\lambda_3 + 30.45\lambda_4 + 98.97\lambda_5 + 61.37\lambda_6 + 105.6\lambda_7 + 64.57\lambda_8 + 114\lambda_9 + 85.71\lambda_{10} + 45.42\lambda_{11} + 74.85\lambda_{12}) \geq 0$

$-\phi\ 10 + (2.71\lambda_1 + 5.3\lambda_2 + 2.07\lambda_3 + 51.05\lambda_4 + 1.36\lambda_5 + 2.58\lambda_6 + 1.8\lambda_7 + 3.04\lambda_8 + 0.93\lambda_9 + 1.42\lambda_{10} + 10\lambda_{11} + 3.27\lambda_{12}) \geq 0$

$12 - (52\lambda_1 + 18\lambda_2 + 23\lambda_3 + 6\lambda_4 + 24\lambda_5 + 15\lambda_6 + 20\lambda_7 + 16\lambda_8 + 6\lambda_9 + 31\lambda_{10} + 12\lambda_{11} + 25\lambda_{12}) \geq 0$

$2526 - (3225\lambda_1 + 1443\lambda_2 + 2005\lambda_3 + 689\lambda_4 + 1804\lambda_5 + 1159\lambda_6 + 1426\lambda_7 + 1075\lambda_8 + 414\lambda_9 + 1847\lambda_{10} + 2526\lambda_{11} + 2304\lambda_{12}) \geq 0$

$127 - (15\lambda_1 + 7\lambda_2 + 20\lambda_3 + 0\ \lambda_4 + 63\lambda_5 + 16\lambda_6 + 22\lambda_7 + 1\ \lambda_8 + 1\ \lambda_9 + 21\lambda_{10} + 127\lambda_{11} + 16\lambda_{12}) \geq 0$

$1697 - (7008\lambda_1 + 2017\lambda_2 + 4618\lambda_3 + 102\lambda_4 + 5979\lambda_5 + 1645\lambda_6 + 2544\lambda_7 + 1335\lambda_8 + 2330\lambda_9 + 12042\lambda_{10} + 1697\lambda_{11} + 3299\lambda_{12}) \geq 0$

$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 + \lambda_8 + \lambda_9 + \lambda_{10} + \lambda_{11} + \lambda_{12} = 1$ (Convexity constraint)

where $\lambda_i \geq 0, \quad i = 1(1)12$

By solving LP-1, LP-2, LP-3, LP-4, LP-5 and LP-6 we obtain the distance function values for JNPT as follows:

$$[d_{0c}^{2012-13}(y_{2012-13}, x_{2012-13})]^{-1} = 1 \qquad [d_{0c}^{2013-14}(y_{2013-14}, x_{2013-14})]^{-1} = 0.75$$
$$[d_{0c}^{2012-13}(y_{2013-14}, x_{2013-14})]^{-1} = 0.7707 \qquad [d_{0c}^{2013-14}(y_{2012-13}, x_{2012-13})]^{-1} = 1.0893$$
$$[d_{0v}^{2012-13}(y_{2012-13}, x_{2012-13})]^{-1} = 1 \qquad [d_{0v}^{2013-14}(y_{2013-14}, x_{2013-14})]^{-1} = 0.8949$$

The Malmquist index value for JNPT can be calculated as follows:

$$m_{0-JNPT} = \sqrt{\frac{0.75}{1} \times \frac{0.7707}{1.0893}} = 0.72845$$

Technical Efficiency Change (TEC) of JNPT can be calculated as follows:

$$TEC_{JNPT} = \frac{d_{0c}^{t}(y_t, x_t)}{d_{0c}^{t+1}(y_{t+1}, x_{t+1})} = \frac{d_{0c}^{2012-13}(y_{2012-13}, x_{2012-13})}{d_{0c}^{2013-14}(y_{2013-14}, x_{2013-14})} = \frac{0.75}{1} = 0.75$$

Pure Efficiency Change (PEC) of JNPT can be calculated as follows:

$$PEC_{JNPT} = \frac{d_{0v}^{t}(y_t, x_t)}{d_{0v}^{t+1}(y_{t+1}, x_{t+1})} = \frac{d_{0v}^{2012-13}(y_{2012-13}, x_{2012-13})}{d_{0v}^{2013-14}(y_{2013-14}, x_{2013-14})} = \frac{0.8949}{1} = 0.8949$$

Scale Efficiency Change (SEC) of JNPT can be calculated as follows:

$$SEC_{JNPT} = \frac{TEC_{JNPT}}{PEC_{JNPT}} = \frac{0.75}{0.8949} = 0.8381$$

Technological Change (TC) of JNPT can be calculated as follows:

$$TC_{JNPT} = \left[\frac{d_{0c}^{t+1}(y_t, x_t)}{d_{0c}^{t}(y_t, x_t)} \times \frac{d_{0c}^{t+1}(y_{t+1}, x_{t+1})}{d_{0c}^{t}(y_{t+1}, x_{t+1})}\right]^{\frac{1}{2}} = \left[\frac{\frac{1}{1.0893}}{\frac{1}{1}} \times \frac{\frac{1}{0.75}}{\frac{1}{0.7707}}\right]^{\frac{1}{2}} = \left[\frac{0.7707}{0.75} \times \frac{1}{1.0893}\right]^{\frac{1}{2}} = 0.97126$$

6.5 Results of MPI (1995-96 to 2006-07):

For the period 1995-96 to 2006-07, only 11 ports were operating in India and thus, values detailing Ennore port do not appear in the following table. The first column represents Technical Efficiency Change (TEC) which is a comparative measure of how well the port actually processes inputs to achieve its outputs, as compared to its maximum potential for doing so, as represented by its production possibility frontier. Pure Efficiency Change (PEC) is a measure of technical efficiency purely reflects the managerial performance to organize the inputs in the production process. Scale Efficiency Change (SEC) represents the ability of management to choose optimum size of resources required to attain the expected production

level. Technological Change (TC) represents technological possibilities of transforming inputs into outputs that are available to the organization. Malmquist Productivity Index (MPI) is shown in the last column.

Table: 6.4 Malmquist Productivity Index – 1995-96 to 2006-07 (Average)

Port/Year	TEC	PEC	SEC	TC	MPI
KHPT	0.994	1.000	0.993	1.071	1.059
PPT	1.002	1.000	1.002	1.026	1.027
VSPT	0.995	1.000	0.995	1.057	1.045
ChPT	0.990	1.001	0.988	1.058	1.041
CbPT	1.030	1.001	1.028	0.965	0.991
CPT	1.035	1.000	1.035	0.985	1.014
NMPT	1.000	1.000	1.000	1.044	1.044
MGPT	1.000	1.000	1.000	1.135	1.135
MbPT	1.008	1.000	1.008	0.996	0.993
JNPT	1.000	1.000	1.000	0.968	0.968
KPT	0.983	1.000	0.983	1.025	1.005
Average	1.003	1.000	1.003	1.030	1.029

6.5.1 Interpretation of MPI Results (1995-96 to 2006-07)

- According to technical efficiency change index (TEC), only 4 ports have increased their average annual technical efficiency. Yet 4 ports have no change has been observed.

- Among the ports that registered increase in technical efficiency, Cochin Port has registered 3.5% takes top position followed by Paradip Port 2%.

- Average annual improvement observed to be 3% (as given as average in table).

- Seven ports have improved, but four have declined technologically during this period.
- Annual average growth in total factor productivity during this period is 2.9%.

- While 8 ports have improved, 3 ports have registered regression.

- MGPT has topped the list with 13.5% TFP improvement and JNPT with 3.2% decline in TFP.

6.6 Results of MPI (2007-08 to 2013-14)

For the period 2007-08 to 2013-14, the results of 12 major ports (including Ennore Pott) are depicted.

Table: 6.5 Malmquist Productivity Index – 2007-08 to 2013-2014 (Average)

Port/Year	TEC	PEC	SEC	TC	MPI
KHPT	0.958	0.983	0.973	1.042	0.986
PPT	1.110	1.000	1.110	0.975	1.076
VSPT	1.021	0.994	1.030	1.012	0.996
ChPT	0.994	1.000	0.996	1.053	1.004
CbPT	1.131	0.999	1.128	0.951	1.042
CPT	1.110	0.990	1.121	0.979	1.031
NMPT	1.055	1.000	1.055	0.975	1.017
MGPT	1.000	1.000	1.000	1.122	1.122
MbPT	0.962	1.000	0.962	1.077	0.965
JNPT	0.999	0.982	1.014	0.993	0.987
KPT	1.049	1.000	1.049	0.999	1.013
EPC	1.000	1.000	1.000	0.861	0.861
Average	1.033	0.996	1.037	1.003	1.008

6.6.1 Interpretation of MPI Results (2007-08 to 2013-14)

- According to technical efficiency change index (TEC), 6 ports have increased their average annual technical efficiency. Yet 4 ports have no change has been observed.

- Among the ports that registered increase in technical efficiency, Chidambaramnar Port has registered 13.1% takes top position followed by CPT and PPT with 11%.

- Average annual improvement observed to be 3.3% (as given as average in table).

- As per technological change efficiency, 5 ports have improved, but 7 ports have declined during this period.

- Annual average growth in total factor productivity during this period is 0.8%.

- While 7 ports have improved, 5 ports have registered regression.

- MGPT has topped the list with 12.2% TFP improvement and EPC with 13.9% decline in TFP.

6.7 Year-wise Average Changes (1995-96 to 2006-07) The following two tables depict year-wise results of individual efficiency changes of MPI.

Table: 6.6 Year-wise Average Changes (1995-96 to 2006-07)

YEAR	EC	PEC	SEC	TC	MI
1997	0.927	0.995	0.931	1.049	0.964
1998	1.044	1.008	1.035	0.992	1.033
1999	1.024	0.999	1.025	0.959	0.981
2000	1.035	1.001	1.035	1.101	1.134
2001	1.025	1.000	1.025	0.985	1.009
2002	0.994	1.000	0.994	1.056	1.038
2003	1.025	1.000	1.025	0.974	0.997
2004	0.964	0.991	0.972	1.052	1.012
2005	0.994	0.999	0.995	1.074	1.066
2006	0.961	1.005	0.956	1.057	1.015
2007	1.045	1.004	1.040	1.030	1.076
Average	1.003	1.000	1.003	1.030	1.029

Table: 6.7 Year-wise Average Changes (2007-08 to 2013-14)					
YEAR	**EC**	**PEC**	**SEC**	**TC**	**MI**
2009	1.144	0.995	1.150	0.867	0.983
2010	1.019	0.996	1.024	0.990	1.008
2011	1.100	1.002	1.098	0.889	0.974
2012	1.066	1.004	1.061	0.938	0.994
2013	1.069	1.005	1.064	1.055	1.099
2014	0.798	0.972	0.823	1.281	0.992
Average	**1.033**	**0.996**	**1.037**	**1.003**	**1.008**

6.7.1 Interpretation of year-wise changes (1995-96 to 2006-07)

- From the yearly averages of all the ports from 1995-96 to 2006-07, it may be seen that the average annual technical efficiency change index increased as 1.003.
- Improvement in scale efficiency is 0.3% and no change in pure efficiency is observed.
- TFP during the period, on an average, has increased as 2.9%.
- Highest level of TFP 13.4% is reached in the year 2000.

6.7.2 Interpretation of year-wise changes (2007-08 to 2013-14)

- From the yearly averages of all the ports from 2007-08 – 2013-14, it may be seen that the average annual technical efficiency change index increased as 1.033.
- Improvement in scale efficiency is 3.7% and but decline of 0.4% in pure efficiency is observed.
- TFP during the period, on an average, has increased as 0.08%.
- Highest level of TFP 9.9% is reached in the year 2010.

6.8 Conclusions

This chapter focused on development of an index based on the MPI results. The results reflect the fact that ports that have invested on technological aspects have improved in their productivity. Between technological change and technical efficiency change, the former has greater role in determining the productivity of ports. The study also bring to light a fact that rather than the size of port, technological investments play a vital role in enhancing port productivity. The study traced that ports with high degree of technological investments perform better even if them are small in size. Overall, the study found that TFP at Indian ports to be better during the period 1995-96 to 2006-07 that the second phase of the study period 2007-08 to 2013-14.

Chapter – 7

Conclusions and Recommendations

7.1 Introduction:

Indian economy needs strong port sector that can ably support its ever growing foreign trade. Indian port sector was dominated by publicly owned major ports during the pre-reform period. Existence of numerous problems has at these ports forced government to opt for private participation that is expected to bring in sustainable efficiency and productivity gains. The current research has assessed the efficiency and productivity at the major ports of India during the last 19 years.

This chapter consolidates the output derived by this research and put forward the same in the form of conclusions. Further the chapter also links the output of this study to existing theoretical constructs and highlights the contribution of this research. A couple of observations that are empirically not tested but have evolved during the research are also listed. An update on the contribution of this research followed by its limitations and future scope of study are also listed. The chapter ends with the concluding remarks that reflect the output of the study.

All the 12 major ports of India were assessed to check their efficiency and productivity for the years 1995-96 to 2013-14. The research used two mathematical techniques of DEA and MPI to check the efficiency and productivity respectively. The results obtained have led to the following findings and conclusions.

7.2 Findings:

The analysis and interpretation of results of efficiency and productivity measurement have led to the following major findings.

a. The research found that both Kolkata port and Chennai port have been inefficient under both CRR and BCC methods for the entire period of 19 years.

b. Cochin port has been inefficient during the first phase of the study period 1995-96 to 2006-07 under both BCC and CRR methods. However, the port has revived itself and

reported efficiencies during the second phase period 2007-08 to 2013-14 under both the methods.

c. Mormugao port has been found efficient for the entire study period 1995-96 to 2006-07 and 2007-08 to 2013-14 under both the methods of BCC and CRR. Like same, Ennore port has maintained efficiency from the year 2007-08 to 2013-14.

d. Jawaharlal Nehru port and New Mangalore port are the two ports that have maintained efficiency during the period 1995-96 to 2006-07 under both CRR and BCC models. However, they could not maintain the same efficiencies during the years 2007-08 to 2013-14.

e. Dependence on mechanised work processes have resulted in efficiency at the smaller ports.

f. Some of the big ports are constrained by saturation levels in their ability for mechanisation and thus are over depended on workforce for operations. This inability for adopting mechanisation and overdependence of manual processes has resulted in inefficiencies.

g. Privatisation of port facilities and activities has resulted in inflow of investments in physical infrastructure and influenced efficiency gains. At the same time working on commercial lines at its fullest level improved their overall efficiency and productivity.

h. Between technological and technical efficiency changes, improvements in technological changes have a greater influence on improving total factor productivity.

i. The study found improvement in productivity at all the ports that have invested in their infrastructure and upgraded their technology.

7.3 Conclusions:

1. **Newer and mechanised ports performing better were found to be smaller**: The results have proved that the youngest of the major ports, Ennore Port, is the efficient port due to high mechanisation. Since the commercial operations of the ports have commenced just around 8 years back, the port is equipped with advanced mechanisation of workflows. The actual workforce at this port is minimal and all operations are mechanised and so it gained advantage of efficiency. However, some

of the major ports like Mumbai and Kolkata ports lacked these advantages and thus recorded inefficiencies.

2. **Privatisation of port facilities resulted in efficiency and productivity gains**: Privatisation at major ports has resulted in private ownership in certain port facilities that run on purely commercial lines. Since these facilities are given on PPP contracts for a specific concession period, the owner of such terminal/berth/facility attempts to optimally use the asset and derive the maximum possible benefits. Since these private operators do not have any financial recourse, they strive hard to provide better services to their clients to maintain sustainable business flow and to generate cash surplus. Absence of any financial recourse in case of loss forces these private operators to provide better services to their clients for generation of cash surplus. Thus, better services with optimal utilisation of resources results in efficiency and productivity gains to the port.

3. **Efficiency hampered due to stagnation in physical infrastructure and overdependence on manual processes**: As it is observed at some of the bigger ports like Mumbai and Kolkata, lowest level of efficiencies are reported due to their overdependence of manual work processes. At the same time the scope of mechanisation at these ports has also reached a level of stagnation.

4. **Technological efficiency improvements are more important than technical efficiency improvements for better TFP**: It is interesting to note that Mormugoa port has maintained consistency, especially during the period 2007-08 to 2013-14, in investing in technological aspects. This feature has made it as the port with highest productivity.

5. **Technological improvements influence port efficiency irrespective of port size**: A common notion that bigger size ports perform better is disproved by this study. It is positive technological changes that influence productivity than size and ports that invest in technological upgradation, whether small or big, would record productivity gains.

7.4 Linking conclusions with theoretical constructs:

Port performance reflected through measurement of efficiency and productivity as identified by literature review is influenced by various operational and financial indicators. Traditional notion that size does influence performance is negated by this research and is found to be in line with other contemporary research outputs (De, 2009; Rajasekar et. al., 2014). The research also found that port productivity is highly influenced by technological improvement than technical efficiency improvements (Song & Cui, 2014; Barros et. al., 2012; Cheon et. al., 2009; De, 2002). Couple of bigger ports that have existed for long period of time failed to maintain consistency in their efficiency for the entire period of 19 years of this study. Researchers (Rajasekar & Deo, 2012; Mokhatar & Shah, 2013) have also proved that size of port would not result in efficiency.

7.5 Observations:

1. Ennore port on the east coast and Mormugoa port on the west coast have been efficient during the years 2007-08 to 2013-14. It might be due to handling of dedicated cargos and due to high level of private participation.

2. Tariff determination at major ports of India, including for the privately operated terminals, is governed by the provisions of TAMP. These provisions force the ports to set lower tariff and adversely impact their financial efficiency.

7.6 Research Contribution:

This research has made an attempt to make useful contribution in the area of port efficiency and productivity:

1. Assessment of efficiency and productivity with reform orientation was not taken up till now. None of the hitherto research works attempted to assess efficiency and productivity gains at Indian major ports during the post reform period;
2. While most studies considered limited timeframe, this research has measured efficiency and productivity levels of ports for an extended period of 19 years.

3. To accommodate and assess all the ports, the study has divided the entire period of assessment into two parts and made a comparison of efficiency and productivity gains between these two timeframes.

7.7 Limitations of the study:

1. The study compared ports on relative efficiency covering port-wise performances. However, external factors like hinterland connectivity, level on local economy, other supporting infrastructural setup required for ports are not considered for study (external factors, geographical aspects).

2. Cargo compositions of different ports differ. Some ports like JNPT, and EPC concentrate on a specific type of cargo. But the study brought all the major ports, irrespective of their cargo handling preferences and capabilities, on to a single platform and attempted to assess them.

3. Ports on the west coast have better connectivity with international links due to international trade links. But the study has put them all on common pitch and measured on common lines.

4. The scope of this research is confined to 12 major ports of India. So this research has not considered the private and non-major ports that growing at faster pace and posing tough competition to these major ports.

5. One of the key constrains posed by DEA technique regarding maintenance of ratio between DMUs and variables for assessment has resulted in selection of only 10 of variables for the study.

7.8 Future scope for study:

This research is an attempt to assess the efficiency and productivity of major ports of India. In analysing the above objective, this work has provided lesser coverage to a number of external economic issues that have significance to the working of ports but beyond the scope of the study.

1. Firstly, the study considered port indicators that are within the control of ports. External factors such as port geographical attributes, hinterland connectivity, economy of the port region etc. are not considered. It would be wonderful if a study considering these factors can be taken up.

2. Private and non-major ports in India are slowly but steadily improving their performance. Studies assessing major ports with private ports allow a comparative study between these two segments can be contemplated in future.

3. Indian ports operate in international environment and are competing with ports across the world. The current study, however, is confined to major ports of India alone. Further studies comparing of Indian ports with foreign ports covering more DMUs provides an opportunity to track improvement of our ports with that of international ports.

4. Major ports of India are witnessing greater participation of private projects in the form of terminal operations. Private parties are being awarded terminals as PPP projects on a concession basis. At a micro level, a comparison of individual terminals at major ports can provide an opportunity to derive deeper efficiencies of major ports.

7.9 Concluding Remarks:

This research has measured the efficiency of 12 major ports of India and build indices that reflect their productivity. Techniques of DEA and MPI were employed to derive efficiency and productivity at these ports during the 19 years period 1995-96 to 2013-14. The results show that ports that are highly mechanised and technologically upgraded have high level of efficiency. The study traced inefficiencies at older ports that are depending on higher level of manual procedures. The study also found technological efficiency changes as more important than technical efficiency changes to achieve total factor productivity.

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PROFILE OF THE AUTHOR

Nookala Bhanu Prakash is a Doctoral student with University of Petroleum and Energy Studies (UPES), Dehradun, India. He has done his B. Com from Osmaina University, Hyderabad and MBA from Acharya Nagarjuna University, Guntur.

He has over 16 years of teaching experience with a exposure to the subjects of Financial Accounting, Management Accounting, Financial Management, Financial Markets, Project Finance, Infrastructure Financing, apart from academic experience to Financial Accounting in Port & Shipping Industry, Financial Management for Port & Shipping Industry, Maritime Economics, Port Planning, and Port Operations.

He is presently associated with University of Petroleum and Energy Studies as Assistant Professor (SS) in the Department of Accounting and Finance, College of Management and Economic Studies.

His has deep interest in the areas of Port and Maritime Finance, and is keen to work on improving the working of Indian ports, which contribute to the Indian Economy.

Nookala Bhanu Prakash has published research paper in journal of repute and has authored two case studies in the area of port efficiency and productivity. He has also presented papers at various international conferences held in India.

Paper Publication

- Bhanu Prakash, "Major Ports of India: Performance Appraisal of Selected Financial Parameters Using Correlation Analysis", The Indian Economic Journal, Vol. 60 (4), 2013.
- Published research paper "Infrastructure in India: Contribution of Ports to the Economy and the Road Ahead" in IUP Journal of infrastructure, Vol. IX, No. 4, December, 2011.

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