DEVELOPMENT OF WEB BASED DECISION SUPPORT SYSTEM FOR PORT PLANNING, DESIGN AND GREEN PORT RATING

A Thesis

Submitted By

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विद्या ददाति विनयं विनयाद्याति पात्रताम् ।
पात्रत्वाद्धनमाप्नोति धनाद्धर्मं ततः सुखम् ॥

Knowledge gives humility, from humility, one attains character /
From character, one acquires wealth; from wealth good deeds
(righteousness) follow and then happiness //

DECLARATION

This is to certify that the thesis entitled **'DEVELOPMENT OF WEB BASED DECISION SUPPORT SYSTEM FOR PORT PLANNING, DESIGN AND GREEN PORT RATING'** submitted to the Cochin University of Science and Technology in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy is a bonafide record of research work carried out by me. The contents of this thesis have not been submitted and will not be submitted to any other University or Institute for the award of any degree.

Thrikkakara
20-11-2015

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CERTIFICATE

This is to certify that the thesis entitled **'DEVELOPMENT OF WEB BASED DECISION SUPPORT SYSTEM FOR PORT PLANNING, DESIGN AND GREEN PORT RATING'** submitted by Vikas V Shenoy to the Cochin University of Science and Technology in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy is a bonafide record of research work carried out by him under my supervision. The contents of this thesis have not been submitted and will not be submitted to any other University or Institute for the award of any degree.

Thrikkakara
20-11-2015

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ABSTRACT

The seaports have been playing an important role in the economic, political and social development of the hinterland. With the development of sea travelling, the port cities started getting importance and became the economic and trading hub of nations. The growth of maritime trade and navy has now given huge importance to ports and their infrastructural development. The changes in shipping business require well equipped and modernized ports in terms of infrastructure, equipment and communication. The introduction of computerization and automation has brought in a new dimension into the shipping industry. The development of port has a great financial and environmental impact on the country. While developing a port importance should be given to various factors so as to minimize the adverse impact on the natural environment. The development in shipping industry has been drastic in the last few decades. With the containerization of cargo, the equipment requirement of loading and unloading of containers is not dependent on the type of cargo being transported. The size of the ships has increased and along with containerization the transport of materials has been made easier and economical. For providing good quality management of transport and port-functioning it is necessary to have sufficient facilities like berthing space, handling equipments and storage area. From the initial step of forecasting the demand to the final step of taking the various decisions of equipment selection need expert domain specific knowledge in various fields of management, economics, environmental studies and engineering. The risks involved with a wrong judgment should be avoided. A standardization of processes can help in checking such mistakes and the easiest way is computerization.

At this modern era a lot of emphasis is given to green construction. Port development has to be done in tune with the norms of the industry. Most countries are laying emphasis on green planning, design and functioning of the port as a whole as well as its various components. Many existing ports are laying down guidelines and parameters for their green functioning and operations. The existing ports will have to make a lot of changes in their functioning for meeting the green norms. Hence, green design has to be made as one of the criteria during the planning stage of the port development. The present study addresses

application of computerized methods for the planning of new generation green ports for handling the containerized cargo.

The various green port parameters have been identified and reported as air environment, climate change, water quality, waste management, dredging, energy conservation and renewable energy, natural resources, green construction, public and staff transport and green zone. The document required to verify the validation of various parameters present in the port have been identified and tabulated. Further, a questionnaire has been prepared and presented to collect data for conducting green port rating survey. A green rating system has been developed by grading the various parameters with points. A green port system has been developed to rate the port in terms of colour code as Green, Yellow, Orange and Red. A web based DSS has been developed to address the planning, design and green port rating criteria a container port. The DSS has been hosted at AWS. The green rating system has been incorporated into the DSS. In order to validate the green port rating system, a case study of a sample port has been done and the findings have been recorded and presented in this thesis.

Port planning and design have been identified as the critical activities for the optimum and economic functioning of port. The first step is to understand the quantity of cargo that the port will handle in the future for which a method of forecasting the future quantity of cargo is essential. In the present study, linear regression and correlation analysis have been used for port traffic forecasting. After forecasting the volume of traffic and identifying the design ship size, the design requirements of the various physical components like entrance width, channel size, depth requirement of the port, turning basin area, handling equipment requirement, storage area requirement and dredging equipment selection have been addressed. The planning and design stages have been incorporated into the DSS.

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ABBREVATIONS

ACT	Automated Container Terminal
AGV	Automated Guidance Vehicles
AS/RS	Automated Storage and Retrieval Structure
ALG	Automated Layout Generator
ASC	Automated Stacking Crane
AWS	Amazon Web Services
BCE	Before Christian Era
BOF	Berth Occupancy Factor
CNG	Compressed Natural Gas
CSCW	Computer Supported Cooperative Work
CSS3	Cascading Style Sheets
DSS	Decision Support System
DWT	Dead Weight
EIA	Environmental Impact Assessment
EEAA	Egyptian Environmental Affairs Agency
GRS	Green Rating System
GR	Grid Rail System
GDP	Gross Domestic Product
GDSS	Group Decision Support System
HTML	Hyper Text Markup Language
HTTP	Hyper Text Transfer Protocol
IMO	International Maritime Organization
IRF	Impulse Response Function
JPEG	Joint Photographic Experts Group
LED	Light Emitting Diode
LMCS	Liner Motor Conveyance System
LRMC	Long Run Marginal Cost
LRE	Long Run Equilibrium
LO/LO	Lift On / Lift Off
MIS	Management Information System
MHC	Mobile Harbour Crane
MTS	Multi Trailer System

NGO	Non-Governmental Organization
PDF	Portable Document Format
PNG	Portable Network Graphics
PVC	Polymerizing Vinyl Chloride
RO/RO	Roll On / Roll Off
RTG	Rubber Tyred Gantry crane
RMG	Rail Mounted Gantry crane
SRMC	Short Run Marginal Cost
STS	Ship To Shore crane
SVG	Scalable Vector Graphics
SWOT	Strength Weakness Opportunity and Threats
TPB	Terminal Planning Board
TEU	Twenty-Foot Equivalent Units
UI	User Interface
ULSD	Ultra Low Sulphur Diesel
URL	Uniform Resource Locator
VEC	Vector Error Correction
VOC	Volatile Organic Compound
WSC	Wide Span Crane

NOTATIONS

a	Vertical axis intercept
b	Slope of the regression line
d	Design ship draught
f	TEU Factor
g	Gravity acceleration
$\hat{h}$	Stacking height
n	Number of observations
r	Coefficient of correlation
r^2	Coefficient of determination
t_d	Average dwell time (days)
x	Independent variable values
y	Dependent variable values
$\bar{y}$	Mean value of the dependent variable
B	Beam of design ship
C	Annual Throughput (TEU/yr)
C_s	Container Storage Yard Capacity
C_q	Quay handling capacity (TEU/yr)
D	Channel depth
D_t	Down time (%)
L	Length of design ship
L_b	Berth use (vessel length + Berthing gap) (m)
L_{br}	Berth length requirement (hrs.m/week)
L_v	Average vessel length (m)
L_q	Quay Length (m)
N_b	Number of berths
N_c	Number of cranes per vessel
N_{dw}	Number of working days per week
N_v	Vessel Arrival (No./week)
N_{TGS}	Number of TEU ground slots
P	Peak factor per week
Q_c	Quay productivity (mvs/hrs)
Q_{cr}	Crane Productivity (TEU/hr)

S	Stack Visits (TEU/yr)
Sp	Parcel Size (TEU)
T_b	Annual berth working hour (hrs/yr)
T_{bw}	Berth working hours per week (hr/week)
T_d	Working hours per day (hrs/yr)
T_s	Total service time (hrs/week)
U_{berth}	Berth occupancy (%)
V_s	Vessel Speed
W_{ct}	Working crane time due to ship total berthing time
X	Values of x that lie on the trend line
Y	Values of the y that lie on the trend line
Z	Squat
μ	Transshipment factor

VOCABULARY

Beam – The maximum width of the ship is termed as beam.

Berth – A place where the ship can moor. In the case of quay or jetty structure it will include the section of the structure where labour, equipment and cargo move to and from the ship.

Channel – A dredged waterway through which ships proceed from the sea to the berth or from one berth to another within the harbour.

Draft of Ship – The draft of a ship refers to the distance between the waterline and the lowest point of the ship; usually the keel. The draft will change when the ship is loaded or unloaded. Draft is the depth of the ship at any given time.

Dredging – It refers to loosening and lifting of earth and sand from the bottom of water bodies. Dredging is often carried out to widen the stream of the river, or to deepen a harbour or navigational channel, or to collect earth and sand for land fill. It is also carried out to remove contaminated bottom deposit or sludge to improve water quality.

Harbour – It is a sheltered area in the coast where the ships can moor and be protected from the rough sea by natural or man-made protection. The various physical parts of the harbour are the entrance, breakwaters, turning basin and channels. The various components of the harbour are designed for the biggest possible vessel which might visit the harbour.

Port – A sheltered place where the ship may receive or discharge cargo. It includes the harbour with its approach channels and anchorage places.

Trim – It is defined as the difference between the draft forward and the draft aft. If the aft draft is greater, the vessel is described as being trimmed by the stern. If the forward draft is greater, ship is trimmed by the bow. Often a ship is not loaded to an even keel in an attempt to improve its steering ability. When the ship is underway the trim can change, though the amount of trim is uncertain.

Turning Basin – It is a specified area for turning the ship in order to go alongside the berth before mooring or after departing.

Squat – When a ship enters shallow water, there is a rapid increase in the height of the waves produced by the ship. Along with this increase in the wave height there is an average decrease in the water surface along the profile of the ship, relative to the still water level. This surface depression causes the ship to sink or squat relative to the channel bottom.

Quay – A berth structure parallel to the shore line.

CHAPTER 1
INTRODUCTION

1.1. General

The seaports have been playing an important role in the economic, political and social development of the hinterland. From ancient times the seaports have been the main place of trade between various countries, and the first mode of mass transport and trades have been through sea. The ports have played a major role in changing the political history of many nations. Sea transport and ports have been used not only for trade and transport but also for warfare and conquering countries.

With the development of sea travelling, the port cities started getting importance and became the economic and trading hub of nations. India with a long coastline of 7516 km, has 13 major ports and 200 notified minor and intermediate ports. The Indian maritime history dates back to 3rd millennium BCE, when the Harappan Era made trade contact with Mesopotamia, through the oldest port of Lothal- known as “The Place for Dead” (2400-1600 BC). This port had features like dockyard, manufacturing factories for vessels and tools. The port also had properly connected drains and solid waste filters giving evidence of importance attributed to sustainable development even at that period.

Ports have become strategic points during time of trade and war. The growth of maritime trade and navy has now given huge importance to ports and its infrastructural development. Countries are competing with each other to provide most modern facilities at their ports to attract traders to use their coastline and port. The changes in shipping business require well equipped and modernized ports in terms of infrastructure, equipments and communication. The introduction of computerization and automation has brought in a new dimension into the shipping industry. The modern communication systems have improved the logistics of the shipping industry and the ports have to keep up with the changes, to not be left behind from the competing ports.

The development of port has a great financial and environmental impact on the country. While developing a port importance should be given to various factors such as climate change, effect on natural flora, fauna and other natural resources that will be used during the development of the port, impact on quality and quantity of ground water table, the impact on air environment, losses to the green zone due to deforestation for the development of the port. The impact on the natural environment should be kept minimum. With this background it would be right to say that the development of port should be a sustainable, so as not to effect the environment badly but to provide an efficient port to improve the economic condition of the nation.

1.2. Definition of Port

A port is a location near the sea with a harbour facility where a ship can dock safely and transfer their goods or people. The harbour provides protection from the waves. The port location is determined keeping in mind, factors like, availability of natural shelter from open sea waves, easy access to harbour facility, space for safe maneuvering of ships, minimum dredging – other than maintenance dredging, provision for future expansion, adequate area for providing storage and cargo handling facilities, adequate labour force and good access to road and rail transport.

A port can be broadly defined as a facility providing sheltered area to ships for embarking safely and unloading or/and loading goods, along with providing areas or facilities for repair and maintenance of ships, facilities for storage and processing of goods, and facilities for transporting the goods to various part of the hinterland.

The various physical components of a port are protected harbour, berths for docking ships, equipments for unloading/loading the ships, equipments for storing or stacking of unloaded goods, storage and transit sheds, roads and rail access for further transport, shipyards for maintenances and repair of ships, servicing area for refilling the ships with water, fuel and other supplies required for further voyage, customs and clearance area, office buildings for the functioning of the port authorities and finally safety and security to the ships and its crew.

1.3. Scope of Present Study

The development in shipping industry has been drastic in the last few decades. Containerization and containerability of goods which at one point of time were difficult to handle as bulk cargo, have changed the face of shipping industry. Previously the goods other than specialized cargo were classified as general cargo and the loading and unloading equipment requirement of each of this cargo could differ, which would consume more time for cargo handling operations. With the containerization of cargo the equipment requirement of loading and unloading of containers is not dependent on the type of cargo being transported. The modern automated equipment have speeded up the process of unloading and loading operations and resulted in minimum labour force requirement which has revolutionized the port operations. Time has become the most important aspect of port functioning and operation. The delay and inefficiency in the port operations and management escalates the operational cost for the ports and ship operators.

The size of the ships has increased with advances in naval architecture and along with containerization the transport of materials has been made easier and economical. Major countries with interconnected water bodies are now focusing on the development of inland waterway transport to decongest their highway since the water transport is economical than road transport. Hence development of ports for inland waterways traffic has also become relevant.

For providing good quality management of transport and port-functioning, it is necessary to have sufficient facilities like berthing space, handling equipments and storage area. The planning for these facilities starts at a very early stage; from the time of identifying the demand and requirement of port facility. An efficient port can be achieved only through proper planning. Ports being a huge infrastructural project involving huge amount of expenditure from the beginning itself, importance should be given to proper planning at the early stages of conceiving the project. A small mistake can lead to failure of the port and in turn incur huge loss to the nation. From the initial step of forecasting the demand to the final step of taking the various decision of equipment requirement necessitates the expert domain specific knowledge in various fields of management, economics, environmental studies and engineering. The risks involved with a wrong judgment should be avoided. A standardization of processes can help in checking such mistakes and the easiest way is computerization.

At this modern era a lot of emphasis is given to green construction. The port development has to be done keeping in with the norms of the industry. Most countries are laying emphasis on green planning, design and functioning of the port as a whole as well as its various components. Many existing ports are laying down guidelines and parameters for their green functioning and operations. The existing ports will have to make lot of changes in their functioning for meeting the green norms. The necessity for making green design as one of the criteria during the planning stage of the port development has been felt.

The present study addresses the application of computerized methods for the planning of new generation green ports for handling the containerized cargo and routes through inland waterways. It is proposed to develop a decision support system to help a planner to design and plan various components of port functions. Besides, the green components of the various stages of port planning are also studied and it is proposed to develop a green index.

Decision Support System(DSS) is an interactive computerized program that gathers and presents data from a wide range of sources; the DSS helps its user in making decisions by presenting the various scenario for solution and in some cases giving recommendation for the same. DSS in some cases gives graphs and diagrams which will help the user have a better understanding of the situation and makes the reading of the situation easier for the user. A DSS can be fully computerized or can be a combination of human experience and knowledge and computer data processing ability. It can also be a combination of models and analytic techniques which has got access to the data that is stored in the database.

DSS developed here is built as a web based application. This kind of application is user friendly and doesn't have to be installed on the device of each user; hence needing a low hardware specification requirement for the accessing device. The user can access the application from the server where it is hosted using a web browser which also gives an advantage of centralized data storage. The most important advantage of a web application is that the updating of the software needs to be done only on the server and for each update the user does not have to reinstall or buy the newer version as in the case of locally hosted software and the web hosted software provide accessibility of 24x7. The user gets the latest information and updates without any time delay and an online training for the use of software can be provided which makes users more comfortable with the use of web based applications.

Port planning process is always overloaded with information and will need multiple and complicated calculations to be made for arriving at a decision. The DSS helps the planner in making fast decision by processing the data given and publishing the result in terms of output which aids in decision making. It works on a particular logic which is preset into the code which will improve the quality, efficiency and effectiveness of decisions and also saves time and cost lost in making complex manual calculations. Logically developed DSS results will reduce the bias in decision making caused by the individual discretion.

1.4. Objectives

The objectives of the study are

1. To review the literature available for understanding various methodologies used for port planning, design and green port policies and to identify appropriate forecasting models to develop a traffic planning methodology for container ports. Also to identify design parameters for various physical characteristics of a port for accommodating them into a DSS for container port planning and design.
2. To identify green rating parameters and to develop a web based software for green rating of ports.
3. To develop a web based DSS with a consolidated approach towards port planning, design and green port rating for a container port.

The present study has been restricted to the engineering aspects of planning, design and construction of the port structures. The functional, operational and economic factors are not discussed here. The DSS has been developed on the general guidelines required to develop a port. The architecture of the DSS has been designed keeping in mind future requirements and can be further developed to incorporate more design parameters or to have customizable green parameters according to the local hinterland conditions.

1.5. Content of Thesis

Chapter 1 deals with general introduction to port, describes the scope of present study and identifies the objectives of the study. The review of literature on design and planning of ports, green ports and DSS for port planning is given in Chapter 2. Chapter 3 presents the principles of planning and design of port traffic, physical characteristics of port and harbour, equipment requirement and dredging equipment selection. Chapter 4 identifies various parameters for green port and a green port rating system has been presented. Chapter 5 provides the description and functionality of the web based DSS developed. Chapter 6 discusses the summary and conclusions of the present study. A case study for green port rating of a sample port is given as appendix.

CHAPTER 2
LITERATURE REVIEW

2.1 General

The review of literature carried out for the present research has been summarized and given under three subtitles, design and planning of ports, green ports and decision support system for port planning.

2.2 Design and Planning of Ports

Lawrence (1973) has designed a computer model based on planning methodology which can facilitate the development process by providing an automated planning frame work for rapid, accurate and thorough analysis of alternative port development plans. The port planning model is centered on a dynamic, stochastic digital computer simulation program. The program is dynamic for the port operation and may be simulated for any desired span of time; thereby providing an estimate of the results of port operation simulated for years. The model is stochastic in the processes which randomly in actual port operation are represented to vary in the same way during the simulation. This added realism in the model increases the accuracy of its result. By properly specifying the input, data planner may evaluate the effect of alternative development plans on the port's operation; and its use is not limited to development planning.

Ergin and Yalciner (1991) have used software HASROL for general cargo and HARCON for container cargo to determine the port size which gives the minimum total port cost by processing the phenomena such as, random arrival and sizes of the ships, queue discipline and service for loading/unloading which fits a statistical distribution. The optimization has been performed for a case study and the sensitivity of the model is investigated concerning the random number generation. They concluded that the optimum port size which has the minimum total cost can be determined by computer simulation model.

Kozan (1997) has presented the major factors influencing the transfer efficiency of a seaport container terminal. For this a queuing technique was used, to draw inference regarding strategies for a container terminal's service improvement by using analytical expressions. A model referred to as a batch-arrival multi server queuing system has been developed and designed as a stochastic model. This analytical model has been compared with another model based on simulation approach and the superiority of the analytical model has been established.

Dundovic and Zenzerovic (2000) have presented the possibility of optimum port capacity design using queuing theory. They have identified the basic parameters of a port system which affect its optimal capacity, as the number of ships arriving within a particular time period and those that can be serviced in the same time period. Using the queuing system appropriate operating indicators such as the number of berths and cranes on the berth can be determined, and can be applied in planning, developing and exploiting the port system capacity.

Liu et al (2002) have described design, analysis and evaluation for various ACT terminal concepts. These concepts include automated container terminals based on the use of AGVs, an LMCS, an overhead GR system, and high-rise AS/RS. The future demand scenario has been used, to design the characteristics of each terminal in terms of configuration, equipment and operations. A microscopic simulation model is developed and used to simulate each terminal system for the same operational scenario and evaluate its performance. A cost model has been used to evaluate the cost associated with each terminal concept and the result indicates that automation could improve the performance of conventional terminals substantially, at a much lower cost.

Moglis and Sanguineri (2003) have examined the challenges that a port faces in achieving its primary objectives as outlined in its master plan, such as economic expansion, employment, the strengthening of the maritime industry, the creation of value added services-benefiting the port and city, the provision and upgrading of infrastructure and development of an efficient management strategy.

Hoshina and Ota (2007) have proposed integrated design methodology for an automated transportation system in a sea port terminal. They have attempted in designing machine specifications which are operating in the automated transportation system. Further in addition, a design of the appropriate number of machines, efficient system layout and system management models have been proposed. The objective of this study was to maximize the system efficiency while minimizing the changes in the specifications. They evaluated the specifications based on the system throughput of the constructed system and then made clear the impacts of the specifications on the system. Finally, for an imposed demand they have designed the results and demonstrated the need to take into consideration the machine specifications.

Zauner (2008) has conducted an explorative study to understand the internal and external conditions of the Rotterdam seaport cluster. A SWOT analysis has been carried out and an internal perspective has been chosen to facilitate the emergence of strengths and weaknesses such as geographical location and lack of intra-port competition. Opportunities including increasing world trade and inter-port co-operation, and threats such as growing competition and industry concentration are reported. The foundation for future strategic planning considerations and implications for other port clusters are provided using this.

Hoshino et al. (2009) have introduced the performance and fleet sizes of the operating machines, such as quay container cranes, automated guided vehicles and rubber-tyred gantry cranes as design objectives. They observed that higher throughput need not be realized from a terminal system, in which larger number of machines is used for higher operation performance. From this a reasonable combination of design parameter with an impact to the system throughput has to be identified. They have used this design strategy and then modified a previously proposed hybrid design methodology. As a case study for the system design they have determined the combinatorial design solution to meet a given demand and reported the effectiveness of the system design.

Lee et al. (2008) have built an ALG program to generate the simulation model automatically, based on the input parameters provided by the user. This program is integrated with simulation optimization algorithms, which can generate new designs, evaluate the design efficiently and finally identify the promising designs.

Jugovic et al. (2011) have studied the forecasting method required for forecasting the traffic demand of a port. They have observed that it requires large amount of data, continuous monitoring of port traffic, capacity, foreign exchange, GDP values and other required indicators, which highly complicates and raises the price of the forecasting process. As a case study they have estimated the container traffic forecast requirement of port Rijeka and compared it with competitive ports of Trieste and Koper. They have used various methods to estimate the traffic, like forecasting through time series analysis, forecasting using GDP, European Commission Estimates and regression analysis. They have concluded that the predicted expected values should be taken as the average of all methods used.

Syafi'i et al. (2005) have used a multivariate autoregressive model to study the demand of container throughput in Indonesia. VEC model has been used to establish cointergration relations and IRF was performed to know the response of a variable on other variables. The empirical analysis has indicated the potential of the forecasting model and verified the stability of the model. They have concluded forecasting the container throughput for Indonesian port up to 2015 with the average annual growth and suggested the development of new ports to handle the future traffic.

Schmidt et al.(2005) have presented the work done in a project called TRAPIST, where the needs of small to medium size ports/terminals with multi-purpose capability needs to be handled. TPB with generic applicability was used to investigate the possibility of extension of Tivoli container terminal in the port of Cork, Republic of Ireland, and was further used to review and improve the layout of the road infrastructure in the port of Kokkola, Finland. It was concluded that the object oriented relational database is capable of displaying existing and alternative terminal layouts. The combination of this database and TPB enabled re-engineering of terminal layouts, selection of cargo handling equipments to increase terminal throughput and terminal efficiency. It helps maximizing the use of existing facilities, operationally feasible results and also supports the efficient layout of new facility.

2.3 Green Ports

Bateman (1996) has studied the issue involved in achieving a balance between environmental protection and the need to recognize the importance of seaborne trade with respect to Australian ports. He identified the environmental risk due to port development and operation and has given guidelines to overcome the risks due to solid waste and dredge spoil, and lays emphasis on the long term risks like global warming and green house effect on local climate change. The environmental impact due to port development and ship movement has been identified and a proposal for overall regulation for maritime transport industry is proposed for sustainable development.

Abul-Azm and Rakha (2002) have studied the main features of EIA guidelines issued by the EEAA. The purpose of the guideline was to outline issues relevant to environmental assessment during the design and construction phases of such projects. They identified the main factors to be considered to develop an environmental impact assessment study and the important factors to be considered for ports, harbour and marinas specifically considering the environmental conditions and laws of Egypt. A case study has been carried out for El Sokhna port and East Port Said Port in the region.

Bailey and Solomon (2004) have studied the environmental and health impact due to air pollution caused by the port operations. It has been identified that the air pollution is due to diesel exhaust, particulate matter, volatile organic compounds, nitrogen oxide, smog and sulphur oxide. It is suggested that an alternative assessment of the problem should be done to solve the environmental damage and the importance of site selection has to be done keeping this impact under consideration. Various methods of improving the air quality have been identified and suggested.

Butt (2007) has studied the effect on the environment of port due to waste generated by cruise ship visiting the port, with respect to Southampton port. The pollution from cruise ship has been identified as air emission, ballast water, waste water and solid waste. The present waste management program of the port of Southampton is reviewed and further suggestions are made to reduce the impact on the local environment due to ship waste disposal.

Anastasopoulos et al. (2011) have introduced modern, eco-friendly and cost efficient methods to promote the Green ports. A case study on two Greek ports has been carried out pertaining to the environmental legislation regarding national, international and European policies, in order to suggest an improvement towards Green Port thinking. The main characteristics of a green port and procedure of transformation of a port to green port has been highlighted in this paper.

Ying and Yijun (2011) have made a case specific study of Tianjin port, and presented requirement of a green port construction after analyzing the significance and problems in green construction of Tianjin Port. The green port features which will help to realize and economize, the clean, safe and sustainable development of the port have been presented and these could be used as a guideline for future green port development in China.

Lam and Notteboom (2012) have investigated the port management tools that the authorities have to enforce and to encourage the implementation of green port parameters on various activities of port operations and development. The investigations covered the tools available with port authorities and functional activities at the port. Case studies have been carried out on leading ports in Asia (Singapore and Shanghai), and in Europe (Antwerp and Rotterdam). It was observed that enforcement approach is more prevalent as ports are exercising environmental standard regulations, but it has been reported that further incentives are however required to be provided to go beyond the standard regulations. It has been observed that for functional activities which are mostly focused on ship traffic, the ports are relying on advisory from IMO. It was also observed that the European ports have higher influence in dictating the green port policy due to open geopolitical culture in Western Europe.

Vieira and Gireli (2012) have developed an alternative for sustainable construction of coastal protection and a new method of reusing disposed plastic bottles. The study deals with the reuse of waste for creative construction purposes. The design and construction methodology for the development of green breakwaters with used plastic bottles has been described and model studies on such breakwaters have been carried out. An emphasis of sustainable concept for coastal protection has been established. The reusing of such disposed items reduces the volume of waste and a green structure has been developed with minimum use of natural resources.

Pavlic et al. (2014) have designed a methodological approach for future realistic solution to the challenges of port development. A case study has been done showing the practical application of green port concept with emphasis on overall energy efficiency improvement based on testing, deployment and demonstration of energy efficient solution. The importance of use of newer technology and developing initiative based on modern energy solution design, to improve efficiency in fuel consumption and emission reduction of rubber tyred gantry crane has been studied and reported.

Wen et al. (2015) have proposed a goal system of low carbon and green container port development which include discharge and control of pollution, carbon emission, energy consumption and use of energy saving technology. The goal system offers decision making and theoretical reference for developing low carbon emitting and green container port.

2.4 Decision Support System for Port Planning

Van Hee and Wijbrands (1988) have described a decision support system for capacity planning of container terminals. For the typical elements of a container terminal such as quay, cranes stack yard and trucks for transport of containers between the quay and the stack yard and vice versa, a model has been devised to describe the performance. The decision support system combined a heuristic analysis of these models to a global model to study the interaction between the elements of a container terminal. The algorithm, flow chart and the architecture of the DSS to be developed has been described in the paper.

Shen and Khoong (1995) have presented a DSS using network optimization models to solve a large scale problem concerning the multi period distribution of empty containers engaged in land and water transport. The DSS helps in decision making about container leasing-in and off –leasing and is equipped to respond to sudden changes in demand and supply of empty containers. The needs of GDSS and other CSCW software have been emphasized. The need of artificial intelligence and forecasting techniques to support and complement the solution generated by DSS has been suggested. Forecasting techniques enable accurate predictions of future demands for empty containers and helps in better prepositioning of empty containers to the ports.

Rida et al. (2003) have developed a container terminal simulation model using Java framework to be used as a tool in port decision support system. The model assesses effectiveness and robustness of decision in a nondeterministic environment. The study has proposed the use of web based information technology to improve inter operability between simulators and other port information system components.

Wijnen et al. (2008) have proposed a decision support system for main port strategic planning, that provide a way for decision makers to quickly and easily generate alternative strategic plans and which also helps in evaluating them with respect to a large number of outcome of interest for a wide range of plausible scenario. The paper describes architecture for such a DSS.

Bruggeling et al. (2011) have developed a DSS for container berth planning for making well planned berth. At the same time it offers maximal support for continuous planning with rapidly changing information. The prototype DSS has been validated with various planners and has been judged to be excellent. The biggest challenge in the work has been the collection of data from various departments and organization. The evaluation has showed that the DSS outperformed the current tools and found easier applications. They have suggested further research in five aspects; viz., testing the tool with real berth planners, the integration of more mathematical approaches such as stochastic, fuzzy and on-line optimization and forecasting techniques into this DSS framework, providing similar tools for other planners at container terminals on how to embed these types of DSS tools into the planning process and making these tools available in the wider supply chain.

Boschianc et al. (2013) have developed a DSS for management of complex logistic system. A case study of flow between Trieste port with the terminal of Fernetti has been done. The DSS simulates and optimizes the flow between the two ports. The DSS is based on the principles of discreet event simulation module combined with optimal computing budget allocation and further optimized using Metaheuristic appeal of harmony search.

2.5 Critique of Literature Review

It has been observed that most of the research contributions reported in the literature in port planning and design are widely numerical, statistical and using simulation techniques which need high level understanding of the principles in the particular field. Lawrence (1973), Ergin and Yalciner (1991) have developed computer program based on simulation techniques addressing a limited field of port planning. Kozan (1997), Dundovic and Zenzerovic (2000) have studied the optimization using queing theory. Liu et al. (2002), Hoshina and Ota (2007), Hoshina et al.(2009) and Lee et al.(2002) have delt with various aspects of equipment planning, performance and selection. Jugovic et al. (2011) has identified statistical method of traffic forecasting of a container port. It has been found that there is no consolidated approach towards the port design and planning. Hence in the presented study, it is proposed to develop a decision support system for overall planning and design of ports.

In the field of green port and sustainable development, many guidelines have been provided on various aspects of environmental impacts. Bateman (1996) has dealt with the Australian ports and their environmental impact, Abul-Azm and Rakha (2002) have studied EIA guidelines in Egypt, Butt(2007) has studied the waste disposal problem in Southampton port. Similarly Anastasopoulous (2011) has studied the environmental impact due to Greek ports and Ying and Yinjum(2011) have addressed the problems of Tianjin port. It is seen that most of the reports are based on case studies and mostly addresses only the problem faced by the concerned port, which may not give a complete picture of general green port requirement. A general approach towards the green port development is lacking. The present study takes into account aspects from the construction stage to the operational life cycle of the port project to identify the green parameters and tries to develop a green port rating system without being case sensitive.

It has been observed from the literature that a few efforts have been made to develop DSS in various fields of port design. Van Hee and Wijbrands (1988) have developed DSS for capacity planning; Shen and Khoong (1995) have developed using network optimization for empty container positioning, Boschianc et al. (2003) for complex logistic system and Wijnen et al. (2008) for strategic planning. It has been observed that there is no consolidated approach to develop a DSS for planning and design of a port facility. In the present study a DSS for port traffic planning and design of various physical characteristics of port and harbour is being developed. The DSS is developed as a user friendly web based application along with a green port rating system.

CHAPTER 3

PORT PLANNING AND DESIGN

3.1 General

Port planning and design are the most important criteria in the optimum and economic functioning of ports. Port development is a massive infrastructural project, which involves huge amount of national resources in terms of money, manpower, materials and machinery. These resources are very important and limited, hence should be used with proper planning to avoid misuse of the national resources. A small mistake in planning can cause huge losses in terms of one or more of the above mentioned resources.

3.2 Principles of Planning

3.2.1 Planning for Uncertainties

The port infrastructure development is a long term project, so it may have to confront uncertainties like changes in future demand of facilities, increase in volume, change in type of facility, changes in traffic like increase/decrease size of ship and parcel size, future technological changes in handling equipment, automation of handling equipment system or changes in local hinterland policies. Planning helps in adapting to the future uncertainties or change of events and in forming the objectives of the project which can be used as the basic guidelines. It ensures easier and faster decision making when changes needs to be made throughout the project development and execution stage. It minimizes the risk from the uncertainties by anticipating the future. Planning helps in co-ordination, as planning revolves around the objectives set forward initially by the planner. All the activities are designed towards this common goal. There will be a requirement of team effort by the various agencies in achieving the objectives. Planning helps in better co ordination of these various agencies.

3.2.2 Flexible Planning

Port and harbour structures like quay walls, berths, breakwaters and handling equipments have high initial cost. So planning of capacity should be done to address the immediate future requirement with provision provided for further long term expansion. The forecast and requirement study should be done for a longer period of time so that the planner can predict the future development required, but the execution should be done on stage wise basis depending on the immediate future requirement or else there would be over investment on facilities which might be ideal for a long period of time till the further requirement rises. The berth and equipment usage should be planned for optimum usage and as the demand increases in the future more facilities should be added without reducing the productivity of the total project. Hence planning should be flexible, and it can be summarized that flexible plan is set on certain initial decisions taken by the planner for the design of the project, and as new changes or requirement occurs, an evaluation of the new challenge is done and a re-design will be required in order to change the basic design to adjust to the new environment that the project will be facing.

Planning creates an atmosphere of order and discipline in the executions of the project. The planner will know in advance what is expected of him in the future stages of the project and helps in easy mobilization of resources. Planning creates a healthy attitude towards work environment which helps in boosting teams morale and efficiency.

3.2.3 Planning Process

The most important requirement to have a successful plan is to set down proper planning process. The various stages of planning process are identifying the objectives, formulating strategies to achieve them, formation of best design to achieve the above objectives and finally the implementation and monitoring. The planning process will require an extensive study on future development of a new port or on the expansion of an existing facility. The planning process involves steps like traffic forecasting, identification of design ship which will be the largest ship that might enter the port facility, planning for physical requirement of port and harbour such as required depth, entrance width, turning basin requirements, maneuvering area requirement, berth requirement, handling equipment and storage area requirement. Further to this planning process should incorporate the green design features required in the sustainable development of ports.

Effective planning process optimizes the utilization of resources which brings economy in operations. It avoids wastage of resources by selecting most appropriate use that will contribute to achieve the objectives of the plan.

3.2.4 Planning Objectives

Planning begins with determination of objectives and defining the various activities that will be undertaken. Planning makes the objectives more clear and specific and helps the planner to focus on his goals. A plan forms a guide which acts as a blue print of the course of action to be followed to achieve the objectives. Planning brings order and rationality in the method of working.

Planning provides a competitive edge to the planner, as planning may involve changing the work methods, quality, quantity, designs, future expansion and sometimes redefining the objectives during the course of execution. A planner can easily do this if there is a predefined plan to make changes at various stages without affecting the overall project.

The major objective of port planning is to assist in developing a flexible plan, provide a systematic approach to the planning process, assist in developing a sustainable and green port, development of a master plan for the complete life cycle of the port project starting from design, construction to operations, integrate port planning with technologies like web based DSS to provide a tool to develop a simpler approach.

3.2.5 Controlling and Monitoring

Port infrastructure development is a long term process. Planning helps in controlling and monitoring of the work. Planner sets a standard of performance for the achievement of objectives which can be reviewed at various stages by periodical monitoring. The port facilities are developed no stage wise basis addressing the near future requirements first and providing a scope for further increase in facility as the volume increases. This helps in reducing the initial cost of the port development and the importance of monitoring is emphasized with that. The functioning of the port against the set standards of productivity requirements should be constantly monitored to access the risk of congestion and idling of facilities. Based on these results the future development of the port should be planned. There are chances of technological changes, and the present day system becoming obsolete in the future and the port should be ready for these kind of changes. But the key to keeping up with competition is in identifying the problem at the right time, for which constant monitoring of project and market study are required on a periodical basis. Initial planning becomes the pre-determined goals against which actual performance can be compared.

3.3 Functions and Services of Ports

The primary function of a seaport is to make space available for a ship to dock and facilitate the loading/unloading of commodities from the ship. Apart from the traditional role, the port has assumed new and significant role in the shipping industry due to the increase in trade through sea and changing technology. Besides the inter port competitions and demand from globalization of trade have added to this. The change in technology in shipping, communication and logistics has brought about constant change in this industry and this in turn has brought about the changes in the traditional functioning of the ports. The various services provided by the ports are discussed below

The most important elementary function of a port is the **traffic management** without which port will fail to provide its user a safe and efficient usage of its facilities. To achieve a good functional efficiency the port will need sufficient capacity required against the demand in terms of infrastructural facility, safe and easy connectivity with the maritime channel as well as with the hinterland. The optimum efficiency of a port can be achieved only by providing a traffic functioning which will match, port capacity with the infrastructure of port, land transportation capacity and other services.

Trading is another important function of a sea port, which needs proper connectivity with sea and land and depends on an efficient traffic management. The port will also require sufficient storage area. The trading aspect includes the purchase and sale of goods, other services provided like storage, de-stuffing, processing, refrigeration facility to perishable goods etc., adding to the value of the trading function. There may be countries near the port which do not have access to sea or do not have facility to provide sea port due to economic or geographical reasons. This is a good opportunity for the port to expand its usage to further areas other than its hinterland and gives value addition to trading function.

The **industrial functions** include shipyards for ship building and repairs, fertilizer industries, oil refineries and chemical industries. Such ports will promote the development of industrial zones and various customs facilities which will keep them ahead of other prior ports.

The **logistic function** of a seaport involves conventional handling of goods and transshipped cargo from other smaller ports.

Services provided by the port include documentation and paper work for the commodities in transit and storage, conservation of goods, quality and quantity control, packing, labeling, commissioning, customs clearing, inspection and consolidation of consignments. These services enhance the value of the port function.

3.4. Challenges from Shipping on Ports

The shipping industry has gone through drastic changes in the last few decades which have required the existing port to update their infrastructure, communications, technology and equipment handling abilities. The port should always be ready for any changes, in terms of trade, equipments, technology and demand.

A proper plan will keep the port prepared for these kind of changes and reduce the risk involved. A good plan will help the port organize its function and services in a better way to build up an efficient short term and long term planning procedure to be prepared for uncertainties. The modern technology has made the sea born transport easier and provided increased accessibility to various hinterlands. This in turn increased the sea trading but has brought in new challenges to port operations. The ports keep facing the following challenges from the shipping industry from time to time due to these changes.

The growth in the seaborne trade has increased the demand of **cargo handling** volume in ports. The ports have to address this problem in two ways. The former, called the Quantitative or capital widening which requires huge investment for providing improved port facilities such as docks, quays, berths etc. The latter called as Qualitative or capital deepening which means increasing the productivity of the existing facilities. The qualitative approach may be adopted in situations where the increase in traffic volume does not justify the huge investments. The quantitative approach must be adopted if required to replace the outdated facility.

There have been issues related to increase in **ship size and speed**. Though the increase in ship size makes way for increase in cargo handling per ship and subsequently decreases the number of ship arrivals. The port should be ready to accommodate these new generation ships, in harbour and port side. The limitations such as insufficient depth, maneuverability restriction or insufficient area for expansion of port facility are the major concerns. Improvements of the existing facility such as deepening harbour and the approach channel, increasing the berth length, increasing the capacity and size of the equipment to serve these bigger ships may have to be provided. Increased sailing speed of the ship has increased the frequency of port calls of these ships and results in demand of over capacity in the port facility. This increases the risk of finanacial losses to the port.

New transport systems like lo/lo containers, ro/ro, barge transport system and containerized cargo demand have brought in total change in the port facility. Such challenges can be addressed by providing suitable equipment handling system and cargo storage space according to the system adopted.

Special trade involves liquefied gas, vehicles; livestock etc. and require building terminals or facilities that are able to handle these complicated and troublesome cargoes. The establishment of berth for special kind cargo involves greater risk compared to multipurpose port facility. If these trades are suddenly lost due to competition or the cargo demand loss, the losses to the port might be considerable because the investment for such kind of facilities might be large. Hence a separate traffic forecast study for future demand of these facilities should be done before making investment. This kind of study will help in understanding if the volume of cargo in special trade will be adequate enough to justify the investments.

Some of the **seasonal cargo** will require special setup, storage system and handling facilities and in such cases the port cannot plan for traffic management capacity for these products throughout the year. The ports will charge higher prices for the services provided to these products but the challenge will be handling of these seasonal fluctuations in traffic without harming the regular traffic.

New methods based on **computerization** are introduced to help the shipping industry to save time and money. The port must keep updating its technology so as not to lose the trade to its competitors, by studying the present and future market trend and changes possible in technology.

3.5. Port Planning

The port development is a challenging process due to constant changes in ship sizes and cargo handling techniques and new analytical methods have been developed and applied to port planning. The use of computers has made the methods of planning and execution systematic. The planning of port has many aspects attached to it from the site selection, visualization of the project, viability of the project, economic demands, port physical planning and technological planning.

3.5.1. Physical Planning of Ports

The physical planning of a port is the most important and critical stage in the port planning as this stage defines the efficiency of the port functioning and services. An inefficient plan can lead to misuse of valuable resources. Various site selection and layout methods are available for the location, selection and development of configurations of a port or terminal. Port planning should be flexible as the port operates in an ever changing dynamic environment and the plan should have flexibility to changes.

Understanding the requirement of the port and planning with the future expansion in terms of technology and increase in the throughput is the key to physical planning of the port. The facilities provided should not be underutilized or over utilized as this will lead to the loss of the resources or congestion in the port. The planner should set his objectives of planning with an aim to develop a port with optimal functionality and with the optimum use of the resources available.

Computerization of the planning process has helped the planner in resolving the tedious and time taking process of planning. Computerization has helped in the making the planning process more flexible and helps the planner to change the plan according to the requirement during the execution of the project.

The computerized models permit the evaluation of a large number of alternatives in terms of sites, boundaries and facility layouts including berth alignment, breakwater configuration, storage area layout and more. Layout criteria can be minimum total transfer distance or transfer cost, maximum berth and storage utilization or various combination of the all these criteria. The use of computerized layout techniques permits the port planner to efficiently trade off physical and operational factors. Mathematical and simulation methods used for various aspects of planning and designing can be simplified using computerization which also reduces the chances of human error during calculations. The planning of the physical structure of the port which involves huge amount of resources should be done with precession and the past experience of the planner and the data collected will help the planner in developing an optimum design for the port development. During the planning of the physical structures of the port the planner should keep in mind the following factors.

3.5.1.1 Terminal Design

The terminal design usually depends on the kind of facility that needs to be planned in the port. The terminal design depends on the type of cargo that needs to be handled at the terminal, according to which various facilities like handling equipment and storage systems needs to be designed. For this purpose it is necessary to ascertain the type and volume of cargo that will be handled in the terminal. This can be done through a forecast and collecting data of the possible traffic that might be required to be handled at the terminal. The forecast will help to identify the volume of traffic the port will have to handle in the future depending on which the capacity can be planned for the near future and with provision being provided for future development. The various kinds to terminals that can be planned based on cargo handling technique depend on the type of cargo and can be classified as

Conventional break- bulk cargo, it is necessary to ascertain the number of berthing-points needed in order to keep the ship waiting time down to economic level.
Container Cargo, it is necessary to determine the area needed to handle the annual through put without effecting the operation.
Specialized bulk cargo, it is necessary to find the hourly rate of discharge or loading that is needed to handle the ships in an acceptable period of time.

The port planning study requires the estimation of productivity, the number and size of facility needed the level of service to be provided. The relationship between terminal capacity and service provided will form the base of the future port development plan.

3.5.1.2 Berthing Capacity

While planning for the berthing capacity the most influencing factor will be the arrival time and the size of the ship arriving at the port. The combination of the various sizes and arrival of the ships is an uncertainty to predict. The time taken to discharge and load a ship will be constant in an ideal condition but unfortunately such ideal conditions can never exist. The time taken to unload/load the ships varies considerably owing to variation in the quantities and type of cargo handled, the way the cargo is stowed and cargo handling rate.

The two extreme conditions of planning for berth capacity are planning for 100 percent birth occupancy and guarantee of no waiting time for ships. The former will lead to queuing of ships and the latter will lead to low average berth occupancies. Both these conditions are not acceptable for optimal planning and a compromise should be achieved between both the conditions.

3.5.1.3 Berth Occupancy

The planner should be able to fix Berth Occupancy Factor (BOF) while planning for the optimal condition without idle time for the berth and the reduced queuing for the ships. BOF is the ratio between berth utilization time and total available time which is the indicator for berth congestion. Higher berth occupancy would indicate congestion at the available berth. BOF is relevant in making investment decisions for addition of new berths or extension of existing ones. The planner should be precise in calculation of berth occupancy by considering the time in working hours rather than in days.

3.5.1.4 Waiting Time – Service Time Ratio

Waiting time is the total time between arrival and berthing for all berthing ships divided by number of berthing ships. Waiting time is normally a small portion of the total turnaround time. Higher waiting time is a sign of congestion in the port due to insufficient berth or higher service time.

Service time is the total time between berthing and departure for all ships divided by the number of ships. Reduction in service time can subsequently reduce the ships turnaround time. The service time dependents on factors like quantity and quality of cargo to be unloaded or loaded, type of ship to be serviced, type of equipment available and other resources used. The expected waiting time ratio increases with higher service time taken. Hence a considerable reduction in service time may have considerable effect on the waiting time and productivity of the port.

The waiting time - service time ratio can be used as a measure of efficiency of service provided by the port. It is usually considered that the waiting time should not be more than 10-15 percent of the working time. [26]

Certain scheduled traffic will have effect on the berth occupancy. When there are expensive or priority facilities which need to be handled without delay other ships will have to be kept waiting. This will lead to low berth occupancy and the only way in which the berth occupancy can be maintained, without keeping the priority ships waiting is to convince the user to schedule their arrival. Specific days can be allotted for such traffic and the operator should ensure that the ship arrives on scheduled time so that they do not have to wait. If several operators agree to such scheduled traffic the berth occupancy will be very high and in such cases the waiting time service time ratio does not apply and the berth requirement can be directly calculated from scheduled arrival. When the scheduled traffic is allotted certain days, the general traffic requirement should be calculated after reducing days provided for scheduled traffic.

3.5.1.5 Traffic Variation

The variation in the port traffic can be attributed to introduction of a new shipping service or additional chartered ships, gradual trend towards larger ship loads in an existing service, more frequent calls by an existing service through the placing of additional ships in service normally announced in advance and exceptional calls like ships diverted from a neighboring congested ports.

Planning with a small margin of spare capacity can have reverse effect on port services. The gradual increase in the traffic or the short term increase in the traffic will lead to congestion in the port and will make it inefficient. The port will reach a situation when the temporary emergency action will be ineffective and cannot recover from congestions. It is always better to have a reserve capacity while planning in initial stages for the excess work load when the demand is high and less when it is low.

There can be short term problems also like arrival of a priority ship may affect the service of other ships for the time being. But the long term problems may lead congestion; like if the commodity of certain goods has gone down the importers may try to take advantage of the situation by increasing their purchase. The duration of such variation needs to be studied, by looking into whether it will be a long term or a short term effect.

The long term variation raises the challenge of increasing the port investment. The choosing of the amount of spare capacity which will be kept in the reserve becomes a critical decision during the initial planning. A balance of investing in reserve capacity keeping expensive facilities idle and probability of port congestion has to be achieved taking into consideration the economic viability.

The seasonal variation will show peak traffic in relatively short duration and can be handled by distributing the load or by seeking increase in the traffic during off season. This kind of planning will give consistent berth occupancy and avoid congestion in the port in the season, as well as resolve the problem of underutilized infrastructure in the off season.

The option of planning for average monthly traffic is desirable but this will increase the waiting time in the peak season. The planner can think of providing secondary facilities notwithstanding the fact that such facilities will not be as efficient as the main facility but will cut down the initial investment.

Further, there can be a scenario in which the seasonal traffic may need special equipment facility for unloading. In such situation the planner can use the option of providing removable equipments which will not be a permanent fixture on the berth and in the off season the berth can be used for the regular traffic services.

3.5.1.6 Specialized Traffic

The port will have a requirement of handling specialized goods which might require separate berths with specialized equipment for the purpose of servicing the ship. The traffic must be assigned individually or in combination with berths as per the requirements and then the capacity of each berth should be designed.

When separate specialized berths are used there is always the loss of flexibility in the usage of the berth. A separate storage area has to be provided for specialized goods according to their storage needs. Due to this, there will be loss in storage area for general cargo in the total capacity.

The specialized berths have an advantage of being highly efficient in servicing the ship, as the equipments used will be designed for the special needs of the goods. Hence there will be an average improvement in the productivity of the port. Specialized berth will be an attraction to a certain class of user; hence the planning can be carried out for scheduled traffic and reducing the congestion on these berths. The planner should think of providing a separate berth for the specialized traffic only when sufficient volume of traffic is available for investing in separate specialized terminal.

3.5.1.7 Economic Optimum

The port planner has to employ the port capacity to maximize the total net benefits, for both the ship owners and the port management. The port management will always be looking for the full utilization of the facilities to maximize their profits and to minimize the cost per ship to be more competitive with other ports. But this might lead to waiting of ships and congestions. If the planner tries to reduce the waiting time by constructing excess facilities, it will lead to increase in the investment cost to the port management/owner. It is a situation which means more facilities means higher cost for the port and lower costs for ship owners; and reduced facilities means lower cost for port and higher cost for the ship owners. The planner should always try to draw a plan for an economic optimum so as to keep a balance which would benefit both the port and the ship owners. Planners always face such difficulties while planning for capacity with fluctuating demand and it is always better to plan for economic optimum. The port planning always tries to reduce the turn-around time of the ship and this is a determining factor to set the economic optimum.

Containerization of cargo reduces substantially the service time needed by ships, and increases the capacity of a given facility. The speed at which containerization is being adapted in cargo transportation and the modern techniques which have helped in containerization of cargo; the need to expand capacity by adding berths to the existing ports has reduced. So containerization of cargo helps in achieving an economic optimum in port planning.

3.5.1.8 Flexibility

The port planning is affected by uncertainties in the market, changes in technology, socio-economic and political developments or all of these. Hence the planner should be ready to make amendments in the plan to suit the new situations. The planner should design port strategies with contingency plans which will allow more flexibility to the port functions. The plan should be able to accommodate the change in traffic demand as well as the technical changes. Flexibility in plan always provides the port a more feasible plan and the port is always ready to face the uncertainties in the operations.

3.5.2. Technological Planning

Technologies are fast changing and new innovations bringing in drastic changes to the total scenario of planning. The use of computers and development of modern age communication facilities has changed completely the port functions and services. The computerization helps the planner in evaluating various complex scene before making the decision. The introduction of artificial intelligence, expert systems and DSS has made the job of the planners easier. The computer permits the evaluation of a large number of alternatives in terms of sites, boundaries and facility layouts including berth alignment breakwater configuration, storage area layout and more. Layout criteria can be minimum total transfer distance or transfer cost, maximum berth and storage utilization or various combinations of all these criteria. The use of computerized layout techniques permits the port planner to efficiently balance physical and operational factors. The mathematical simulation in the planning of the layout and operational work flow can also be designed using the computer models. Technological planning is interpreted as developing an effective program that uses past data for future decisions.

Computers are being used by ships, operators, freight forwarders, customs services and other ports for communication and to improve operational efficiency. If the port is not updated with this technology the shippers will prefer other ports so as to better their operations. The other major problem the port faces is the collection and documentation of data, so that this data can be used to extract useful information that will add to the knowledge base of the planner while planning for future uncertainties.

3.6 Port Design

The port design can be categorized into two sections viz., the harbour side and the port side. The harbour side components are basically, the various physical characteristics such as width of channel, entrance width, channel and basin depth, basin area, turning circle requirement and dredging equipment selection. The port side components are quay and berth requirement, handling equipment requirement and storage yard requirement.

The above mentioned facilities can be designed based on the port traffic and design ship size. The traffic of the port can be classified based on methods of handling the cargo and packaging as bulk, liquid specialized and container cargo. The design ship size has been defined as the maximum ship size that will enter the port facility. The port traffic is estimated using appropriate forecasting techniques and the design ship size is arrived based on the existing fleet data. Traffic forecasting, design ship selection and the various waterside and landside components are described in the subsequent sections.

3.6.1 Traffic Forecasting

Traffic forecasting is a method of using mathematical techniques and past data to project the probable future data. Traffic forecasting is based on commercial and economic knowledge as well as appropriate mathematical techniques. The accuracy of the forecast depends on the understanding of the commercial and economic factors. The most important challenge to be handled in forecasting is the degree of uncertainty in any forecast, and to take steps to minimize the risk caused by these uncertainties.

Forecasting of the port traffic is based on various factors such as economic changes in the hinterland, changes in technology, changes in market conditions of the hinterland and changes in mode of transportation of certain goods. The planner also has to ensure the system of observation in order to spot when the observed traffic starts to deviate from the forecasted traffic.

The deciding factors for port traffic forecasting are; packing and conveyance method of commodities as maritime cargo, quantitative and qualitative description of commodities which will be handled through maritime cargo and description of ship types, tonnage and frequency of calls i.e. turnaround time of ships which will be as a result of above two factors.

The progress in the application of quantitative methods for forecasting has been a result of the rapid development of computers and software that enables analysis of large volume of data.

The various forecasting methods are generally categorized into qualitative and quantitative methods. Delphi Method, Market Research, Product Life Cycle analogy and Expert Judgment are the qualitative methods. The various quantitative methods are Simple Average (SA), Moving Average (MA), Weighted Moving Average (WMA), Moving Average with linear Trend (MAT), Single Exponential Smoothing (SES), Single Exponential Smoothing with Trend (SEST), Double Exponential Smoothing (DES), Double Exponential Smoothing with Trend (DEST), Adoptive Exponential Smoothing (AES), Linear Regression with Time (LR), Holt Winters Additive algorithm (HWA) and Holt Winters Multiplicative algorithm (HWM).

Of these, the trend forecasting by least square/regression method is found to be more useful in practical situations to project the traffic on the basis of past achievements. Based on the figures for the past traffic, a trend analysis is done using the theory of least square to find out the trends in the traffic both at present and that for future. This technique has been recommended by the UNCTAD Secretariat [25]. From the parameters obtained from past performance, an equation is established to identify the future trend. In the present study linear regression and correlation analysis has been used for port traffic forecasting.

The linear regression analysis is a forecasting model that establishes a relationship between a dependent variable and one or more independent variables. It uses the knowledge about the relationship between dependent and independent variables to forecast the future values of the dependent variable. In simple linear regression analysis time period is the only independent variable, and the dependent variable is traffic volume.

The model of linear regression is called as regression equation and is of the form

$$Y=a+bX, \tag{3.1}$$

$$a = \frac{\sum x^2 \sum y - \sum x \sum xy}{n \sum x^2 - (\sum x^2)} \tag{3.2}$$

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x^2)} \tag{3.3}$$

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2}} \tag{3.4}$$

x will be entered as years like 1999,2000, 2001 etc. for the calculation of components in the formula with x then initial year entered is considered as 0 and the subsequent years as 1,2…. up to final year n.

The coefficient of correlation (r) explains the relative importance of the relationship between *y* and *x*; the sign of r shows the direction of the relationship, and the absolute value of r shows the strength of the relationship. r varies between -1 to +1 .The sign of r and b are same. A negative r indicates the value of *y* and *x* tend to move in opposite directions, and a positive r indicates that the value of *y* and *x* in the same direction. The various values of r interpreted as, when the of r is -1, it is a perfect negative relationship in which as *y* goes up *x* goes down and vice versa. When the value of r is +1, it is a perfect positive relationship in which as *y* goes up, *x* goes up and vice versa and if the value of r is zero then it is interpreted that there is no relationship between *y* and *x*.

Although the coefficient of correlation is helpful in measuring the relationship between *x* and *y*, terms such as strong, moderate and weak are not very specific measures of the relationship. The coefficient of determination (r^2) is the square of the coefficient of correlation. The seemingly insignificant modification of r to r^2 allows us to shift from subjective measure of relationship to a more specific measure. The coefficient of determination, therefore, illustrates how much of the dependent variable *y* is explained by *x* or the trend line.

Both the coefficient of correlation and coefficient of determination are helpful measures of the strength of the relationship between dependent and independent variables and thus of the value of regression equations as forecasting models. The stronger the relationship, the more accurate the forecasts resulting from the regression equation are likely to be.

3.6.2 Design Ship Size

The design ship will be the largest ship that might enter the port. The size of ship depends on the volume and type of traffic that the port needs to handle. The design ship size is the most critical decision taken while planning for the port. The physical aspects of the port like depth and width of channel, berth capacity, equipment scheduling all depends on the design ship size. A change in ship size after the construction of port will incur huge losses and sometimes it will not be possible to accommodate such ships in the port. The planner should also study the present fleets of vessels that use similar ports and their cargo handling capacity. It will always be easier to select the design ship from the existing fleet as all the dimensions and other physical data of the ships will be available. The Table 3.1 gives the details of container ship fleets from which the planner can select the ship size as required while designing a container terminal.

Table 3.1 Present Day Available Ship Fleet Dimensions [Alphaliner and Container – Transportation.com]

Sl.No.	Particulars	Length (L) m	Beam (B) m	Draft (D) m	TEU nos.
1	TBN	440.00	59.00	16.50	20200
2	EMMA MAERSK	397.00	56.40	16.00	15200
3	GUDRUN MAERSK	367.00	42.80	15.00	9500
4	SOVERIGN MAERSK	347.00	42.80	14.50	8200
5	NYK ALTAIR	300.00	37.10	13.00	4953
6	PRESIDENT TRUMAN	275.00	39.40	12.50	4538
7	PANMAX	250.00	32.00	12.50	3400
8	FULLY CELLULAR	215.00	20.00	10.00	2500
9	CONVERTED TANKER	200.00	20.00	9.00	800
10	CONVERTED CARGO SHIP	137.00	17.00	9.00	500

3.6.3 Harbour Design

The major parts of the harbour which are important for the safe movement of the ship are the harbour entrance and the harbour basin. The design of the harbour depends on the largest ship which will enter the harbour. The details of dimensions of the design ship discussed earlier are used to arrive at the various dimensions of harbour entrance and channel such as channel width, harbour entrance width, channel and basin depth, maneuvering area requirement and turing basin dimensions.

3.6.3.1 Harbour Channel Design

Width and depth of channel are the parameters evaluated for the purpose of harbour channel design.

The design of the **width of channel** depends on the number of maneuvering lanes required in the channel (single or double). This decision has to be taken by the planner depending on the traffic volume and area availability at the proposed harbour. In some cases where dredging of the channel is required the planner has to see the traffic volume, even if the area is available for double lane to save on the dredging cost. The various components of the channel for single lane are maneuvering lane and bank clearance, and for double lane are maneuvering lane, bank clearance and passing clearance as shown in Figure 3.1 and Figure 3.2

Maneuvering lane is the width required to allow for the movement of the ship. The width is calculated for the design ship which is the largest ship that will be using the harbour.

Ship/passing clearance is the distance required between the two maneuvering lanes in case of a double lane traffic system. As two vessels pass, there is a strong interaction forces mobilized between them, giving rise to path deviations and heading changes. Even though the interaction forces are quite large, the magnitudes of the path deviation and heading changes during the actual passing of the ships are small. The real danger lies after the ships have passed when the dynamic disturbances imparted to the ship during passing can combine with the bank effects and lead to oscillating diverging motion if not properly controlled.

Bank clearance, when a ship moves through water, the water is displaced at the bow and transported back around the hull to fill the void behind the stern. Flow-produced lateral pressures are balanced when the ship is proceeding in an open channel or on the centre-line of a symmetrical channel. When the ship is moving parallel and off the channel centre-line, the force is asymmetrical and produces a yawing moment. The yawing moment is produced by the building of a wave system between the bow and the near channel bank.

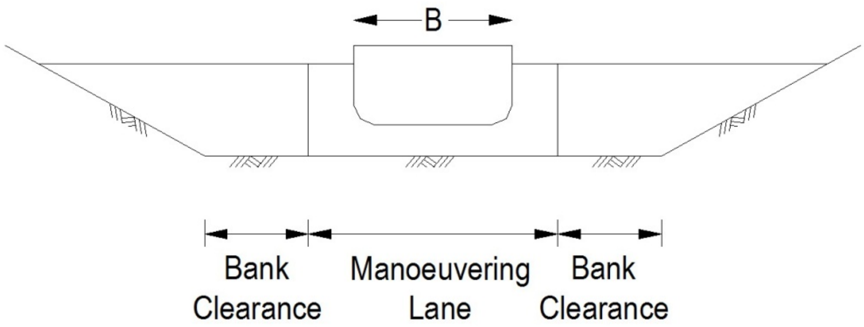

Figure 3.1 Various Components of One Lane Channel. [IS 4651 (Part V) – 1980].

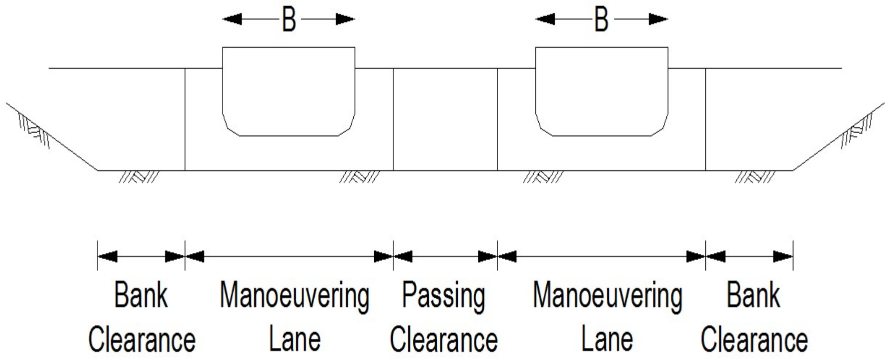

Figure 3.2 Various Components of Two Lane Channel [IS 4651 (Part V) – 1980].

IS 4651 (Part V) – 1980, Indian standard code of practice for planning and design of ports and harbors Part V Layout and functional requirements, has provided standards for the layout design and the various physical aspects of the port structures which are being adopted here to design a harbour for container terminal. The channel width can be calculated by using the equations 3.5 and 3.6 as provided by the code.

Single Lane Channel

Bottom Width = 3.3 – 5.0 B (3.5)

Maneuvering Lane = 1.8 – 2.0 B,

Bank Clearance = 0.75 – 1.5 B,

Double Lane Channel

Bottom Width = 5.1 – 8.0 B, (3.6)

Maneuvering Lane = 1.8 – 2.0 B,

Bank Clearance = 0.75 – 1.5 B

Passing clearance = B of the largest ship

3.6.3.2 Harbour Entrance Width

The harbour entrance width should be designed in such a way that the harbour basin and the channel are accessible to the ship without exposing the interior area to the waves and allows the safe entry of the design ship.

The width of the channel should be wide enough for navigation of ship and narrow enough to restrict the entry of the waves. It depends on the degree of wave protection that is required inside the harbour and depends on wave currents and depth. It is recommended that the orientation of the entrance be such that ship entering the harbour has prevailing wind to the fore. Transverse winds and waves create difficult conditions for steering a ship while entering the harbour.

IS 4651 (Part V) – 1980, Indian standard code of practice for planning and design of ports and harbors Part V Layout and functional requirements lays guidelines for entrance width as,

Entrance width = 0.7 L (3.7)

Where L is the length of ship or 100m to 150m for medium ships and 200m to 250 for large vessels whichever is more.

3.6.3.3 Channel and Basin Depth

The minimum depth for safe navigation is calculated from the sum of the draught of the design vessel as well as sum of various allowances. Depth required is a total sum of Design ship draught, trim, squat, exposure allowance, fresh water adjustment, bottom material allowance, over depth allowance and depth transition less tidal allowance. The components of the depth are shown in Figure 3.3

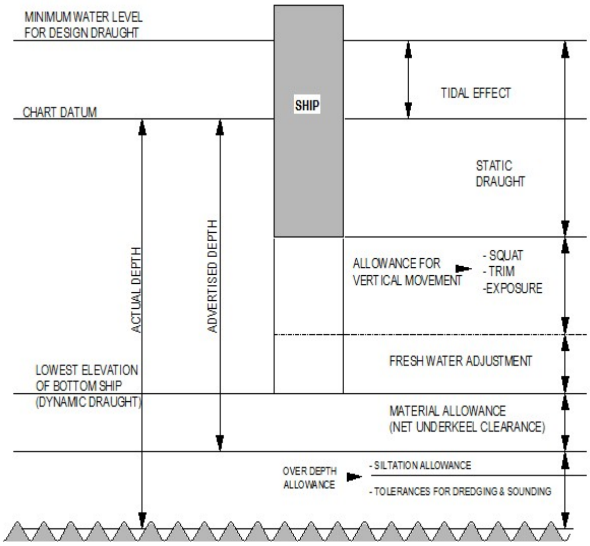

Figure 3.3 Various Components of Waterway Depth
[Safe Waterways Part 1(a)]

The further calculation of each of these is as follows.

Trim is usually calculated as 0.25m/100m L. (3.8)

Squat is calculated by Eryuzlu Equation

$Z\,(d/D^2) = a\,[\,v_s / \sqrt{g\,d}\,]^b\,[D/d]^c\,F_w$ (3.9)

With $F_w = 1$, where W > 9.61 B;

a,b,c are common coefficients: a = 0.298, b = 2.289 and c = -2.972.

$F_w = \frac{3.1}{\sqrt{\frac{W}{B}}}$ where W < 9.61 B.

Exposure allowance should take into account the movements of heaving; pitching and rolling caused by the local conditions.

Fresh water adjustment is when the salinity increases the density of water, in turn reducing the draught of the ship in the waterway. An adjustment for fresh water should account for the decreased buoyancy of the ship. A rule of thumb to determine the additional allowance for ships in fresh water is to set it at 2-3% of the salt water draught. [35]

Bottom material allowance is the minimum safety margin between the keel of the vessel and the projected depth of the channel. This additional allowance is to ensure a safety margin against striking the bottom. This allowance depends on the type of the bottom material being soft or hard.

Maneuverability margin is made up of the allowance for bottom material and the exposure allowance. This margin is a measure of minimum depth required to allow the ship to maneuver adequately in the channel. A minimum margin of 1m is generally used. [35]

Over depth allowance is provided for accounting the siltation between maintenance dredging and the average acceptable tolerance is 0.3m. If the bottom material is soft and can be displaced by a ship and no tolerance allowance is necessary.

Depth Transition is required to be taken into consideration because the bottom of the sea bed may have various depths, due to the natural conditions. If the transition between reaches is large, the sudden change in bottom clearance will have effect on ships performance, maneuverability and draught. The squat might increase by 15% to 20% when the transition is from deep water to shallow water. [35]

Tidal Allowance can be arrived at only by studying the historical data of tidal pattern, to derive as to what extent tidal height above the chart datum should be included a part of the normally available water depth.

The required minimum depth for the safe passage of ship can be hence calculated as

$$\text{Depth} = \text{Design ship draught} + \text{Trim} + \text{Squat} + \text{Exposure allowance} + \text{Fresh water adjustment} + \text{Bottom material allowance} + \text{Over depth allowance} + \text{Depth transition} - \text{Tidal allowance.} \quad (3.10)$$

The depth can also be calculated by the guidelines provided in IS 4651 (Part V) – 1980, Indian standard code of practice for planning and design of ports and harbors Part V Layout and functional requirements, as follows

The minimum under keel clearance should not less than

Depth in Channel = D + (10 * D)/100 (3.11)

Depth in Turning basin = D + (15 * D)/100 (3.12)

Depth at Entrance = D + (20 * D)/100 (3.13)

If the loaded draught is not available along with the dimension of the ship, the planner can use rule of thumb that as full loaded draught in meters equals square root of dwt, in thousand, plus 5.

3.6.3.4 Basin Area

The main components of harbour basin design are the depth, water area requirement for maneuvering area for ship and turning basin/circle. Maneuvering area of the basin is where the ship slows down to proceed towards anchoring. The requirements of the maneuvering area depend on the type of berth that is proposed in the port that is 90 degree, 45 degree or parallel berthing.

The turning basin is the area required for maneuvering the ship when it tries to berth or leave the harbour, so that the ship can leave the port head-on. The size of the turning basin depends on the dimension of the design ship. The size of the turning basin also depends upon whether the ship turns with or without the help of tug.

The water area required for mooring of ships depends up on the type of mooring system and the number of ships that need protection or facilities for unloading. The selection of mooring system also depends on the area available, degree of exposure of waves in the harbour and bottom material.

IS 4651 (Part V) – 1980, Indian standard code of practice for planning and design of ports and harbors Part V Layout and functional requirements has given limits for minimum depth of water within the harbour depending on the bottom material, area requirement based of degree of berthing, diameter of turning basin and various mooring area requirement.

Depth should not be less than the loaded draught of the largest/design vessel plus 0.60 to 0.75m for under keel clearance. For harbour with hard bottom the allowance should be 1m and additional clearance may be required in basin where energy disturbance exists.

Maneuvering Area is the width required to permit a vessel to swing freely to a berthing position is

90 degree berth = 2L (3.14)

45 degree berth = 1.5L (3.15)

Parallel Berth = 0.60L, Where L is the length of the ship. (3.16)

The size and/or diameter of the **turning basin** would depend on the geometry of water area available and berth arrangement. The diameter of the turning circle

Where vessel may be wrapped round turning dolphins – minimum 1.2 L of the largest vessel to be turned (3.17)

Where vessels turn by free interplay of the propeller and rudder assisted by tugs the minimum diameter of the turning circle should be 1.70 L to 2L.

In Protected Location 1.7 * L (3.18)

In Exposed Location 2.00 * L (3.18a)

Where no tug assistance is available the diameter of the turning basin may be as large as 4*L (3.19)

3.6.4 Berth Design

The **berth design** is the most important aspect of port structure design in terms of port economics, port functioning and structural stability. This involves the design of the quay wall structure arriving at the length of the berth, making decision on number of berths and estimation of frequency of ship arrival at the port. The important factors to be considered during berth design are as follows, The **quay wall structure** will need the highest individual amount of investment when compared to the other structures in the port. The structural adquacy of the quay is very important, as other than the wave action there will be an impact from the ship while berthing.

The **length** of the berth depends on the length of design ship. To determine the quay length the first input required is the actual throughput the port will be handling, the design ship size and frequency of call or number of ships that will be visiting the port.

The **number of berth** required is a decision to be made by the planner keeping in mind the berth occupancy factor and the waiting time to service time ratio which has been discussed in detail in section 3.5.1.

The **frequency** of ship arriving to the port also plays an important role in designing the berth dimension and numbers, as this decides the occupancy requirement of the berth.

It can be said that quay wall is the most expensive asset in the terminal and sometimes the planner will have to compromise on the required number of berths which might lead to congestion in the port. The input can be collected as the total number of TEU loading and unloading over the quay wall or in terms of annual number of calls and the volume of containers loading and unloading per call. Other important factors to determine the required number and length of berth are service time and annual berth working hours. The planner should understand that a slight oversight while designing the berthing volume will lead to congestion in port or low berth occupancy, both of which are not desirable beyond a limit and shall affect the economics of the port as discussed in section 3.5.1.

To calculate the requirement of length and number of berth required, the service time of ship, number and productivity of cranes per berth, parcel size and number calls are necessary. The service time can be calculated as

Total service time (hour/vessel) = (un) loading time + (un) mooring time (3.20)

The following formula can be used to determine the (un)loading time (un)loading time = $\frac{Sp}{Nc \times Qcr \times Wct}$ (3.21)

Given the downtime factor and total working hours, the berth working hours can be calculated as follows:

$T_{bw} = (1- D_t) \times T_d \times N_{dw}$ (3.22)

The berth length requirement for loading and unloading a vessel can be calculated as

$L_{br} = T_s \times N_v \times L_b$ (3.23)

To determine the sufficient quay length with a given berth occupancy, the following equation is used

$$L_q = \frac{L_{br} \times P}{T_b \times U_{berth}} \quad (3.24)$$

The quay length is used to determine the number of quay cranes and number of berths. The rule of thumb to calculate the number of quay cranes states that one quay crane is needed for each 80 – 100m of quay length. The number of berth can be calculated as

$$N_b = \frac{L_q - \text{Berthing Gap}}{(L_v + \text{Berthing Gap}) \times 1.1} \quad (3.25)$$

The quay productivity can be estimated as follows

$$Q_c = \frac{C}{f \times N_b \times T_b} \quad (3.26)$$

If the quay productivity is not satisfactory it can be improved by variation of the design parameters such as number of cranes per vessel or operational working hours.

3.7 Handling Equipment Selection

Handling equipment selection will primarily depend on the type and size of cargo that will be handled at the port and secondly on the size of the ship that will be serviced in the terminal. In bulk cargo terminals the handling equipments will require various types of attachment to suit the cargo unloading and shifting the cargo to the storage area or to load it to the trucks. With containerization coming to forefront and study on containerization of various material has made the process of unloading container ship faster and easier compared to the bulk cargo terminal. Containerization has also reduced the service time of the ship as the standardization of the container has made it easier to design equipments for the ships and there is no need to customize the equipment for various types of cargo. Moreover the automation of the handling equipment system and systematic loading of container has also helped the computerization of the process. The various handling equipment used in port operations are discussed subsequently

3.7.1. Quay Side Cranes

These cranes are used to unload/ load cargo from the ship to the quay side. These cranes are very expensive and their performance is very important to reduce the service time of the ship. There are basically three types of quay cranes viz. ship to shore, mobile harbour cranes and wide span cranes.

Ship to Shore (STS) gantry crane is a specialized gantry crane designed with rigid structure to handle cargo between ship and quay in straight lines. There are two types of STS cranes single trolley and dual trolley crane. The single trolley crane moves the cargo directly from the ship to the horizontal transport equipments from the berth. The problem with single trolley system is that if there are a limited number of horizontal transport systems the productivity of the crane gets affected as the crane will have to wait for the arrival of the next horizontal equipment. A dual trolley system is an improvement to this problem as one trolley moves the cargo from the ship and stacks it on the berth and the second trolley lifts the cargo from the berth and loads it to the horizontal transport equipment thereby not affecting the productivity of the crane and the service time of the ship. The performance of STS depends on the hoisting/lowering speed and trolley travelling speed of the crane. The advantage of STS is that these cranes have high throughput capacity and need limited space between cranes. The downside of STS crane systems is that they have very high investment and maintenance cost, limited flexibility and high surface load.

Mobile harbour cranes (MHC) are wheel type cranes with various types of spreaders providing flexibility to the planner for container handling and bulk operations of general cargo. MHCs are less productive compared to STS but are a cheap alternative. An important feature of MHC is the large back reach which allows it to place the cargo directly in the storage yard thereby reducing the number of horizontal transport equipments required. Hence it can be summarized that MHCs have an edge over STS in flexibility, low investment and possibility to reduce the cost on horizontal transport equipment. But the down side of the system is that the productivity of these cranes are low and need more work space and have less accuracy due to sway.

Wide span cranes (WSC) have wide span compared to other cranes which provides storage area under the crane span thereby eliminating the requirement of horizontal transport and reduces the storage yard requirement. These kinds of cranes are suggested for medium and small sized terminals where space availability for storage is limited. Another advantage of this kind of crane systems is shorter cycle time due to the elimination of horizontal transport system. The advantages being compact design and absence of horizontal transport system but at a cost of less flexibility and are not suited for ports which will require future expansion.

3.7.2. Horizontal Transport

These vehicles are used to transport the cargo from the quay side to the storage area. There are two type of equipments used for this purpose viz., non lifting transporters and lifting transporters.

Non Lifting transporters are vehicles which do not have a self lifting ability of the cargo and hence loading/unloading needs to be done by other equipments like cranes in the quay area and the storage area equipments in the stock yard. Basically there are two types of non lifting transporters; port tractor vehicles and automated guided vehicles

Port Tractor Vehicles need to be loaded by cranes on berth side and other equipments to unload at storage yard. Generally in big ports the cargo is stored in the storage yards, but in case of small ports the cargo might be stored on top of the trailer. To increase the capacity of this system a multi trailer system (MTS) is used wherein a single tractor is used to tow multiple trailers. The advantage of this system is high throughput capacity and low investment cost. But there is a problem of less flexibility in operations.

Automated Guided Vehicles (AGV) is a driver less vehicle were the vehicle follows a standard track that consists of electrical wires or transponders in the pavement between berth and storage yard. AGVs can move faster and their accuracy is good. AGVs have high throughput capacity but are again high on investment and maintenance cost and are complicated sensitive equipment.

Lifting transporters are equipments which can lift cargo stacked near the quay on their own thereby decoupling the quay and yard crane cycle. This reduces the cycle duration of the quay side cranes since they don't have to load the cargo on the horizontal transport equipment,

Forklift truck and Reach Stacker is highly flexible and relatively less economical equipment that can be used in stacking cargo in the storage yard also. These are mainly used in medium or small container terminal where the container volume is low and the planner save in the cost of storage yard equipment. The fork lift has a guide rail which assists the lifting of the container where as the reach stacker uses a boom for the purpose. These equipments are highly flexible with low investment cost, but have low productivity and need more working space.

Straddle carrier is the most flexible equipment in this category. They can handle a variety of operations like loading, unloading, stacking and moving cargo from storage area to quay side and has a great deal of space efficiency. This equipment is preferred due to its advantages of high throughput and flexibility of single equipment for all operations in the terminal, but has a high initial and maintenance cost and is complicated equipment.

3.7.3. Storage Yard Equipment

Some of the quay side horizontal transport equipments are non lifting type; for this purpose the storage area needs to have equipments to lift the cargo from the trailers and stack them. Gantry cranes are used for this purpose as they are highly efficient and productive.

Rubber Tyred Gantry (RTG) is used in terminals with huge amount of throughput of cargo because they are very flexible and have a high stacking capacity. They move on wheels hence can be used in hinterlands also. The advantages of these equipments are that the storage yard needs are reduced, highly flexible and productive but have high maintenance cost. The cost of storage yard preparation is increased due to the requirement of good subsoil conditioning and hard pavement to move on.

Rail Mounted Gantry (RMG) is wider than the RTG hence having ability to stack higher and wider than RTG's. The advantage of this system is that since rail can spread loads better than wheel, they can be used in conditions where the subsoil condition is not optimal and moreover they can be automated if required and have high productivity, on the down side they have high maintenance and investment on rails are required and do not have flexibility like RTG.

Automated Stacking Crane (ASC) is an automated RMG's, in this system, the operating cost is reduced and increases the utilization rate of equipment.

3.7.4. Equipment System for Container Handling

The movement of containers from the ship to the storage yard is carried out using various types of equipment. The various stages of container movement inside the port can be classified as from ship to shore which is done using cranes, from near the crane to the storage yard and stacking to the required height and pattern using lifting equipments, horizontal transport equipment and storage yard equipments. Some of the equipment described above may handle all these tasks together otherwise the requirements might be for specialized equipments for each operation. The combination of various systems for handling equipment operations are

In the **Quay Crane – Reach Stacker – Trailer System** the quay crane unloads the container from the ship to trailer which transports the container to the storage yard where the reach stacker is employed to unload the container and stack it to position. The reach stacker can stack up to maximum 5 container height. This kind of system is good for small port with less traffic as the investment and maintenance cost on the reach stacker and trailer system is comparatively low. The reach stackers can be further used for loading the containers on the trucks or rail transport system. Although there will be a huge requirement of manual operations the skill level required will be less. The port will need large area for the movement of the trailer this might take up space and lead to congestion at the loading and unloading areas due to manual operation.

Whereas in the **Quay Crane – Straddle Carrier System** the containers unloaded by quay crane is transported and stacked in the storage yard using straddle carrier. The advantage of this system is that there is no need of extra equipment for transportation from the ship side to storage yard. Straddle carriers can be used to stack up to 4 container height. The system is optimum for medium size ports. Since the Straddle carriers can be used for all the operations like loading/ unloading and transportation, the quay crane needs to stack the containers by the quay side and does not have to wait for the trailers to be loaded, this helps in the uninterrupted operation of the quay crane as the operation of the quay crane and straddle carriers are not dependent. The disadvantage of this system is the high initial cost, high maintenance cost of straddle carriers and the system is labour intensive compared to other automated systems.

In **Quay Crane – RTG Crane – Trailer System** the quay crane unloads the container onto a waiting trailer which transports the container to the storage yard and rubber tyred gantry crane is used to stack the containers. The RTG can stack up to 8 container height and can be used for long stacks. This method can be used in large container terminals to handle huge traffic volumes and RTG has the flexibility to transport the container from ship side to handling yard if required without the use of the trailer system, this reduces the dependency of quay crane on arrival of trailer and can just stack the containers up to 8 stack height for the RTG to transport it to the container to yard. The cost of RTG is comparatively less to RMG as they are generally smaller and lighter. The down side of this system is the road and pavements since the travel length of the RTG needs to be strengthened which will be an additional cost compared to the other systems and if the trailers are used there is a dependence of quay carne on the trailer and this method cannot be automated.

Quay Crane – RMG Crane – Trailer System is the same as the above discussed RTG – Trailer system, the only difference being the rubber mounted gantry crane is replaced by rail mounted gantry cranes. RMG's are bigger and can stack up to 12 containers wide and 7 containers high. They are more durable and have less maintenance cost than RTG and can be automated easily. The RMG's are not as flexible as the RTG as they move on rails hence care should be taken to arrange the layout properly to get the maximum utilization of space. This system is largely used when the staking yards are parallel to the quay. They are more expensive as there is an initial cost of laying the tracks.

Quay Crane – RMG Crane – AGV or Shuttle Carrier System uses the AGV or shuttle carriers to transport the container from the quay side the lifting area of the RMG. This system is used when the stacking yard is perpendicular to the quay. The automation of the system reduces the labour cost and makes the system highly productive. The system is less flexible due to automation and rail system of RMG. The system has very high initial cost and requires trained operators.

The requirement of quay crane can be determined by the thumb rule one quay crane per 80-100m of quay length. The number of quay cranes also affects the productivity of the berth and hence to improve the berth productivity one of the method used is to increase the number of quay cranes. But this has to be done only after looking into the traffic volume of the terminal or else will lead to ideal time of the equipment.

The selection of a particular system for handling the container from quay side to storage area depends on various factors like volume of containers that needs to be handled, cost of equipment, productivity of the equipment, area available for storage of container, stacking height, layout of the container storage yard, maintenance cost and port connectivity (road and rail). Table 3.2 gives a thumb rule for the requirement of various handling equipment per quay crane for the functioning of the container terminal.

Table 3.2 Requirement of Various Handling Equipment per Quay Crane [Handbook of Terminal Planning, Springer 2011(6)]

Equipment Type	Numbers required per Quay Crane
Reach Stacker	4
Tractor & Trailer	5
Straddle Carrier	5
RTG or RMG	2
Shuttle Carrier	3
AGV	6

3.8. Storage Yard Capacity Design

Storage facility in a port depends on the type of cargo that is being handled at the terminal. In a container terminal the storage capacity need to be planned for inbound and outbound laden containers and for empty containers which will need repositioning. In port area if there is an imbalance in incoming and outgoing laden containers with rate of higher incoming containers, such situation will lead to higher quantity of empty containers which will need to be repositioned. So while planning for storage yard facility the requirement of laden container and empty container should be studied separately to get a clear understanding and optimal utilization of the storage capacity.

Storage capacity planning is an important factor in container terminal facility as excessive storage area will lead to underutilization and will increase the cost of terminal facility, the port will have to invest on the soil strengthening in the storage area, on roads and pavements for the movement of equipments, whereas an insufficient storage area will lead to congestion of containers. While planning for the storage capacity the type of containers that will be handled and their volume should be taken into consideration. If there is requirement of special goods which need special treatment like containers with refrigeration facility and if the volume of this traffic is high special yards should be planned for this kind of containers facility. While planning for container yard calculation should be made for laden and empty separately

Storage yard capacity can be calculated using formula given by equation 3.27

$$C_s = \frac{S \text{ x } t_d \text{ x } P}{365} \qquad (3.27)$$

Where $S = C_q\,(1 - 0.5\,\mu)$ (3.28)

The TEU ground slots can be calculated by dividing the storage yard capacity C_s, by the maximum stacking height.

$$N_{TGS} = \frac{C_s}{\hat{h}} \qquad (3.29)$$

The storage yard capacity can be decreased by reducing the number of TEU ground slots or increasing the stack height but this depends on the stacking capacity of the storage yard equipment being used.

3.9 Dredging Design

3.9.1 Introduction

Dredging is the process of increasing the depth of the harbour to the design depth requirement. Dredging quantities depends on the design depth requirement which again is derived from the design ship size. Dredging is done in two stages first the capital dredging; this is done while developing a new port where the access channel or harbour depth deepening is required and is a onetime process, secondly the requirement of maintenance dredging is to address the problem of decrease in depth due to sedimentation. There are various types of dredging equipment and their selection depends on the type of soil condition in the harbour.

3.9.2 Type of Dredgers

Dredgers can broadly be classified based on the type of methods used for removing the dredged materials. On this basis these are classified as mechanical dredgers and hydraulic dredgers.

3.9.2.1 Mechanical Dredgers

Bucket dredger system is one of the oldest methods used for dredging. It is a chain of bucket fixed to a belt which while scraping the bottom of the sea bed will remove the materials. The materials are transported to a barge and dumped it. They are usually a rectangular pontoon with a central well in which heavy steel frame or ladder is suspended. The ladder supports an endless chain of buckets, each of which is equipped with a cutting edge. By rotating the bucket chain about flat-sided wheels (known as tumblers) at each end of the ladder, material can be loosened and transported. A small proportion of dredgers of this type are self-propelled. The propulsion machinery is used to move the vessel from site to site, but is not used in the extraction operation. The size of a bucket dredger is usually described by the capacity of the buckets. Bucket ladder dredgers are able to dredge almost any material up to the point where blasting is required, and if fitted with ripper teeth may even be directly able to dredge weak rock. Maximum dredging depths are normally around 20 m. Bucket ladder dredgers are complex and expensive machines to operate but can dredge to the required depth very accurately.

Grab dredger is a stationary dredger, moored on anchors. The dredging tool is a grab normally consisting of two half-shells operated by wires. The grab can be mounted on a dragline or on a hydraulic excavator of the backhoe type. The grab dredger is used in harbours and the dragline type are also used in deep water. The dredged material is loaded in barges. Grab dredgers, sometimes called clamshells, can be fitted on pontoon and self-propelled forms, the latter usually including a hopper within the vessel. The pontoon type grab dredger comprises of a rectangular pontoon on which a revolving crane equipped with a grab is mounted. The extraction operation consists of lowering the grab to the bottom, closing the grab, raising the filled grab to the surface and loading the contents into a barge or onto the adjoining bank. The size of this type of dredger is expressed in terms of the hopper capacity. The smaller vessels have a single crane, but some of the larger craft have up to four. Productivity depends upon crane, grab size, water depth and in the case of the self-propelled variety on the distance to the material relocation site. The grab is a relatively simple and inexpensive machine and performs best in consolidated silt, clays and loose sand, but the large, heavy versions are good for removing rubbish, old piles, rubble and similar obstructions. Grabs can also be used effectively for removing material from close to quay walls and in corners of docks and basins that are otherwise difficult to access. A basic grab dredger can be quickly and economically made from conventional land machines securely fixed to pontoons for short term adhoc tasks, but care needs to be taken to check stability.

Backhoe dredger is a stationary dredger, moored on anchors or on spud-poles. A spud is a large pole that can anchor a ship while allowing a rotating movement around the point of anchorage. Small backhoe dredgers can be track mounted and work from the banks of ditches. A backhoe dredger is a mechanical excavator equipped with a half open shell. This shell is filled moving towards the machine. Usually the dredged material is loaded in barges. This machine is mainly used in harbours and other shallow waters. Material is excavated using a bucket of size compatible with the in-situ strength of the material being dredged. The excavated material is either loaded into barges or placed ashore. This type of dredger, the dipper or face shovel, used a wire operated integral excavator and are very heavily built to allow for dredging of hard materials such as old masonry and unblasted rock. Production is dependent upon bucket size and the hardness of the material. Backhoe excavator is very efficient and has good vertical and horizontal control; carefully worked it will produce a smooth profile. Since the bucket is heavy and relatively rigid, care needs to be taken to avoid damage to quay walls and canal linings.

3.9.2.2 Hydraulic Dredgers

When deeper dredging is required hydraulic dredgers are recommended. They are even capable of dredging even up to a depth of 100 meters. The performance of dredger depends on the permeability of the material. These dredgers work on the principle that loosened material is raised from the bed through pipe system in a suspension state using pumps. If the materials are naturally in loose state, suction alone may be sufficient but harder materials may require loosening. These dredgers are most efficient while working with fine materials as they can be easily sucked up in suspension, coarser materials can also be worked on but the requirement on the power of the pump will be higher and when the surface is hard there will be requirement of loosening the materials and depending on this the dredgers are classified as cut suction dredger and hopper dredger

Cut suction dredger is a stationary hydraulic dredger which uses a cutter head to loosen the material and latter the materials are lifted using suction pump. The material is pumped using pipeline to the barge or shore. The cutter heads are removable type can be changed according to the material that needs to be dredged. The most common method is using a rotary cutter, the head of the pipe is fixed with the cutter head which is lowered and also supported by suction pipes. The loosened material enters the suction pipe mouth and passes through the pumps to the delivery line. A smooth bottom can be achieved using this method. These types of dredgers are able to achieve high output in good conditions. The loosened materials dredged can be disposed of to shore through pipeline. They are mostly used for new work dredging when reclamation of nearby land is required using this materials, the delivery pipeline can be laid at the channel bottom without obstructing the movement of other vessels or boats. Large heavy duty cutter dredgers have been successful in dredging some types of rocks. An alternative to the rotary cutter is using a bucket wheel cutter.

Hopper dredger is a self-propelled vessel which fills its hopper during dredging following a preset track. The hopper can be emptied by opening bottom doors or by pumping its load to the shore. The dredgers are good for use in open sea conditions. The hopper dredgers are designed as a conventional ship with a hull and operating without any mooring. The materials are lifted using pumps and loaded in to the hull. The suction pipes ends at drag head which have system for cutting like a water jet system, teeth's or other means of dredging the compacted materials. The drag head allows the material to flow to the suction pipe. It works like a floating vacuum cleaner. When the hull is filled the vessel moves to the disposal site where the door at the bottom of the hull which have doors are opened to deposit the dredged materials or the material can be pumped to shore using pumps. These vessels are difficult to use in confined spaces as the maneuverability is not efficient and are not recommended in close to quay and jetties. They are also not recommended on hard materials which will require a cutter dredger to loosen the material. This technique of dredging is mostly used for maintenance dredging, and new works when the bottom bed is of loose material and is ideal for reclamation projects.

3.9.3 Dredging Depth

The most important aspects while designing a dredging project is the characteristics of the material, the quantity and the rate of removal of the material to achieve the design depth of the project. The bore analysis will provide the characteristics of the sea bed and the depth is determined using the design ship as explained in section 3.6.3.3. Once the dredging depth is fixed the machine required to attain the dredging can be decided. The dredging depths are classified as,

Design depth which is the minimum depth that has to be attained during the dredging operation as per the design for the safe passage of the design ship.

Over depth, while dredging sometimes the dredger will have to excavate in excess, so as to attain the design depth this may be due to the uneven bottom profile, due to presence of rocks some time when the rocks are removed the depth might increase. It is in general practice to dredge more than the designed depth due to soil conditions and inaccuracies.

Paid/ allowable over depth is buffer depth which is planned while designing the depth requirements, to compensate the inaccuracies, uneven profile or presence of boulders. This is allowable over depth for which the dredger will be paid and hence is called the paid allowable over depth.

Non-pay over depth dredging is done outside the allowable/ paid over depth which may occur due to uncertain substrata, removal of boulders or other obstructions, due to the inaccuracy of the operator.

3.9.4 Dredging System Design

The requirements for designing a dredging system are estimate of the quantity to be excavated and nature of the material to be dredged out.

Estimation of Quantity – An accurate quantity of the material to dredge is important for the selection of the type of dredger to be used as this will decide the rate of dredging. For calculating the volume of material to be dredged the process to be followed are a demarcated plan of the area to be dredged should be prepared, the design depth requirement should be estimated at regular intervals, a contour survey should be done at regular intervals and a soil investigation report with lab testing showing the various layers of soil and depths.

Characteristics of material to be dredge – The physical, chemical and biological characteristics of the soil need to be investigated. The physical characteristics are important so as to fix the type of dredger that will be used. The chemical characteristics are important to decide the disposal of the materials and the biological investigation shows the impact on flora and fauna, toxicity and pollution level if any.

The two of the important stages of dredging are initially cutting or digging of the materials which depends on the characteristics of the sea bed and latter the disposal of the dredged materials which depends on the characteristics of materials and the place of disposal. The dredging processes cannot be accurately executed, and no dredger can excavate a perfect flat bottom so it is necessary for the planner to provide an allowance for these inaccuracies while fixing the depths of dredging. This inaccuracy depends on the type dredging equipments used, the soil condition of the sea bed which needs to be excavated and the physical condition of the harbour like tide, waves and sedimentation.

Another important point the planner should take into consideration while fixing the type of dredgers is the soil condition. The conditions during new work and maintenance dredging will be totally various. In case of new dredging the soil might be consolidated and hard and will sometime require blasting whereas during the maintenance dredging the soil will be relatively loose and new due to the sedimentation so a relatively easier and less expensive method can be employed. The soil strata can be classified as

Clay – fine-grained material or the fine-grained portion of soil that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air dried.

Silt (inorganic silt, rock flour) – material passing the No. 200 (75-µm) that is non-plastic or very slightly plastic and that exhibits little or no strength when air-dried.

Sand - particles of rock that will pass the No. 4 (4.75-mm) sieve and be retained on the No. 200 (75-µm).

Rock – natural solid mineral matter in large masses or fragments.

Glacial till (till) – material deposited by glaciations, usually composed of a wide range of particle sizes, which has not been subjected to the sorting action of water.

The dredging system design and selection of dredging equipment depends on the type of material to be dredged, the environment in which the dredging is to be done that is whether it is open sea or closed harbour condition and most importantly whether it is new work or maintenance dredging. Based on these the selection of dredging equipments has been classified with their characteristics and abilities the planner can select the dredging equipment from Table 3.3 & 3.4 which will satisfy required conditions.

This table has been prepared using the work condition as the main requirement viz., whether it is a new work or maintenance dredging. In new works the sea bed might be hard. Once the dredging is completed the sedimentation process and the type and the rate of sedimentation of the material that might be deposited in the sea bed should be studied before planning for method and frequency of maintenance dredging. Once the planner selects the work as new or maintenance the next question will be the condition of work be whether the dredging is to be done in open sea or harbour conditions. The selection of dredging equipment in both these conditions will differ as some of the equipments will not be able to have free mobility in the restricted harbour conditions due to the presence of various harbour structures. The further the classification are subdivided based on the type of soil condition as Rock/ consolidated/soft conditions the table also provides recommendation on the paid to non paid over depth ratio and the depth characterization of material which will help the planner to make the right decision. This Table also provides the expected accuracy of the machinery in the various conditions.

Tables no 3.3 Selection of Equipment for New Work Dredging

Dredging Condition	Material Type	Pay :Over Depth Ratio	Accuracy	Bottom Condition	Suggestion		Dredger Type.
					Recommendation	Material Charecterisation depth	
Open Sea	Consolidated	1:2	Poor	Uneven	Not Recommended due to high down time in rough sea.	Minimum of 6ft below required depth.	Mechanical
Open Sea	Consolidated	1:2.5	Morderate	Uneven	Tend to disturb consolidated materials several feet below than required depth	Minimum of 7ft below required depth.	Cutter Suction
Open Sea	Consolidated	2:1	good	Even	Not Recommended due to absence of mechanical power.	-	Hopper
Open Sea	Soft	1:2	poor	Uneven	Not Recommended due to high down time in rough sea.	Minimum of 6ft below required depth.	Mechanical
Open Sea	Soft	1:2.5	Morderate	Uneven	Disturb Materials 3ft more than required depth.	Minimum of 7ft below required depth.	Cutter Suction
Open Sea	Soft	2:1	Good	Even	Tend to disturb material 1 ft deeper than required depth	Minimum of 4ft below the required depth.	Hopper
Open Sea	Rock	1:2	Poor	Uneven	Not Recommended due to high down time in rough sea.	Minimum of 6ft below required depth.	Mechanical
Open Sea	Rock	1:2.5	Poor	Uneven	-	Minimum of 7ft below required depth.	Cutter Suction
Protected Harbour	Consolidated	1:2	Poor	Uneven	Highly Recommended in the Protected harbours.	Minimum of 6ft below required depth.	Mechanical
Protected Harbour	Consolidated	1:2.5	Morderate	Uneven	-	Minimum of 7ft below required depth.	Cutter Suction
Protected Harbour	Consolidated	2:1	Good	Even	Not Recommended due to absence of mechanical power.	-	Hopper
Protected Harbour	Soft	1:2	Good	Even	Highly Recommended in limited movement condition and close to structures.	Minimum of 6ft below required depth.	Mechanical
Protected Harbour	Soft	1:2.5	Good	Even	Disturb Materials 3ft more than required depth.	Minimum of 7ft below required depth.	Cutter Suction
Protected Harbour	Soft	2:1	Good	Uneven	Tend to disturb material 1 ft deeper than required depth	Minimum of 3ft below required depth.	Hopper
Protected Harbour	Rock	1:2	Moderate	Uneven	Highly Recommended	Minimum of 6ft below required depth.	Mechanical
Protected Harbour	Rock	1:2.5	Morderate	Uneven	-	Minimum of 7ft below required depth.	Cutter Suction

Tables no 3.4 Selection of Equipment for Maintenance Dredging

Dredging Conditions	Material Type	Pay : Non Pay Over Depth Ratio	Accuracy	Bottom Condition	Suggestion: Recommendation	Suggestion: Material Charecterisation depth	Dredger Type.
Open Sea	Consolidated	1:2	Poor	Uneven	Not Recommended due to high down time in rough sea.	Minimum of 6ft below required depth.	Mechanical
Open Sea	Consolidated	1:2.5	Moderate	Uneven	Tend to disturb consolidated materials several feet below than required depth	Minimum of 7ft below required depth.	Cutter Suction
Open Sea	Consolidated	2:1	Good	Even	Not Recommended due to absence of mechanical power.	-	Hopper
Open Sea	Soft	1:2	Poor	Uneven	Not Recommended due to high down time in rough sea.	Minimum of 6ft below required depth.	Mechanical
Open Sea	Soft	1:2.5	Moderate	Uneven	Will Disturb Materials to a larger depth than the required depth.	Minimum of 7ft below required depth.	Cutter Suction
Open Sea	Soft	2:1	Good	Uneven	Tend to disturb material 1 ft deeper than required depth	Minimum of 4ft below the required depth.	Hopper
Protected Harbour	Consolidated	1:2	Poor	Uneven	Highly Recommended in the Protected harbours.	Minimum of 6ft below required depth.	Mechanical
Protected Harbour	Consolidated	1:2.5	Moderate	Uneven	-	Minimum of 7ft below required depth.	Cutter Suction
Protected Harbour	Consolidated	2:1	Good	Even	Not Recommended due to absence of mechanical power.	-	Hopper
Protected Harbour	Soft	1:2	Moderate	Even	Highly Recommended in limited movement condition and close to structures.	Minimum of 6ft below required depth.	Mechanical
Protected Harbour	Soft	1:2.5	Good	Uneven	Will Disturb Materials to a larger depth than the required depth.	Minimum of 7ft below required depth.	Cutter Suction
Protected Harbour	Soft	2:1	Fair	Even	Tend to disturb material 1 ft deeper than required depth	Minimum of 1ft below the required depth.	Hopper

CHAPTER 4

GREEN PORT PLANNING

4.1 Introduction

Green and sustainable development of ports is a chance to utilize the natural resources more efficiently. The green port is a continuous process starting from the planning, design, execution and working stages. The port has to be reviewed at each of these stages to confirm that the green standards are maintained. Environment (protection) Act 1986 [EIAGM, 2009] has made it mandatory to obtain environmental clearance for scheduled projects and the ministry has also set some standards for all kind of projects.

Port and harbour developments are huge infrastructural developments which will have a direct impact on the surrounding environment. The impact of such developments will be there on air quality, water resources and marine environment. An EIA report has to be submitted to get such clearances. The environmental impact on the port ecosystem will be from ship movement and operations during the construction and functioning of the port. The construction and functioning of the port will affect the ecosystem. The air in the port area will be polluted and the quality would be reduced due to the increase in gases like SO_2, NOx, hydrocarbons and other hazardous gases. There will be climate change due to the change in atmospheric composition. The groundwater table will be disturbed due to the change in topography. The disposal of waste water into groundwater table without treatment will pollute the natural groundwater table. The environment will get polluted due to improper waste disposal; which may be construction, electronic or office waste. Dredging plays the most important part in creating a misbalance in the marine life of the port area. The marine flora, fauna and other biological life forms will be affected due to dredging and reclamation of the land, which in turn affects the ecosystem. But these should not be a reason to form a hindrance for huge development projects like port, shipyards and habour facility which will lead to the development of the country. The best way is to introduce methods by which losses to the ecosystem can be minimized and a sustainable development can be brought out. This is where the concept of green construction helps a planner to develop a huge infrastructural project as well as to show his responsibility towards the ecosystem and environment. The green construction should not be considered as a mandatory process to get clearance from the government bodies; but should be taken up as a responsibility of the engineer to not to disturb the ecosystem.

The introduction of a green rating system of project will be encouragement to the planner to self assess the project. The government should provide incentives to green projects in terms of reduction in taxes, levies or a special economic green zone status which will encourage others also to follow these measures. The use of energy conservation programs and power generation through renewable sources should be encouraged and rewarded. Conservation of ecosystem, environment and natural resources should be a moral responsibility of every designer and planner for having a healthier living environment.

4.2 Green Port Rating Parameters

The design and functioning of ports will affect the various components of the ecosystem, which have to be carefully studied and the remedial measures need to be taken for the better planning of a green port. Ministry of Environment & Forests, Government of India, has set up an Environmental Impact Assessment Guidance Manual for ports and harbours which will help the planners to design a green port and reduce the impact on the environment during the construction and operation of the port. These guidelines are used here to plan a green port. The parameters required for green rating are described under various subheadings and each parameter is further divided for assigning the weightage for ranking purpose.

4.2.1 Air Environment

The air quality will be the most affected during the construction and functioning of port. The quality of air is reduced by the emission of dust during construction and cargo handling, emission of gases from cargo handling equipment, ships, trucks and equipments used for construction purposes. Further there can be risks due to accidental leakage of gases from the hazardous cargo while being transported. The air borne pollution will have an immediate effect on the surrounding environment and on the people working in the port and living around the area. There should be proper air monitoring stations in the port to study the quality of air in the port area and proper measures should be taken so as the air quality is not affected due to the port functioning. EIA specifies the monitoring of the air environment for RSPM, nitrogen dioxide, sulphur dioxide, carbon monoxide, heavy metals and other harmful air pollutants. EIA lays down guidelines that the area up to 5km should be monitored and specific importance should be given to 1km from the boundary of the port project. EIA provides the air quality standards for the various parameters.

i. **Air Inventory Monitory System** - The most important aspect to have a cleaner air environment is to understand the present quality and quantity of pollutants in the air and continuous monitoring of the air quality. The green port should have an air inventory monitory system in place for handling the air quality aspects. Such a monitory system helps in identifying the source of pollution and once the source has been identified appropriate measures can be used to control the air pollution from the particular source. The air inventory management system can be studied by going through the architectural master plan of the port and checking for the presence of air monitoring stations, number of stations and distance between the stations and if proper records are maintained at these stations with specified periodical readings.

ii. **Ship Speed Reduction –** The ship's engine is the main source of pollution in the port area as fossil fuel is burnt to run the engine. By reducing the speed of the ship in the port area the load on the engine is reduced, which will lead to less fuel consumption, which in turn reduces the air pollution due to emission of hazardous gases from the burning of fossil fuel. The traffic control document needs to be checked, for the communication to various ships entering the port limits to reduce their speed to the specified limits to reduce the air pollution.

iii. **Shore Powering –** This is another method that the port can use to reduce the pollution from running of the ship engines. The ship will have power requirement to support various activities while at berth. The primary source of power for a ship is its engine. To reduce the use of fossil fuel to run the engine, the port can supply power produced from cleaner sources to the ship while it is at berth. This helps in controlling the pollution from the burning of fossil fuels. The port service manuals and power supply system to ship at the berth needs to be verified.

iv. **Equipment Repowering –** Replacing of equipments like Quay cranes, RTG, tug boats and pilot boats will be a costly solution to reduce the air pollution, which will not be viable for port economics. It is best to repower these older equipments with ecofriendly burning engines to meet the pollution standards. Equipment workshop maintenance policy and periodical maintenance register of the various equipments needs to scrutinized to understand the methodology used in the port.

v. **Equipment Replacement Program –** The ports should have an equipment replacement program which will phase out the older less efficient equipments with newer eco friendly equipments in a stage by stage procedure which will not be a financial burden to the port.

vi. **Retrofit Devices for Emission –** Equipments can also be retrofitted with emission control devices to reduce the pollution. This can be adopted on a temporary basis till the phasing out of the equipment after its life cycle, to be replaced by a newer one which will meet the pollution norms. Retrofitting equipments and vehicles with emission reduction devices is also a cost effective method towards a green port movement. The measure can be taken up by the port management by introducing low emission hydrographic port vessels fitted with NOx catalyzer and soot filters into service. Equipment Workshop maintenance policy, periodical maintenance register of the various equipments and emission certificate from pollution control board for the older equipment and vehicles have to be verified.

vii. **Hybrid/Electric Fleet Vehicles and Hybrid/Electric Yard Equipments –** The port should use hybrid diesel-electric equipment in the storage yards and as fleet vehicles. Hybrid vehicles reduce the burning of fuel and make less noise, hence reduce noise and air pollution. The electric power can be used when the power requirements are less; like when the yard equipment is transporting the cargo horizontally or when it is moving without load. When lifting operations are required, the need for more power arises and this leads to usage of diesel power. Similarly the fleet vehicles when loaded can use diesel engine and while moving empty containers or running without load can use electric power. Manual, suppliers invoice of the various fleet vehicles and equipment can be verified to confirm if the particular parameter is satisfied.

viii. **Clean Truck Program-** The port is always visited by outside trucks to bring in or take out containers. The port should lay down standards to truck operators and enforce clean truck program to reduce pollution from this source. Contract agreement with outside agencies about green commitment to reduce pollution and registers of checking if they are meeting the commitment in the contract.

ix. **Reduced Idling Program-** The port should have reduced idle time program which needs proper planning of the port operations. The equipments and fleet will not be used optimally while running idle engine which burns unwanted fuel without any output. Port traffic records and vehicle register at the gate and parking area can be verified to check for flow of traffic and congestions.

x. **Rail and Road Congestion Projects-** Traffic congestion always leads to burning of fuel without any output. The port should have Rail and Road congestion program to avoid such situation. This can be achieved by investing on the port rail and road infrastructure. The port should have a traffic control policy to check congestion at various points in the port area.

xi. **Use of Alternative Fuel like CNG/ Biodiesel and ULSD** - Replace the diesel and gasoline vehicles with hybrid or alternative fuel powered vehicles. Using cleaner burning fuels such as natural gas, propane, ultra low sulfur diesel and biodiesel reduces pollution. These are also cost effective methods than replacing the equipment. The fuel purchase invoices in the accounts department have to be scrutinized to confirm the purchase of alternative fuel like CNG, biodiesel and ULSD.

4.2.2 Climate Change

The reduction in air quality accounts to the climate changes in the local environment. Port development alone may not have an immediate effect on the climate but if precautions are not taken the future infrastructural development projects in the hinterland, operations and functioning of port may aid to the climate change. The carbon dioxide emitted from the various operations in the port mainly due to burning of the fossil fuels may lead to thicker green house gases in the air and which in turn leads to global warming and climate changes.

i. **Greenhouse Gas Inventory** – The development and later functioning of ports may lead to expulsion of green house gases which may add up to the climate change along with other reasons. To keep a check on this possibility the port should maintain a green house gas inventory. This is a method of accounting the greenhouse gases emitted to the environment and the quantity of such gases removed from the atmosphere due to reformed measures. This helps in identifying the sources of emission, taking corrective actions and tracking for future emission problems.

ii. **Carbon Footprint Calculation** - Another way of checking the climate change is the carbon footprint calculation which will help in keeping check all the processes to reduce the emission of carbon dioxide and other harmful gases.

iii. **Carbon Neutral Commitment** - The port management should also have a carbon neutral commitment which means trying to achieve net zero carbon emissions. This concept has to be extended to other green house gases like methane, nitrous oxide, hydroflurocarbons, sulphurhexafluoride and perfluorocarbons to achieve climate neutral commitment in the broader sense. The best ways of achieving this can be, through balancing carbon gases emitted by using renewable energies that will not produce carbon footprints, by carbon offsetting like planting trees or by funding projects which prevent the future green house emission.

iv. **Climate Change Risk Assessment** - The port management should also have a climate change risk assessment which will look in the future for any chances of climate changes due to the various operations in the port development.

v. **Operational Changes** – Once the port development starts and during the operational functioning of the port there should be a periodical check into the processes and the authorities should be altered of the risks, this will help the port authorities to take necessary steps to mitigate the risk.

The ports climate change check commitment and the various requirements to satisfy the green index parameter can be assessed by checking the greenhouse gas inventory register maintained at the port. Greenhouse gas and climate change policy document which will outline the various methods and procedures to be followed to check climate change. These documents can be used as a blue print to verify the various green parameters on climate change.

4.2.3 Water Quality

The fresh water requirement for the development of infrastructural project like port and harbour is enormous. Even after the commissioning of these projects there will be demand for fresh water of large quantities for various purposes such as cleaning, irrigation, in toilets etc. Water quality is an issue which needs to be dealt with equal seriousness for a green port management. The green port requirement suggests various methods to improve and maintain the water quality.

i. **Surface Water Infiltration Swales-** Rain water is a great source of natural fresh water. Most of the rain water is lost as storm water runoff. It happens when rain water flows over the ground surface, roads, pavement, driveways, rooftops which do not allow the infiltration of the rain water into the ground. Storm water should not be allowed to meet the water body instead should be filtered into the ground by using swales, drywells and pervious pavements. The landscaping plan and rainwater drain layout drawings should be verified to rate this parameter.

ii. **Pervious Pavements-** The port internal roads and pavements should be constructed of breathing materials which allows the rain water to seep through them and meet the ground water table and hence preventing the surface run off. The architectural plan and tender document showing the specification of materials to be used for the pavements have to be verified.

iii. **Cyclonic Devices, Filtering Devices and Oil/Water Separators-** Another important aspect of maintaining water quality is the disposal of waste water into the ground water. The waste water treatment depends on where the waste water has been generated from; domestic or industrial use. Depending on the impurities the waste water is treated for purification. Port can use oil/water separator, filter system, cyclonic devices, rain gardens and biofiltration. Once treated to the required level the water will be ready for reuse or can be discharged into the ground water. The waste water treatment report will give a clear idea of how the various kind of waste water depending on the type of impurities treated and devices used for the same.

iv. **Water Conservation Program-** The mantra of water conservation is water management system. The port should have a water conservation program which can be done by educating the port users and staff about the importance of conserving fresh water which is scarce and limiting the wastage of water in port. The water conservation program should also be aimed at controlling water pollution. The port should have a clearly laid out water conservation policy document specifying the duties and responsibilities of various agencies involved in the port functioning regarding water conservation.

v. **Plumbing and Irrigation Retrofits-** Water conservation can be achieved by using plumbing retrofits like sensor taps and automated plumbing system, which aid in reducing the water wastage. Similarly, the irrigation system should be fitted with retrofits to reduce water wastage and should also use innovative techniques like drip irrigation and planting of drought tolerant plants to reduce the consumption and wastage of water. The plumbing and irrigation material specification and the maintenance register have to be checked.

vi. **Ballast Water and Hull Fouling Program-** The water bodies in harbour also face threat of contamination from ballast water and hull fouling which the port has to keep a check on. The ballast water treatment will not be easy as the ship will have to discharge the ballast water at a very high rate when the unloading is going on, and the treatment at the same rate will not be easy. So the port will have to encourage the use of segregated ballast tank to reduce the contamination from cargoes like oil and other toxic materials. The hull fouling also leads to changes in the aquatic life of the harbour. The port should have proper program for inspection of hulls for foreign organisms which will affect the flora and fauna of the harbour. The ship's wastewater treatment program and methods employed have to be studied.

4.2.4 Waste Management

The probable wastes that can be generated during operations of a port are decomposable food waste, construction debris, waste from repair of vehicles and machineries and electronic waste. The port should have separate programs for disposal, recycling, reuse and reduction of waste from each of these operations. The ports should follow a reduce-reuse-recycle system to provide a green and sustainable development program.

i. **Port Recycling Program-** Waste management can be achieved through the study of generation, segregation, minimization, treatment, recycling, reuse and reducing of the waste. The port should have a program for recycling, reuse and reduction of wastes like paper, glass and construction byproducts. The port should publish guidelines to the users and staffs on how to manage the waste. They should have a program for segregated disposal of waste and an efficient collecting system. The port should have separate programs for office, mechanical, construction and electronic waste management.

ii. **Office Waste Management Program –** The office waste management starts with educating the staff on how to identify the waste and segregating them. A proper guideline should be established on segregation and collection system of the office waste. The dustbin should be colour coded starting from green to red. The staff should segregate the recyclable waste into the green and the hazardous ones into the red bin. A list of all possible disposable office waste with their categorization with colour code should be circulated among the staff.

iii. **Mechanical Waste Management Program-** The mechanical waste is generated from the workshops. The mechanics and workshop managers should be trained on the waste management program about the nature of waste and categorization the philosophy of recycle reduce and reuse of spare parts should be practiced.

iv. **Construction Waste Management Program-** The port should have a clear plan laid down for the waste generated from construction process. The waste can be generated during a new construction or while demolishing of an existing facility for upgradation. Before demolishing existing structure the component materials should be studied and a list of such parts should be made. The waste should be classified as recyclable, reusable and hazardous. The building should be dismantled to the smallest reusable component and then the remaining should be demolished.

v. **Electronic Waste Management Program-** The electronic waste is the biggest problem faced by any organization. The fast upgradation of software and hardware makes the existing parts unusable. The port should have a high level program for electronic waste management. The machines which are replaced should be used for less important work. The part of the machines being dismantled should be stored to repair other machines, the port can also donate used computer to educational institutions, NGO's and other such organizations.

vi. **Participation in Hinterland Waste Management Program-** As being a part of the surrounding hinterland the port can initiate drives to educate the people about the waste management program. The port should also take part in the hinterland waste management program. The port staff can conduct training in societies and owners associations and educate people of waste management and environmental commitment.

The port should have a clear laid down policy regarding the waste management program on how it proposes to handle the various waste like office, machinery, and construction and electronic. The waste management policies should be planned on the principles of recycling, reuse and reduce. The policy document should have the methods of collection, waste management program and safe disposal program. This policy document will be the base of judging the green index based on waste management.

4.2.5 Dredging

i. **Planned Reuse of Dredged Materials** - In the initial dredging operation the quantity of dredge materials will be huge and generally the disposal of these materials will have to be planned in advance. At some instances the dredged materials might be contaminated. The dredging operations and disposal of dredged materials have to be studied and planned extensively or there may be threats to the water quality, flora and fauna, and might be hazardous to the environment. The timing of the dredging operations should also be planned as not to affect the marine ecosystem. Hence, the testing of the material to be dredged becomes important. After testing and obtaining the required clearances, the dredged materials can be reused for filling areas to be reclaimed for the port use, or hinterland areas which are undergoing development. The beneficial and innovative reuse of the dredged material should be planned. The materials should be filled in the nearby areas as far as possible so as to reduce the carbon footprint due to the transportation of these materials. The tender document for new work and maintenance dredging will specify how the port plans to dispose the dredged soil or materials. This can be used for the validation of green index.

ii. **Sediment Suspension System** - The maintenance dredging happens due to the settlement of materials which move into the harbour channels due to the water current. Using of innovative methods like water jets laid at bottom of the bed keeps the materials suspended and prevents them from settling down. This will help in reducing the maintenance dredging.

4.2.6 Energy Conservation and Renewable Energy

The port construction and functioning have a huge energy requirement. To achieve a green port, the planner should promote the use of renewable energy, which will also help in reducing the carbon footprint caused during the development of the project.

i. **Solar and Wind Energy Production –** The port should invest on generating renewable energy like solar farms, wind turbines or install plants to convert organic waste into biofuel. Even if the conventional electricity or fuel cannot be replaced by this kind of renewable energy, the port should have a specific plan about the use of this kind of energy from renewable sources, and should slowly replace energy produced from fossil fuels wherever possible. The architectural plan showing areas for installation of solar and wind energy devices, the purchase invoices of equipment to generate renewable energy have to be verified before awarding points.

ii. **Purchase of Renewable Energy –** If the port cannot invest on this kind of renewable sources initially, as a positive step towards energy conservation the port should purchase renewable electric energy from the local supplier encouraging them to invest on solar and wind energy. The purchase invoice should be scrutinized to understand the type of energy being supplied.

iii. **Energy Audits-** The port should have energy audits as a broader outlook towards energy conservation and to be responsible towards its environmental commitment. The energy audit policy and reports will form the base of awarding rating to this parameter.

iv. **Lighting Replacement Program** – The production of renewable energy is a huge investment, but the port can take small step towards developing a culture of energy conservation by replacing the inefficient lighting system with an energy efficient system; like replacing the bulbs with LED bulbs, using solar powered street and terminal lighting system. The electrical maintenance register and purchase bills of light fittings have to be checked.

4.2.7 Natural Resources

The area identified for port development will be mostly in an environmental sensitive zone. The construction of port will be in green field area and will involve reclamation of water bodies. The natural resources like land, fresh water bodies, local flora and fauna all will be affected during the development of the port.

i. **Natural Resource Team** – The port, as a commitment towards the protection of the natural resources of the hinterland and port area, should set a team to study the local eco system and find out what will be the effect on these resources due to the development of the port.

ii. **Specific Approach to Problems** - The environmental problems faced by each port will be various and the cause of these developments will also be case specific. The port will have to understand the source of the problem and develop a solution for each case. The port needs to have a case by case approach for handling the natural resources. A general approach or set programs will not be sufficient to handle the natural resources issues. Hence this emphasizes the need of a natural resources team during the development stages and later during the operational stage.

iii. **Wetland Mitigation** - The port should have a wetland mitigation banking program, which is for the preservation, creation, enhancement and conservation of ecosystem which has been disturbed by the development of port or any such project in the local area. The port can develop an ecosystem conservation area which will compensate the damages caused to the ecosystem due to the construction activities for the development of the port.

iv. **Participation in Local Program** - The port should take initiative to participate in various programs implemented by the local authorities for the natural resource preservation. The port is the part of the local ecosystem. It should work in partnership with the local authorities for the forest preservation, development of green belt, protection of fresh water sources and shoreline protection programs, which will ensure a long term sustainable development of the hinterland and safe guard its natural resources.

v. **Protection of Endangered Species -** The port can also take part and fund in programs like promoting the protection of the endangered species in the local area of both plants and animals. This will show the social commitment of the port towards the natural environment of the hinterland.

vi. **Invasive Species Program -** Another issue which will threaten the local natural eco system of flora and fauna is the invasive species which enter the port through haul fouling. The foreign species might threaten the existence of the local species. The port should have program to check such dangerous invasive species as a commitment to the local ecosystem.

The port should have a natural resource policy laid down, identifying the endangered species in the local hinterland. The policy should broadly mention the steps and measures the port will take to address the problem of natural resource conservation. This policy document will be the base of awarding the green index for this parameter.

4.2.8 Green Construction

The port development has huge and wide range of requirement of materials for construction of various components. The construction components of ports are breakwaters, quays and wharves, road network, administrative buildings, storage area sheds and godowns. The materials requirement range from raw materials like cement, structural steel, fine and coarse aggregates, rubble, wooden sections and finished products like paving tiles, flooring materials, natural stones, plumbing and electrification materials, glass, roofing sheets etc. At the design stage itself the designer should set certain guidelines for green construction.

i. **Use of Recycled Materials** – While planning a green port the designer should use modern construction technology like promoting use of recycled materials, hence reducing the use of new materials which in turn will reduce the carbon footprint from the process of manufacturing of new material.

ii. **Reuse of Materials** - The reuse of materials from existing building whereever possible should be encouraged. Demolished building waste or dredged material from the port can be used for filling, there by promoting the reuse of materials. To what extent the materials can be reused has been emphasized in Vieira and Gireli (2012).

iii. **Purchase of Reusable Furniture** - The purchase of reused furniture for office use is a good idea towards green construction.

iv. **Minimum Use of PVC Products** - The use of PVC should be avoided wherever possible as PVC is not recyclable and not considered as a green material.

v. **Promote Green Certified Manufacturers** - If new materials are purchased the specification should insist the requirement of meeting green norms during production. The manufacturer with green certification should be promoted for procuring materials.

vi. **Use of Low Maintenance Materials** – The planner should study the maintenance requirement of the materials used in various components of the construction and should give high rating to materials which have low maintenance cost.

vii. **Use of Locally Available Materials** - The local products should be promoted so as to reduce the transportation requirement which will save the fuel burning and will have minimum carbon footprints.

viii. **Study of Recyclability and Reuse of Components Used** - While designing building the recyclability of the construction materials should be studied and such materials should be used in practice.

ix. **Use of Low VOC Paints –** Promote the use of low VOC paints. Avoid the use of asbestos and materials which use synthetic mineral fibers.

x. **Natural Air Circulation System / Maximum Natural Ventilation** - Other important factors which will help in reducing the use of electricity, is planning the working area giving maximum emphasis on natural ventilation. Provide windows and opening to maximize day light and reduce the use of artificial lighting during day time. Proper air circulation system should be provided to control the humidity to reduce the use of air conditioning and artificial climate control system.

xi. **Indoor Plants in Working Space** – Provide indoor plants in the working space to circulate the carbon dioxide and hence reducing the requirement of artificial air circulation system.

xii. **Use of Non Chemical Cleaning Agents** – The use of cleaning agents with toxic chemical contents should be discouraged and non chemical materials should be promoted.

The tender document will give specifications of type of materials that have to be used along with the quality, green rating requirement of the product and the material supplier. This can be used as the base for providing rating to parameters regarding the use of materials like recyclable or reusable materials. The architectural plan of buildings will have to be verified to check if sufficient natural ventilation has been provided.

4.2.9 Public and Staff Transport

The problem of pollution from public and staff vehicle is one of the reasons to reduce the air quality in the port area. The port vehicle's pollution can be controlled by retrofitting or using cleaner fuel but this cannot be imposed on staff or public using the port facility. The pollution from the vehicles that visit the port should also be addressed to reduce the carbon footprints or global warming due to gases emitted from burning of fossil fuel.

i. **Bicycle Lanes with Proper Connectivity** - The port should restrict the use of private vehicles and promote the use of bicycles. The port should provide proper bicycle lanes connecting the various facilities and buildings in the port. The port should provide bicycle at the entrance so that the employees can use public transport up to the gate and then use the bicycle provided by the port inside the facility. The architectural layout showing the internal roads and connectivity to various parts of the port will have to be checked to see if special lanes are provided for bicycling other than the main roads.

ii. **Facility like Storage, Changing and Shower for Cyclist** – To promote the use of cycle the port should provide facilities like storage space for cycles, locker facility, changing room and shower room to the cyclist to freshen up as cycling will lead to sweating and the employees will complaint on hygiene issue in the working environment. The provisions can be verified from the architectural plan.

iii. **Employee Pickup System** – The port should provide bus pick up facility to the port employee thereby discouraging them from using their own vehicles. Every establishment will have a transportation department which clearly lays down policies regarding the employee transportation. The various modes may be having own fleet of vehicles to pick up the employees or contracting outside private vehicles.

iv. **Car Pooling System** - The port should encourage the car pooling program among its employees and limit the car parking space inside the port facility or provide car parking at a far distance which will discourage the employees as they will have to walk a long distance from the car park to their work place, thereby forcing them to make use of public transport system provided by the port. The staff transportation policies will have program regarding carpooling system employed by the port. The port can also develop a mobile application for car pooling which will help the employees in the same route to communicate with each other.

v. **Transport Facility to Nearby Public Transport System** – The port should provide bus connectivity to nearby public transport system like railway stations, metro stations and bus stands at regular intervals. The port can also arrange pickup and drop facilities to employees from the nearby public transport facility. The transport policies regarding the employee pick up and drop point needs to be verified.

vi. **Video Conferencing for Meetings** - At a higher level the port can reduce the business travels of staff within the facility and outside by providing facilities like videoconferencing and thereby reduce the carbon footprint due to vehicle operations. In addition the port will make monitory gains due to reduced travelling and the absence due to business travel can be reduced. The architectural plan should be verified to see if special areas are provided for video conferencing and the tender for supply for these equipments can also be used as a base for the awarding green rating to this parameter.

vii. **Proper Lane and Gate Facility to Reduce Idling** - The port should also provide enough traffic lanes to avoid traffic congestion and idling of vehicles at the gate and inside the facility. The gate register needs to be verified to check for congestion.

4.2.10 Green Zone

The development of port may result in deforesting and converting of green field for the construction of the facility. This has to be compensated to maintain balance in the ecosystem. The port planner should promote planting of trees and provide landscaped gardens wherever possible in the port facility which will give a good working environment as well as help in reducing pollution and global warming.

i. **Green Belt Development Program** – The port should have a green belt development program involving the support of the local authorities and people. The port architectural zoning layout should be verified to see if green belts are provided as special zone around the port as well as the landscaping inside the port like providing special recreational parks.

ii. **Plant a Tree Program** - The port should have a plant a tree program for the employees so as to bring in an environmental commitment. The port green belt development policy and the staff welfare policy document will have to be verified regarding the plant a tree program. The plant a tree program will help the staff to be a part of the green drive.

iii. **Use of Recycled Materials / Reused Materials for Landscape** – Wherever possible the planner should use recyclable and reused material for landscaping. The use of environmental friendly products in the landscape like watering systems, reused paving or walking stones, untreated timber and reused or recycled benches in the park should be encouraged. The use of chemical or poisonous pesticides should be banned and natural and organic products should be promoted. The tender document for landscaping materials will have clear guidelines of quality, type and green rating of materials to be purchased for landscaping works. This can be verified for providing ratings.

iv. **Revival of Endangered Local Species** - The landscape should be done as far as possible with the local native species as they will be used to the climate and water requirement and will not need any special systems there by supporting the green cause of reducing carbon footprints. The landscape should try to incorporate the endangered local flora in the design so as to reviving the species. The architectural landscaping plan and the tender document for landscaping or gardening contract can be verified to find out the type of trees that are proposed to be used for landscaping purpose.

v. **Landscaping without cutting down existing trees** - The landscaping should not be done by cutting down the existing trees but by incorporating them into the design. The initial land survey document will have the positions of trees marked on it. This has to be verified with the proposed architectural and landscaping plan, to find out how many of the existing trees are saved after the port development.

While rating the port on the above said parameters the user should verify the documents corresponding to each parameter before awarding the points. Table 4.1 lists the documents to be verified for various criteria and this document should be maintained by the port as a base of green port rating requirement.

Table 4.1 Documents to be Verified for Various Green Rating Criteria

Sl.No.	**Green Rating Criteria**	**Document to be Verified**
1	**Air quality Maintenance Measures**	
1.1	Air Inventory Monitoring	Architectural Master Plan and Air Monitoring Registers
1.2	Ship Speed Reduction Program	Traffic Control Document
1.3	Shore Powering of Ships	Port Service Manuals and Power Supply System to ships.
1.4	Equipment Repowering	Equipment Workshop Maintenance Policy and Periodical Maintenance Register
1.5	Equipment Replacement Program	Equipment Workshop Maintenance Policy
1.6	Retrofit Devices for Emission	Equipment Workshop Maintenance Policy,

Sl.No.	Green Rating Criteria	Document to be Verified
		Periodical Maintenance Register and Emission Certificate from Pollution Control Board
1.7	Hybrid / Electric Fleet Vehicles	Vehicle Manuals and Suppliers Invoice
1.8	Hybrid / Electric Yard Equipments	Vehicle Manuals and Suppliers Invoice
1.9	Clean Truck Program	Contract Agreement with outside agencies about green commitment
1.10	Reduced Idling Program	Port Traffic Records and Registers at gate and Parking area.
1.11	Rail and Road Congestion Projects	Traffic Control Policy
1.12	Use of alternative fuel Like CNG , Biodiesel or USLD	Fuel Purchase Invoice
2	**Climate Change**	
2.1	Greenhouse Gas Inventory	greenhouse gas inventory register maintained at port, greenhouse gas and climate change policy document
2.2	Carbon Foot Print Calculation	
2.3	Carbon Neutral Commitment	
2.4	Climate Change Risk Assessment	
2.5	Operational Changes Program	
3	**Water Quality**	
3.1	Surface Water Infiltration Swales	Landscaping Plan and Rainwater Drain Layout Drawings
3.2	Pervious Pavements	Architectural Plan and Tender Document
3.3	Cyclonic Devices	Waste Water Treatment Report
3.4	Filtering Devices	Waste Water Treatment Report
3.5	Oil / Water Separators	Waste Water Treatment Report
3.6	Water Conservation Program	Water Conservation Policy Document
3.7	Plumbing and Irrigation Retrofits	Plumbing and Irrigation Material Specification and Maintenance Register
3.8	Ballast Water and Hull Fouiling Program	Ship Waste Water Treatment Program and Methods Employed
4	**Solid Waste Management**	
4.1	Port Recycling Program	Solid Waste Management

Sl.No.	Green Rating Criteria	Document to be Verified
4.2	Office Waste Management Program	Policy Documents
4.3	Mechanical Waste Management Program	
4.4	Construction Waste Management Program	
4.5	Electronic Waste Management Program	
4.6	Participation in Hinterland Waste Management Program	
5	**Dredging**	
5.1	Planned Reuse of Materials	Dredging Plan and Dredging Tender Documents
5.2	Sediment Suspension Systems	
6	**Energy Conservation**	
6.1	Solar and Wind Energy Production	Architectural Plan and Purchase Invoices of Equipment
6.2	Purchase of Renewable Energy	Purchase Invoice
6.3	Energy Audits	Energy Audit Policy and Reports
6.4	Lighting Replacement Program	Electrical Equipments Maintenance Register and Purchase Bills of Light Fittings
7	**Natural Resource Protection**	
7.1	Natural Resource Team	
7.2	Specific Approach to Problems	
7.3	Wetland Mitigation	
7.4	Participation in Local Program	Natural Resource Conservation Policy Document
7.5	Protection of Endangered Species	
7.6	Invasive Species Program	
8	**Green Construction**	
8.1	Use of Recycled Materials	Tender Documents
8.2	Use of Reused Materials	
8.3	Purchase of Reusable Furniture's	
8.4	Minimum Use of PVC Products	
8.5	Promote Green Certified Manufactures	
8.6	Use of Low Maintenance Materials	
8.7	Use of Locally Available Materials	
8.8	Study of Recyclability and Reuse of Components Used	

Sl.No.	Green Rating Criteria	Document to be Verified
8.9	Use of Low VOC Paints	
8.10	Natural Air Circulation System	
8.11	Maximum Natural Ventilation	
8.12	Indoor Plants in Workspace	Architectural Plan
8.13	Use of Non Chemical Cleaning Agents	
9	**Public and Staff Transport**	
9.1	Bicycle Lanes with Proper Connectivity	
9.2	Facility like Storage, Changing and Shower for Cyclist	Architectural Plan and Layout
9.3	Employee Pick Up System	
9.4	Car Pooling System	
9.5	Transport Facility to Nearby Public Transport Systems	Employee Transportation Policy Document
9.6	Video conferencing for Meetings	Architectural Plan and Tender Document for Supply of Video Conferencing Equipments.
9.7	Proper Lane and Gate Facility to Reduce Idling	Entry Register at Gate
10	**Green Zone**	
10.1	Green Belt Development Program	Architectural Zoning Layout
10.2	Plant a Tree Program For Employees	Port Green Belt Development Policy Document and Staff Welfare Policy Document
10.3	Use of Recycled Materials in Landscape	Tender Document for supply of landscaping materials
10.4	Use of Reused Materials	
10.5	Revival of Endangered Local Species	Architectural Landscaping Plan and Tender Document for landscaping or gardening contract
10.6	Landscaping Without Cutting Down Existing Trees	Initial Land Survey Document and Architectural Landscaping Plan

4.3 Green Rating System

The green rating system to rank a port and harbour infrastructural development is developed based on the above described parameters. The main criteria are namely air quality, climate change, water quality, waste management, dredging, energy conservation, natural resource protection, green construction, public and staff transport and green zone are given weightage according to the magnitude of impact it will cause to the environment. The total rating point is defined as 100 and the points are allocated to each of the main criteria depending on the weightages allocated. For example if the weightage allocated to air quality is 20% then the points for this section is calculated as (20/100) x 100 which is 20 points. Similarly the points of each of the section are calculated to arrive at the section points all adding up to 100. The weightages and arrived points are shown in Table 4.2

Table 4.2 Weightage and Points Allocated to Each Parameter

Sl.No.	Criteria	Weightage (%)	Points
1	Air quality Maintenance Measures	20	20
2	Climate Change	15	15
3	Water Quality	10	10
4	Solid Waste Management	10	10
5	Dredging	5	5
6	Energy Conservation	10	10
7	Natural Resource Protection	5	5
8	Green Construction	15	15
9	Public and Staff Transport	5	5
10	Green Zone	5	5
	Total	100	100

Each section is further divided in to actual green parameters based on which the port's green port ranking is decided. The design of the green rating system is a questionnaire which consists of implementation of green concepts which will improve the green rating of the project. The user will have to answer in simple yes/no depending on whether the particular criteria are implemented. Each question in the section are given weightage totaling to 100 per section and the points are calculated as explained earlier on the total point of the particular section and these questions are the actual parameters which will judge the green index of the port. The details of individual weightage and per question points are shown in Table 4.3

Table 4.3 Weightage and Points Allocated to Green Port Parameters

Sl.No.	Green Rating Criteria	Weightage (%)	Points
1	**Air quality Maintenance Measures**	**20**	**20**
1.1	Air Inventory Monitoring	25	5
1.2	Ship Speed Reduction Program	15	3
1.3	Shore Powering of Ships	15	3
1.4	Equipment Repowering	5	1
1.5	Equipment Replacement Program	5	1
1.6	Retrofit Devices for Emission	5	1
1.7	Hybrid / Electric Fleet Vehicles	5	1
1.8	Hybrid / Electric Yard Equipments	5	1
1.9	Clean Truck Program	5	1
1.10	Reduced Idling Program	5	1
1.11	Rail and Road Congestion Projects	5	1
1.12	Use of alternative fuel Like CNG , Biodiesel or ULSD	5	1
	Section Total Points.		**20**
2	**Climate Change**	**15**	**15**
2.1	Green House Gas Inventory	25	3.75
2.2	Carbon Foot Print Calculation	25	3.75
2.3	Carbon Neutral Commitment	20	3
2.4	Climate Change Risk Assessment	15	2.25
2.5	Operational Changes Program	15	2.25
	Section Total Points.		**15**
3	**Water Quality**	**10**	**10**
3.1	Surface Water Infiltration Swales	20	2
3.2	Pervious Pavements	20	2
3.3	Cyclonic Devices	10	1
3.4	Filtering Devices	10	1
3.5	Oil / Water Separators	10	1
3.6	Water Conservation Program	10	1
3.7	Plumbing and Irrigation Retrofits	10	1

Sl.No.	Green Rating Criteria	Weightage (%)	Points
3.8	Ballast Water and Hull Fouiling Program	10	1
	Section Total Points.		**10**
4	**Solid Waste Management**	**10**	**10**
4.1	Port Recycling Program	30	3
4.2	Office Waste Management Program	15	1.5
4.3	Mechanical Waste Management Program	15	1.5
4.4	Construction Waste Management Program	15	1.5
4.5	Electronic Waste Management Program	15	1.5
4.6	Participation in Hinterland Waste Management Program	10	1
	Section Total Points.		**10**
5	**Dredging**	**5**	**5**
5.1	Planned Reuse of Materials	80	4
5.2	Sediment Suspension Systems	20	1
	Section Total Points.		**5**
6	**Energy Conservation**	**10**	**10**
6.1	Solar and Wind Energy Production	60	6
6.2	Purchase of Renewable Energy	15	1.5
6.3	Energy Audits	15	1.5
6.4	Lighting Replacement Program	10	1
	Section Total Points.		**10**
7	**Natural Resource Protection**	**5**	**5**
7.1	Natural Resource Team	25	1.25
7.2	Specific Approach to Problems	10	0.5
7.3	Wetland Mitigation	20	1
7.4	Participation in Local Program	10	0.5
7.5	Protection of Endangered Species	20	1
7.6	Invasive Species Program	15	0.75
	Section Total Points.	100	**5**
8	**Green Construction**	**15**	**15**
8.1	Use of Recycled Materials	15	2.25
8.2	Reuse of Materials	10	1.5
8.3	Purchase of Reusable Furniture	5	0.75
8.4	Minimum Use of PVC Products	10	1.5
8.5	Promote Green Certified Manufactures	5	0.75
8.6	Use of Low Maintenance Materials	5	0.75
8.7	Use of Locally Available Materials	10	1.5
8.8	Study of Recyclability and Reuse of Components Used	5	0.75
8.9	Use of Low VOC Paints	5	0.75
8.10	Natural Air Circulation System	10	1.5

Sl.No.	Green Rating Criteria	Weightage (%)	Points
8.11	Maximum Natural Ventilation	10	1.5
8.12	Indoor Plants in Workspace	5	0.75
8.13	Use of Non Chemical Cleaning Agents	5	0.75
	Section Total Points.		**15**
9	**Public and Staff Transport.**	**5**	**5**
9.1	Bicycle Lanes with Proper Connectivity.	15	0.75
9.2	Facility like Storage, Changing and Shower for Cyclist.	10	0.5
9.3	Employee Pick Up System.	15	0.75
9.4	Car Pooling System.	15	0.75
9.5	Transport Facility to Nearby Public Transport Systems.	15	0.75
9.6	Videoconferencing for Meetings.	15	0.75
9.7	Proper Lane and Gate Facility to Reduce Idling.	15	0.75
	Section Total Points.		**5**
10	**Green Zone.**	**5**	**5**
10.1	Green Belt Development Program.	25	1.25
10.2	Plant a Tree Program For Employees.	15	0.75
10.3	Use of Recycled Materials in Landscape.	15	0.75
10.4	Use of Reused Materials.	15	0.75
10.5	Revival of Endangered Local Species.	15	0.75
10.6	Landscaping Without Cutting Down Existing Trees.	15	0.75
	Section Total Points.		**5**
	Total Green Rating Points		**100**

The points are awarded depending on the yes/no answer to each question. If the parameter is satisfied total points of the said parameter are awarded. If not the point awarded is zero. The sectional total is calculated and percentage points of each section is calculated depending on the points gained in each section and is rated as Excellent, Good, Moderate and Poor. Similarly a colour coding system is also provided based on the sectional percentage ranging from Green, Yellow, Orange and Red respectively to the rating system. Apart from the sectional percentage a total percentage is also calculated to rate the port in the same way as the sectional rating. The rating system and the colour coding based on the percentage points are explained in Table 4.4. The individual sectional rating helps in identifying which area or parameter needs to be improved to get an overall higher rating for the project.

Table 4.4 Rating and Colour Code System

Points	Colour Code	Comment
Below 25%	Red	Poor
Between 26% to 50%	Orange	Moderate
Between 51% to 75%	Yellow	Good
Between 76% to100%	Green	Excellent

For the evaluation of the various criteria of port a questionnaire has been developed in a simple yes or no format as shown in Table 4.5 Questionnaire for Green Data Collection. The questions are developed corresponding to various parameters as described in Table 4.3. The answers to each question have to be answered as yes or no after verifying the relevant document to the corresponding section as presented in Table 4.1.

Table 4.5 Questionnaire for Green Data Collection

Sl.No.	Question	Yes	No
1	**Air Quality Maintenance Measures**		
1.1	Does the port have air monitoring stations for testing air quality?		
1.2	Are the ships entering the port asked to reduce the speed to attain better air quality?		
1.3	Are the ships at berth supplied power from the sources on shore?		
1.4	Does the port maintenance department follow an Equipment repowering program for heavy equipment for making them eco friendly?		
1.5	Does the port have an equipment replacement program to replace the existing older and less efficient equipment with eco friendly equipment?		
1.6	Are the existing non eco friendly equipment retrofitted with devices to meet the pollution standards?		
1.7	Does port have hybrid/electric fleet vehicles?		
1.8	Does port have hybrid/electric Yard Equipments?		
1.9	Does the port have a clean truck program for the trucks entering the port?		
1.1	Does the port have any specific program/schedule to reduce idling time for the various equipments and vehicles?		
1.11	Does the port have any specific scheduling program to reduce rail and road congestion inside the port area?		
1.12	Does the port use alternative fuel like CNG/ biodiesel and USLD?		
2	**Climate Change**		
2.1	Does the port maintain and check green house gas inventory?		
2.2	Does the port calculate the carbon footprints caused by the various port operations?		
2.3	Does the port follow a carbon neutral commitment by offsetting for the carbon footprints caused by the port operations?		
2.4	Does the port have a climate change risk assessment program?		
2.5	Does the port have regular checks to assess the climate change risk caused due to the various operations and does the port make any corrective measures?		

Sl.No.	Question	Yes	No
3	**Water Quality**		
3.1	Does the rain water and surface runoff water made to filter into the ground water table using infiltration swales or any other methods?		
3.2	Does the port have pervious pavement to let the rain water filter into the ground water?		
3.3	Does the port use cyclonic devices to improve water quality?		
3.4	Does the port use filtering devices to improve water quality?		
3.5	Does the port have oil/water separator to improve water quality?		
3.6	Does the port have a water conservation program?		
3.7	Does the port maintenance division use plumbing and irrigation retrofits to conserve water?		
3.8	Does the port have a ballast water treatment and haul fouling program to keep in check water contamination from ship waste water?		
4	**Waste Management**		
4.1	Does the port have an in house recycling program?		
4.2	Does the port have an office waste management program?		
4.3	Does the port have a mechanical waste management program?		
4.4	Does the port have a construction waste management program?		
4.5	Does the port have an electronic waste management program?		
4.6	Does the port participate in the hinterland waste management program?		
5	**Dredging**		
5.1	Does the port have a program to make planned reuse of dredging material?		
5.2	Does the port have a sediment suspension system to avoid settlement of materials?		
6	**Energy Conservation and Renewable Energy**		
6.1	Has the port invested in producing solar or wind energy?		
6.2	Does the port purchase energy from		

Sl.No.	Question	Yes	No
	renewable sources?		
6.3	Does the port have energy audits?		
6.4	Does the port have lighting replacement program to replace the existing low efficient system with LED lights?		
7	**Natural Resources**		
7.1	Does the port have a natural resource team to study the effect on the natural resources due to the operation of port?		
7.2	Does the port follow a problem specific approach while handling the various issues to natural resources due to port functioning?		
7.3	Does the port have a wetland mitigation program?		
7.4	Does the port participate or take initiative in any local program to conserve the natural resources of the hinterland?		
7.5	Does the port fund or take part in conservation of endangered species program?		
7.6	Does the port have an invasive species program to check the effect of invasive species on local species due to hull fouling?		
8	**Green Construction**		
8.1	Does the port promote the use of recycled product?		
8.2	Does the port promote the reuse of material removed to less important areas?		
8.3	Does the port purchase used furniture?		
8.4	Does the port lay strict norms on reducing the use of PVC products?		
8.5	Does the port promote the green certified manufacturers and vendors?		
8.6	Does the port insist on materials with low maintenance?		
8.7	Does the port promote on use of locally available materials for construction?		
8.8	Does the port do a study of recyclability and reuse of materials used in construction of various components?		
8.9	Does the port insist on use of low VOC paints?		
8.1	Does the port relay on natural air circulation system in office space?		

Sl.No.	Question	Yes	No
8.11	Are the office and other work space designed for maximum natural ventilation to reduce the use of electricity consumption due to artificial lighting in the morning time?		
8.12	Does the port promote indoor plant in work space for fresh air circulation?		
8.13	Does the port insist on nonchemical cleaning agents in the office space?		
9	**Public and Staff Transport**		
9.1	Does the port have proper bicycle lane connectivity between various buildings and operational areas?		
9.2	Does the port have separate area for storage of bicycles and special facility for changing and taking shower for the cyclists?		
9.3	Does the port have an employee pick up system?		
9.4	Does the port promote and have a car pooling program to coordinate between the employees?		
9.5	Does the port have transport facility to nearby public transport facility?		
9.6	Does the port promote and have facility for video conferencing to reduce frequent travels for meetings?		
9.7	Does the port have sufficient lane and gate facility to reduce idling and traffic congestion in the port?		
10	**Green Zone**		
10.1	Does the port have a green belt development program?		
10.2	Does the port have plant a tree program for the employees?		
10.3	Does the port promote the use of recycled materials in landscaping?		
10.4	Does the port promote the use of used materials in landscaping?		
10.5	Does the port have a program for the revival of endangered plant species in the green zone development area?		
10.6	Does the port do landscaping design without cutting down trees?		

4.4 Software Development for Green Rating

The input requirement for the awarding of green rating to the port design has been explained in Green Rating Input Page in section 5.4.6 in the next chapter followed by the Green Rating Output page in section 5.4.7. The questionnaire for green data collection as shown in Table 4.5 is taken as the basis for entering data in to the software.

CHAPTER 5

DEVELOPMENT OF DECISION SUPPORT SYSTEM FOR PORT PLANNING AND GREEN PORT RATING

5.1 Introduction

The DSS is developed here on a web based platform to be hosted from Amazon web server. The DSS developed to address the planning, design and green port requirement of a port and harbour during the development stage. It is developed in three stages to assist the user in planning by forecasting the future traffic of the port, to make various decision regarding the design and requirements of the physical components of the port structure and provides a green port rating system which will assist in sustainable development of the port. The DSS is designed with a fair degree of separation so that the user can select which of the above sections is to be executed, further reducing the requirement of collecting data for other sections. For example if the user needs to get only the green port rating he can select this section thereby skipping the planning and design sections.

The traffic forecast planning mainly depends on the data availability of the past traffic, which at sometimes might be difficult to obtain. Hence three methods are proposed; first method depends on the past data of the port, second on the GDP of the hinterland and third on the past data of the competing ports in the same route. When more than one method is available and used for forecasting, the software provides an option of average forecast which helps in averaging skewed forecast if any due to inconsistency in data collection.

The various physical components of the harbour like the channel and entrance width, depth, maneuvering area and turning basin requirement are designed and compared with the available dimensions and recommendations are given to help the user in making decisions on further actions required for the development of the port. The software also designs the various requirements of a container port like berth, handling equipment, dredging equipment selection and storage area requirement to aid the user in decision making process of port design.

The final section of the software is developed for green port rating; this helps the user in assessing the green index of the port for sustainable development of the project. The user can rate an existing port using the software and give suggestions for the improvement of green index to the port management. In the case of a new port development once all the policies regarding the construction and functioning of the port are decided the software can be used for testing the port green index and necessary changes can be implemented before the execution of the project.

5.2 Software Architecture

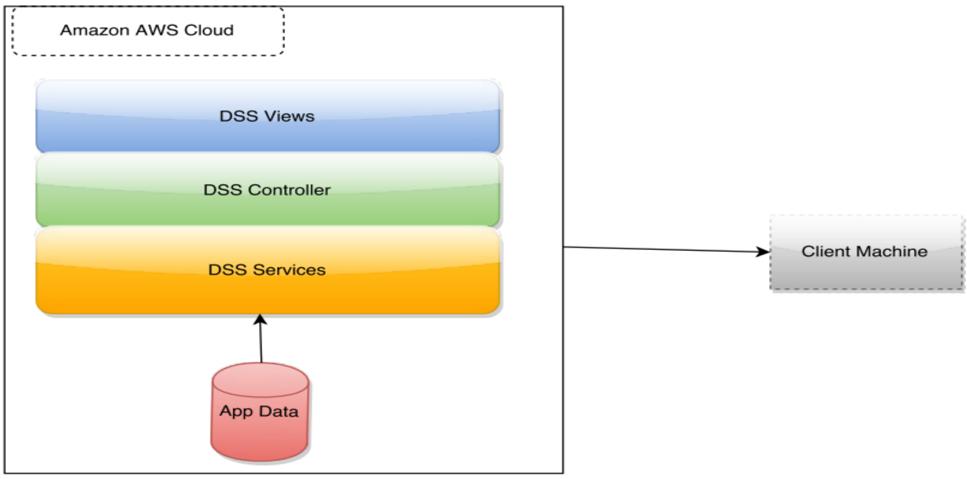

Fig 5.1 Software Architecture Diagram

The DSS is developed using Model View Controller (MVC) architecture; the basic principle is to have a degree of separation between the various components of the DSS which when works together will give a high level of scalability. MVC provides easy maintainability and are reusable for further studies. The components of MVC are M, C and V as explained below

Model- It is the central component of the MVC; the model is the component which stores the data and processes the logic and rules of the DSS. Shown in Fig 5.1 as the DSS Services, which means in general the kind of service the DSS provides. The DSS service in the present application developed is coded using Angular JS structural framework.

Controller – It is the component with which the user interacts like providing values or other inputs. The controller then interacts with the model for the processing of the data further to get the results. The DSS controller developed in the present study is coded using Angular JS structural framework.

View – The output generated by the model is presented to the user through the view. The output in the DSS developed, uses HTML 5 with Angular JS framework and CSS3 for UI development. The tables and graphs are presented using Highchart library.

The biggest advantage of having this separated approach is that the changes in any of the components can be done individually without affecting the total model. The approach gives an edge of adding more models using the same controller and view. The separated approach makes it easier to make changes to any one component of the DSS without affecting the other parts. The coding language used is Angular JS which is the latest technology used for web based application design. The Angular JS platform is amply supported by Google which provides huge amount of flexibility and can be used for responsive design. Angular JS has open source compatibility which allows the use of libraries and high charts and results in minimal code-writing.

5.3 System Requirements

The DSS is hosted on AWS, which acts as the server. The web hosting reduces the cost of server maintenance and the service provider takes the responsibility of maintaining the service 24x7. The service can be accessed using a latest version of Google chrome web browser. The biggest advantage of web based services is the limited system requirement.

5.4 Software Functionality

5.4.1 Login and Home Page

5.4.1.1 Login Page

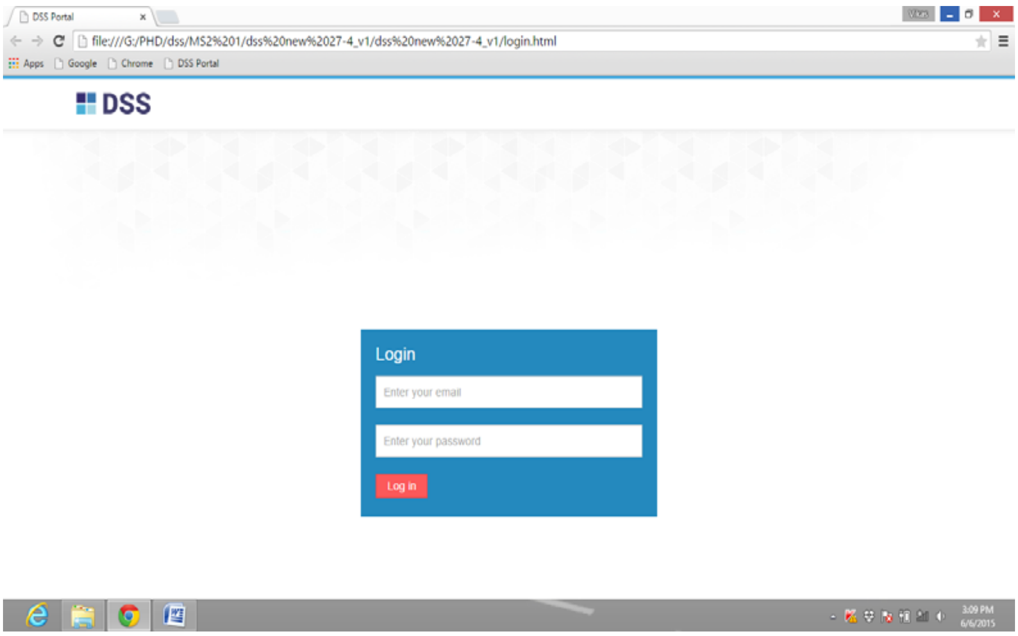

Fig 5.2 Login Page

Entry Criteria

The web application can be accessed at URL http://portdss.s3-website-ap-southeast-1.amazonaws.com/ using Google Chrome web browser (latest version) and would display the login page as shown in Fig 5.2.

Business Rules/ Logic

The access to the application has been provided through an authorized login name and password. The user will have to sign in with a registered login id and a valid password. At present the user id **"admin"** with password **"password"** can be used to access the application. The login and the password are case sensitive and have to be entered in lower case only.

Exit Criteria

Once the user enters the valid user name and password and clicks on the “Log in” button the application proceeds to the home page.

Error Handling

Error No.	Error Handling / Messages Displayed
1	Invalid User Name “The user credentials do not match. Please try again. “
2	Invalid Password “The user credentials do not match. Please try again. “

5.4.1.2 Home Page

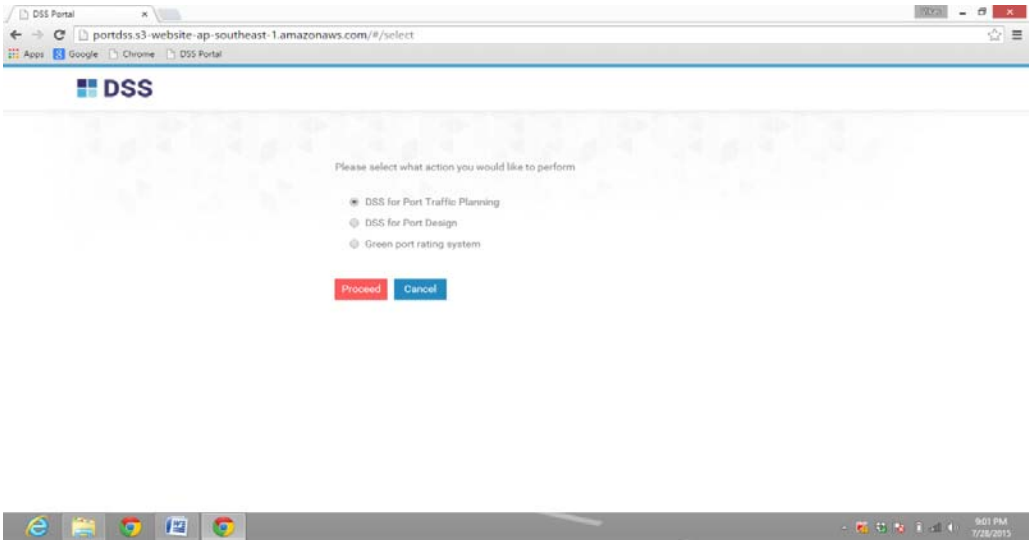

Fig 5.3 Home Page

Entry Criteria

The valid log in criteria proceeds to the home page to gain access to the application.

Business Rules / Logic

This page has three options; DSS for Port Traffic Planning, DSS for Port Design and Green port rating system as shown in fig 5.3. The user can select which action he wants to proceed by using the radio button. The radio button is default set on the first option. So if the user clicks the Proceed button without making any choice the application will move on to next page of DSS without displaying any error. This action of default setting has been done to avoid displaying an error message.

Exit Criteria

Once the choice of action to be performed has been made the user should click proceed to go to next page or cancel to move back to login page.

5.4.2 Forecasting Input Pages

5.4.2.1 Method Selection Page

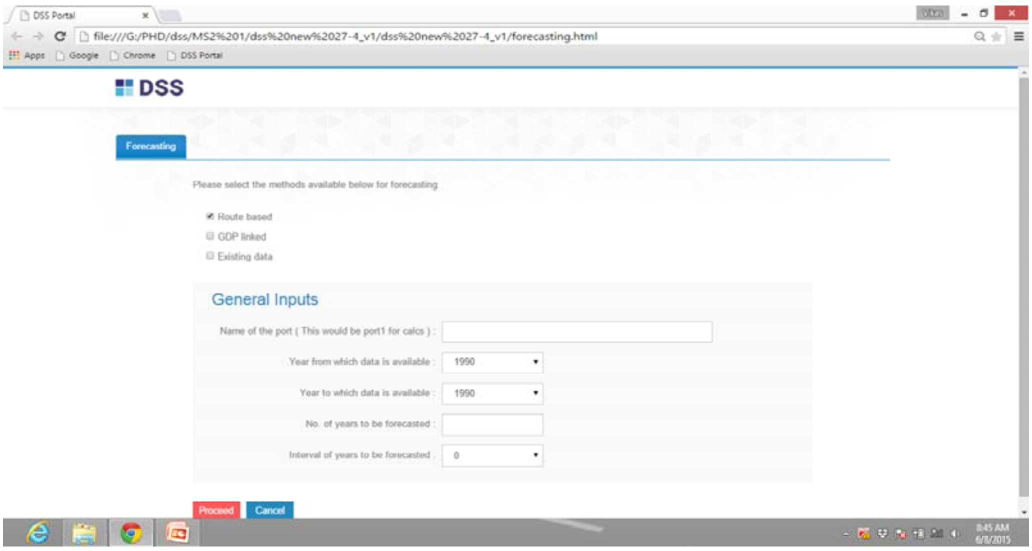

Fig 5.4 Forecasting Method Selection Page

Entry Criteria

If the user selects the DSS for Container Port Planning option in the home page and clicks proceeds the page shown in Fig 5.4 for forecasting method selection is displayed.

Business Rules/Logic

This page takes the input for type of forecasting method to be used and the general inputs required for the forecasting procedure. Three methods are provided for forecasting; Route Based Method, GDP Based and Existing Data.

The user will have to select at least one of the above methods and also has the option of selecting more than one method or all the methods using the radio button provided. The radio button is default set on route based method. So, if the user misses the selection the default method of route based is selected. After selecting the method the user has to fill in the details requested in the general input. All the fields are mandatory before proceeding further. The fields have to be filled using following criteria

Name of Port this will be the port for which the forecasting will be done. The name of the port has to be entered here.

Year from which data is available; this is a drop down menu and has got fields from 1990 to 2015 the user has to select from which year the past data for forecasting is available and this entry will be the first one in the forecasting table.

Year to which data is available; this too is a drop down menu and has fields from 1990 to 2015 the user has to select up to which the past data is available. The forecasting prediction is done from the year starting after this selected year. The software validates if the To year is greater than From year or else displays an error message.

No. of years to be forecasted this field requires the user to manually enter the number of years, from the final year for which past data is available, up to which forecasting is to be done.

Interval duration of years to be forecasted if the user selects 50 or 100 years of forecast displaying and reading of such value will be difficult. Hence, the application provides an option of displaying the results of forecast in interval years. The field is set as a drop down option with preset values of intervals as 1, 5 and 10. The user needs to select the intervals from the drop down.

All fields in this section are mandatory and if the user misses any of the field, error message will be displayed and the form will not be submitted until all the fields are completed.

Exit Criteria

If the user selects the route based method as one of the option or as the only option for forecasting then the application proceeds to more input page of route based as shown in fig 5.5 else the common more input page for the other two methods as shown in fig 5.6.

Error Handling

Error No.	Error Handling / Messages Displayed
3	If all fields are not entered “ Please enter the data for all the fields”
4	If From Year is greater “From date is greater than to date. “

5.4.2.2 Past Data Input Page

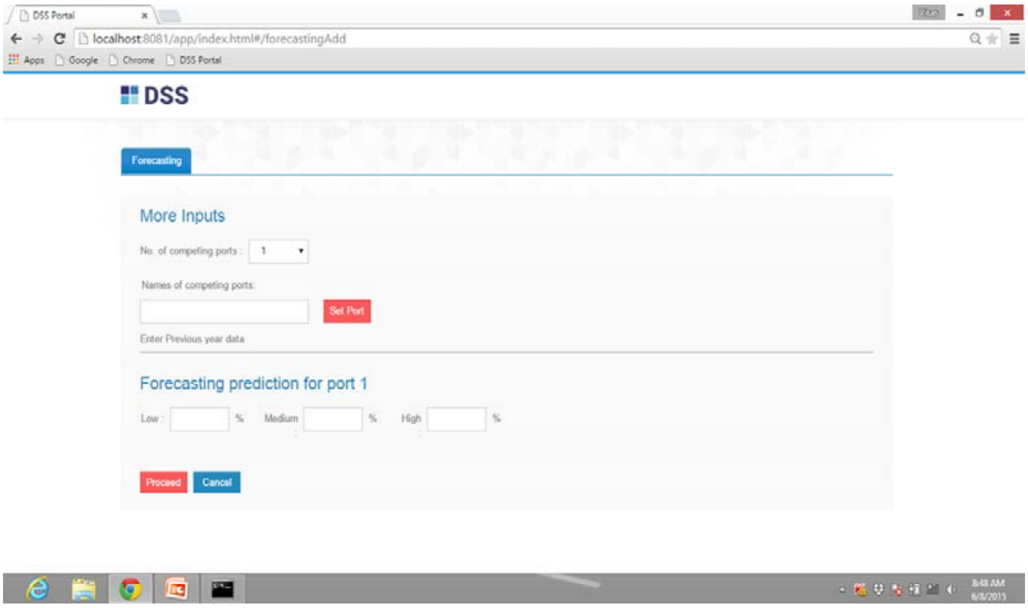

Fig 5.5 Route Based More Inputs Page

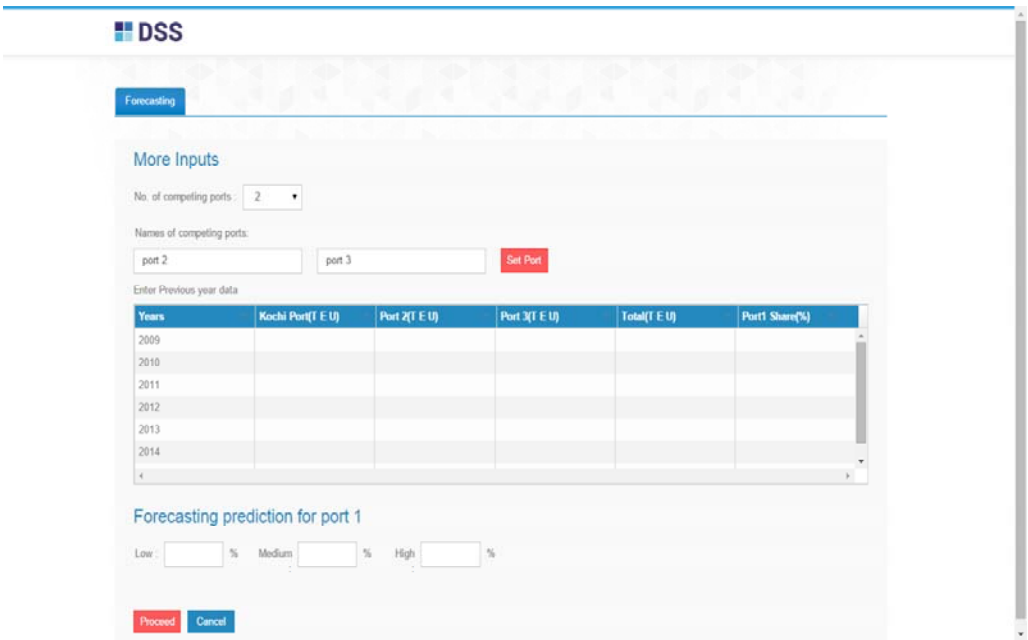

Fig 5.6 Common Past Data Entry Page

Entry Criteria

If the user selects the route based as the only or one of the methods of forecasting then the Route Based method input page shown in the Fig 5.5 is displayed and more inputs are taken in this page.

Business Rules/ Logic

The route based method compares the traffic in a particular route and the possibility of the business shift from competing port to the newly developed port due to the development or future expansion in the port infrastructure. The application allows a maximum of two competing ports. The number of competing ports can be entered as 1 or 2 through the dropdown option provided. The competing port field is default set at 1 and can be increased to 2. Once the number of competing port is selected the fields for entering the names of the port is activated depending on the number of competing ports selected. After entering the names of the port the user has to press the button “Set Port”. This will enable a table to enter the previous year data for the all the competing ports. As shown in the Fig 5.6. This table would be the common past data entry form if only route based is selected or if any other method is selected along with route based the same table will be used as a common past data entry table for all the methods. The user has to input the past data for all the ports in this table and the port 1 data will be used for GDP method and existing data method calculations.

As the user inputs the respective data for all the ports the software dynamically calculates the total traffic and the share in percentage of port 1 in the total traffic. All the fields in the table are mandatory. Port 1 for which forecasting has to be done, it is mandatory to enter the quantity and for the competing ports if the data is not entered then it is by default considered as 0. Once the table is complete the user has to fill fields of what percentage of the total traffic will shift towards the port after the development of the new facility. The percentage has to be entered as low, medium and high predictions. The idea of this percentage can be obtained from the market study and looking at the present market share of the port in the total traffic calculated.

Exit Criteria

Once all the fields are completed the user can click Proceed button to move to the next page or Cancel to go back to the previous page.

Error Handling

Error No.	Error Handling / Messages Displayed
5	If Names of port are not entered " Please enter the data for the ports"
6	If Ports are not Set "Please put in the additional port info"
7	If value of port 1 is not entered then "Error in row (number). Please check the values in all columns"
8	If Medium percentage value is smaller than Low percentage value "Medium should be greater than Low Values"
9	If High percentage value is lower than medium or low percentage value "High should be greater than medium or low values"
10	If decimal values are input in table for TEU then "Only non decimal values are allowed in input column"
11	If decimal values are input in the percentage box " The value for percentage should not be a fraction"

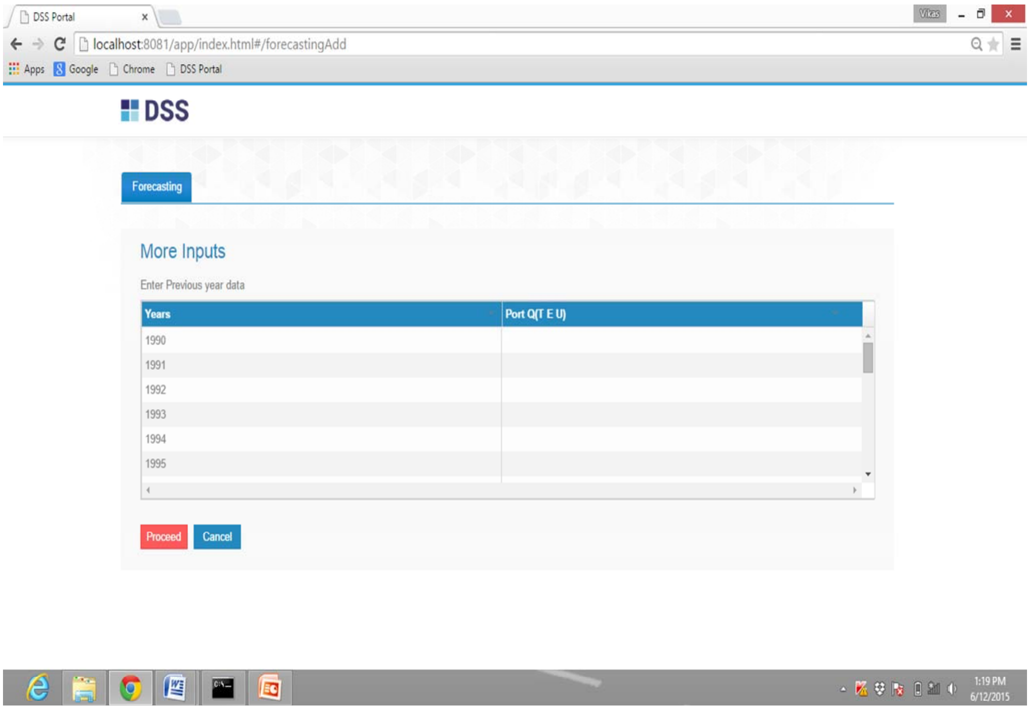

Fig 5.7 GDP and Existing Data Method More Inputs Page

Entry Criteria

If the user does not select route based method in the forecasting method selection page shown in Fig 5.4 and instead selects both GDP / Existing Data method or anyone and proceeds further more input page shown in fig 5.7 is displayed.

Business Rules/Logic

The page displays a table to take the inputs of the past data for the specified number of years.

Exit Criteria

The Proceed button moves to the next page of forecasting output and Cancel to the previous page.

Error Handling

Error No.	Error Handling / Messages Displayed
12	If value of port 1 is not entered then “Error in row (number). Please check the values in all columns”
13	If decimal values are input in table for TEU then “Only non decimal values are allowed in input column”

5.4.3 Forecasting Output Pages

5.4.3.1 Method Based Output Page

Fig 5.8 Forecasting Output Page – with Route Based Tab ON

Entry Criteria

After entering the required input depending on the method selected the output page as shown in Fig 5.8 is displayed

Business Rules/Logic

The forecasting output page has output tabs on top which are displayed according to the methods selected. If only one method is selected then the tab related to that method is displayed. If multiple methods are selected the output tab is displayed accordingly. Whichever tab is being displayed on the screen is highlighted. Fig 5.8, 5.9 and 5.10 show the various methods being displayed

Forecasted Data - Route Based- For the route based method from the input screen shown in Fig 5.6 the total traffic of all the competing ports is used to calculate the forecast for the required duration. Using the total forecast a linear equation of the form $Y = a + bX$ is formed where a and b are calculated using the equation 3.2 and 3.3.

In the table shown in Fig 5.8 the years table will be filled according to the input taken in the forecasting method selection page, the first year in the table will be the year after the final year for which the past data is available and the subsequent rows will be filled according to the interval entered by the user. In the equation $Y= a + bX$, X is the year for which the forecast has to be done. The value of X is calculated by subtracting the first year for which the data is available from the year for which prediction is to be done. For example if 1999 is the "From year" entered and 2015 is the "To year" for which past data is available and we need to predict the value of the year 2020 using the equation. The value of X for the above said equation will be 2020 minus 1999 which will be 21. Using this logic the values of predicted traffic for the required interval years is calculated using the equation 3.1 and displayed in the table under the column Total Forecast against the subsequent column 1 of Year.

After the calculation of total traffic the share of Port 1 for which the forecasting is to be done is calculated depending on the low, medium and high share which is entered in the common past data entry page shown in Fig 5.6 and displayed under the column Share of Port1 Low, Medium and High against the subsequent years.

The coefficient of correlation will be calculated by using the equation 3.4 for the total traffic forecast and the coefficient of determination is calculated as square of coefficient of correlation and is expressed in percentage. A legend is provided in the sheet to judge the strength of relationship between X and Y using the coefficient of correlation.

A graph is plotted for total, low, medium and high forecasted traffic in which the years will be shown in the X axis and Y axis will show 4 series each for Total forecasted traffic, Low Share, Medium Share and High Share. The graphs plot is colour coded and the legend is displayed at the bottom of the graph. An option of printing the graph is provided or the graph can be downloaded and saved as PNG, JPEG, PDF or SVG vector image for reference.

Forecasted Data – GDP Based (Only for Port 1) In this method there are no competing ports and the forecasting is done using future GDP data of the hinterland. The tab displays a table as shown in Fig 5.9 in which the "To Year" for which the past data is available becomes the first row and is displayed along with the TEU entered in the input page. The second column is the GDP for which the first value for the available year is default set as 0. The year column will be filled according to the intervals required in the initial input. The user will have to input the predicted GDP increase/decrease in the hinterland area respective to the year column. The percentage increase/decrease in GDP of a particular year is used to calculate the percentage increase/decrease of traffic from the previous year and is displayed against the respective year column. For example the traffic of year 2004 is 5000 TEU and the GDP increase is 5% up to 2006. Then the traffic of 2006 is calculated as 5000 + (5*5000/100) which is 5250 TEUs. A graph is plotted with year as X and TEUs traffic as Y. The graph is plotted real time as the user enters the value of the GDP. An option of printing the graph is provided or the graph can be downloaded and saved as PNG, JPEG, PDF or SVG vector image for reference.

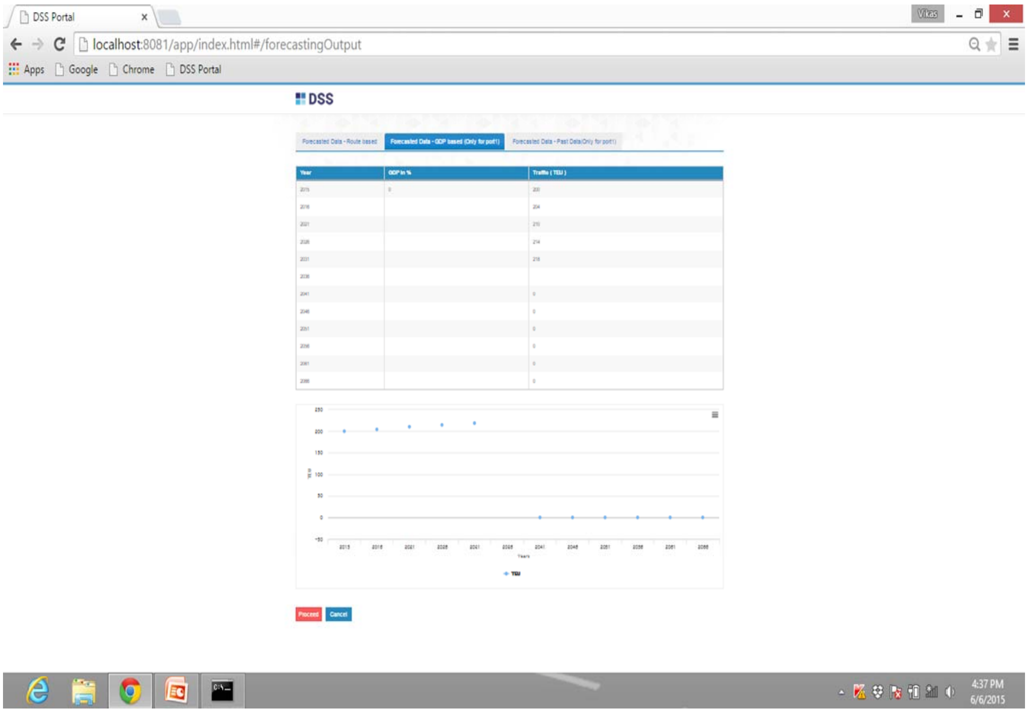

Fig 5.9 Forecasting Output Page – with GDP Tab ON

Forecasted Data- Past Data (For Port 1 only) - This option is used when the past data for the port is available and there are no competing ports. The table as shown in fig 5.10 is displayed the calculation are done using the linear equation 3.1 and the method is similar to that explained in Route Based method only difference being the traffic of Port 1 is used instead of Total Traffic. All other calculations are same and a graph is plotted with years shown in the X axis and Y axis will show forecasted traffic of Port 1. An option of printing the graph is provided or the graph can be downloaded and saved as PNG, JPEG, PDF or SVG vector image for reference.

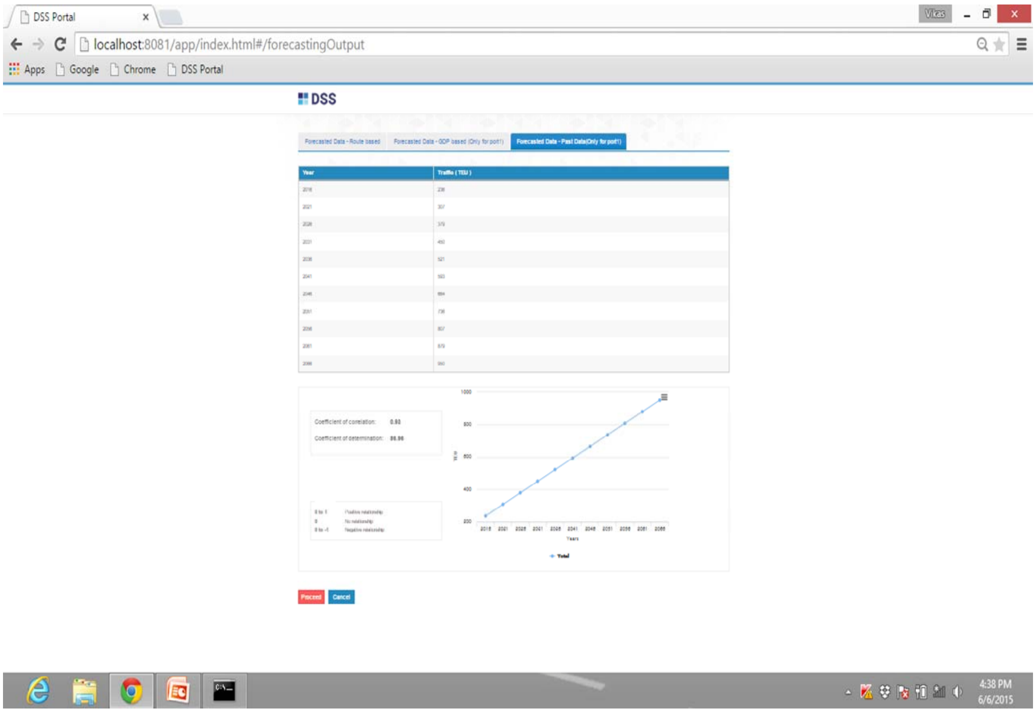

Fig 5.10 Forecasting Output Page – with Existing data Tab ON

Exit Criteria

If the user has selected only one method of forecast and clicks on the Proceed button then the home page shown in fig 5.3 is displayed for further action else if the user has selected more than one method and on clicking the Proceed button the DSS moves to the next page of average forecast. If the user clicks the Cancel button the DSS moves back to the previous page.

5.4.3.2 Average Forecast Output Page

Entry Criteria

On choosing to proceed from the Forecasting Output Page and if the user has selected more than one method of forecasting then the page of Average Forecast is displayed as shown in Fig 5.11.

Business Rules/ Logic

If the user has selected all the methods or route based method along with any one of the other methods the page displays the first field with radio button for the user to select which of the port share forecast (low, medium or high) in the route based method is to be used for calculating average forecast. The user can select between low, medium and high forecast by clicking the respective radio button. The button is by default set at the low forecast and the results of low forecast is displayed in the column under Route based (Low) TEU and the averages are calculated using this figures. If the user selects medium or high then this values are displayed as Route based (Medium/High) TEU and averages are calculated based on these values.

If the user does not select the Route Based method the radio buttons for selection of Low, Medium and High are not displayed.

The values of methods selected are displayed and the average forecast is calculated for each year. If any method is not selected then that row is default set as 0. A graph is plotted with years shown in the X axis and Y axis will show average forecasted traffic of Port 1. An option of printing the graph is provided or the graph can be downloaded and saved as PNG, JPEG, PDF or SVG vector image for reference.

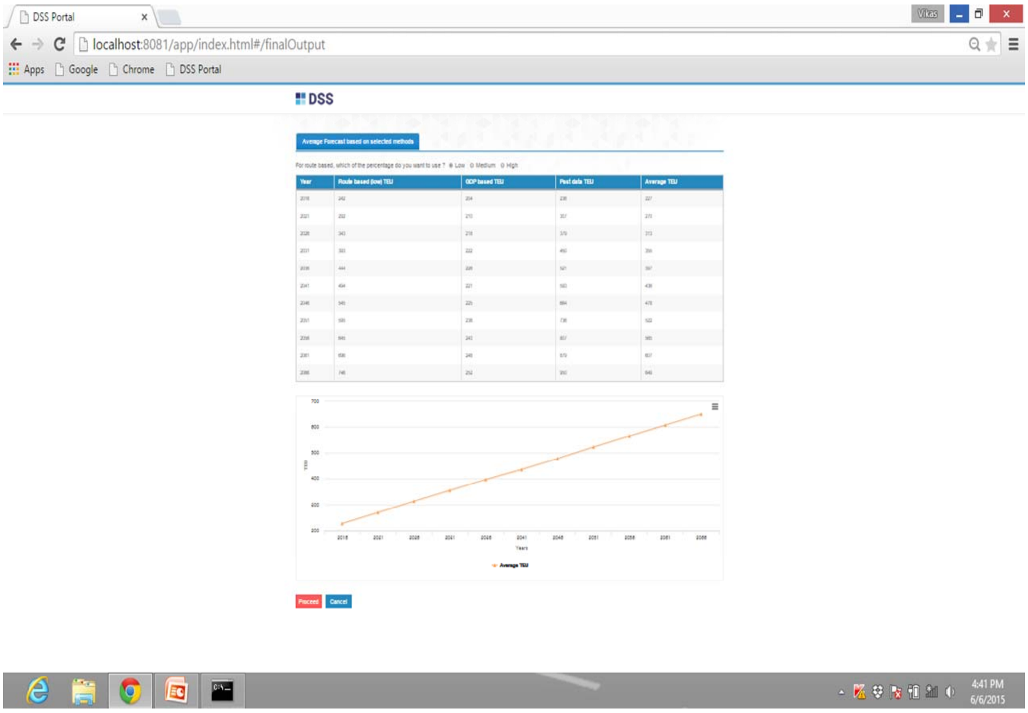

Fig 5.11 Average Forecast Page

Exit Criteria

The user can click proceed button to move to the Home page as shown in fig 5.3 or Cancel button to move to the previous page.

5.4.4 Port Design Input Pages

5.4.4.1 Design Ship Size Selection Page

Entry Criteria

On selecting the option of DSS for port design in the home page and clicking the proceed button the Design Ship Size selection page is displayed as shown in Fig 5.12

Business Rules/ Logic

The port's physical parameters depend on the design ship which is the largest possible ship that will enter the port. The page displays the ship sizes in Table 3.1. The user is given an option of selecting one from the available ten ship sizes in the table using a radio button or there is an eleventh option where the user can enter the ship size of his requirement by enabling the radio button against the option. All the fields are mandatory in the eleventh option and the fields are to be filled in the same unit's length, beam and draft in meters and TEU in numbers.

Exit Criteria

After choosing the required design ship size click Proceed to move to next page and Cancel to Home page.

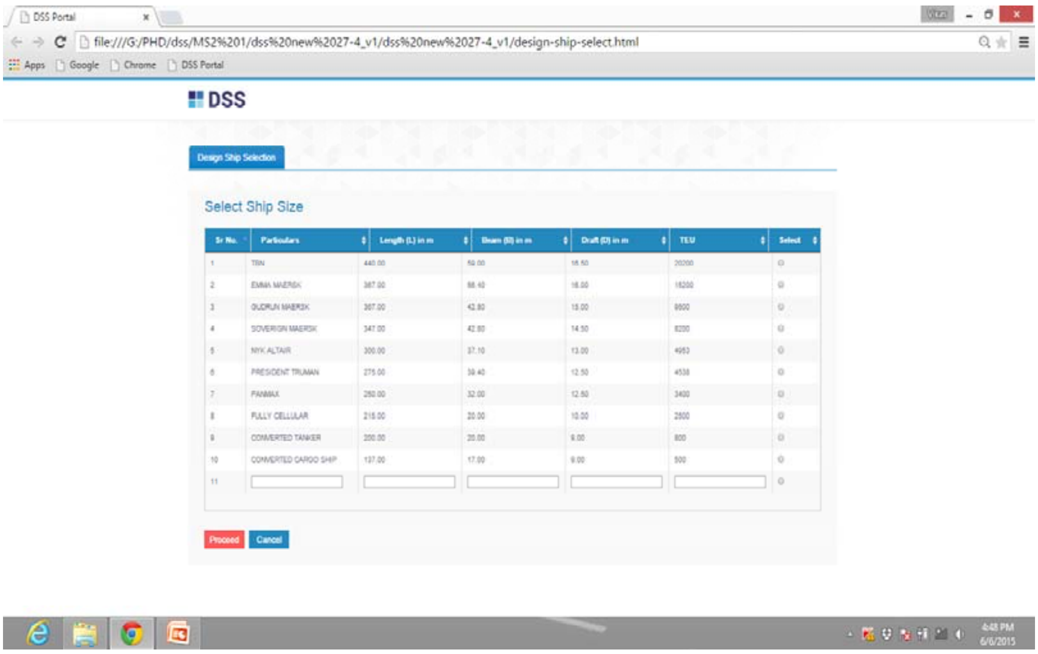

Fig 5.12 Design Ship Selection Page

Error Handling

Error No.	Error Handling / Messages Displayed
14	If a ship size is not selected " Please select a ship size to Proceed"
15	If all field in option 11 are not entered "Please fill all mandatory fields for Option 11"

5.4.4.2 Port and Harbour Design Input Page

Entry Criteria

On choosing to proceed from the Design Ship Size Selection page the software displays Port and Harbour Design Input page as shown in Fig 5.13

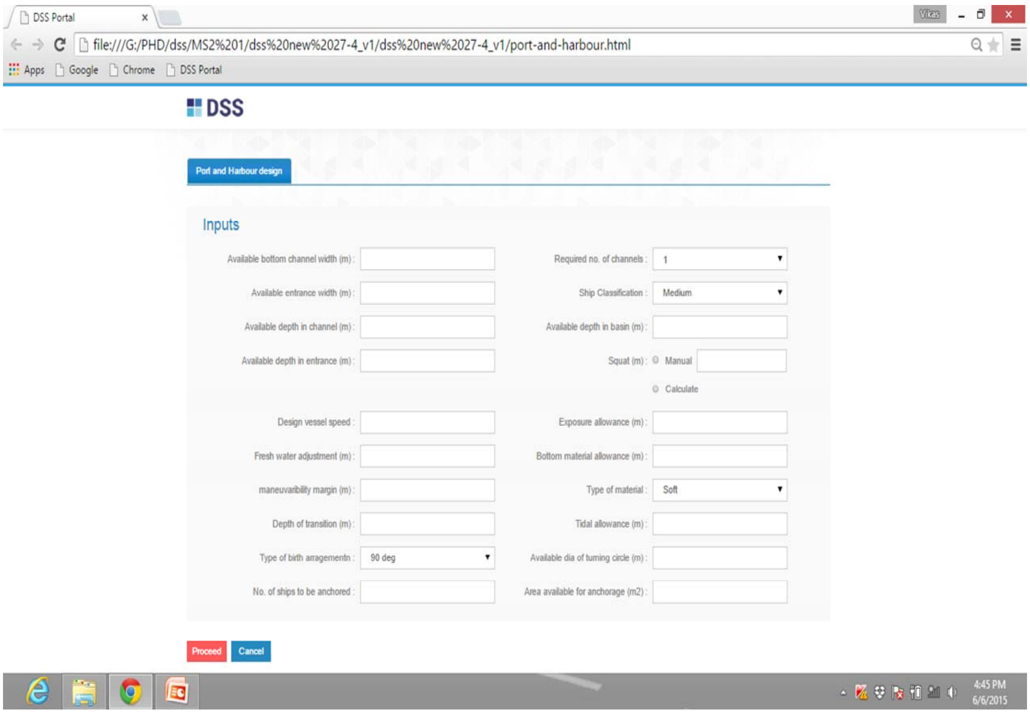

Fig 5.13 Port and Harbour Design Input Page

Business Rules/ Logic

The page takes input for the design of various port and harbour physical parameters like width, depth and area requirements. The units in which input should be provided is defined along the various field and the user should convert the dimensions to the required units before entering into the fields or else the result will be wrong. Few fields like Required no. of channels, Ship Classification and Type of Berth arrangement are dropdown and the values preferred should be selected from the dropdown menu provided along the respective text box. For the field "Squat", there are 2 radio buttons – Manual and Calculate. When Manual is selected, textbox next to it is activated and the user can enter the value of squat manually and when the option Calculate is selected the Manual entry text box will be disabled. All the fields in this page are mandatory.

Exit Criteria

After entering all the mandatory fields click Proceed to go to next page or Cancel to go to previous page.

Error Handling

Error No.	Error Handling / Messages Displayed
16	If any field is not entered "Please enter all the fields"

5.4.4.3 Berth Size Design Input Page

Entry Criteria

On choosing to proceed from the previous page Berth Size Design Input page is displayed as shown in Fig 5.14.

Business Rules/ Logic

This page takes the input required for the calculation of berth size. All the fields are mandatory. Working crane time field is a dropdown and the value of this field should be selected from the dropdown menu provided. All the fields should be filled according to units specified against the field.

Exit Criteria

After entering all the mandatory fields click Proceed to go to next page or Cancel to go to previous page.

Error Handling

Error No.	Error Handling / Messages Displayed
17	If any field is not entered "Please enter all the fields"

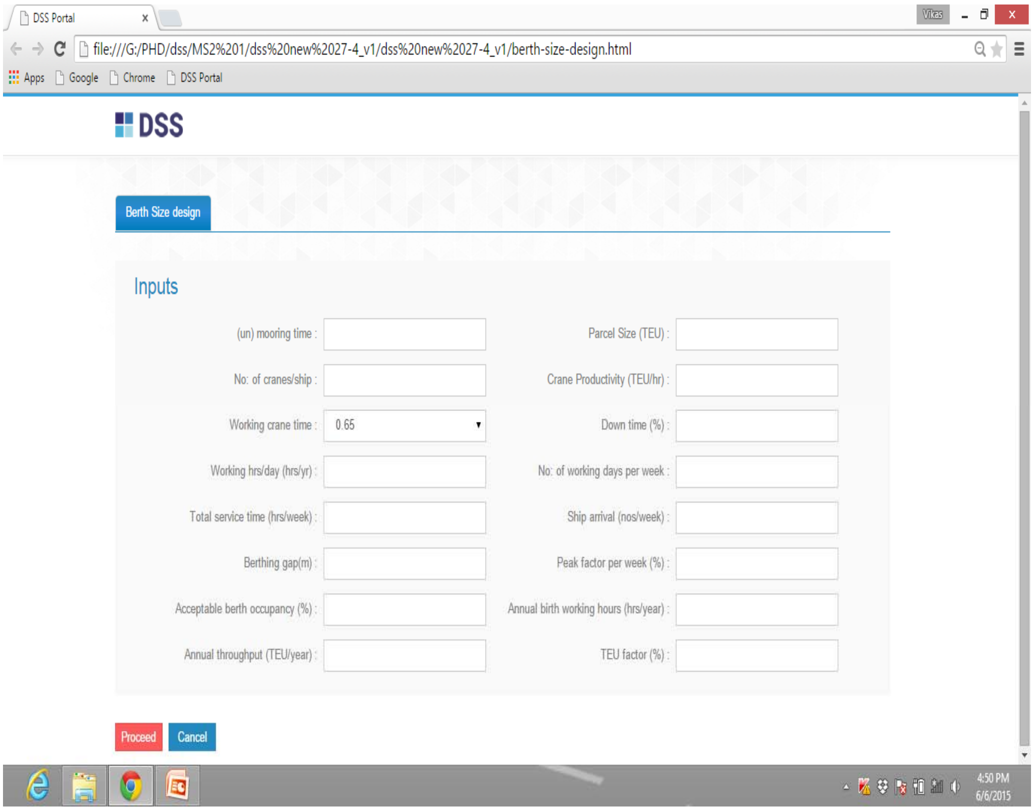

Fig 5.14 Berth Size Design Input Page

5.4.4.4 Storage Yard Requirement Input Page

Entry Criteria

On choosing to proceed from the previous page Storage Yard Requirement Input page is displayed as shown in Fig 5.15.

Business Rules/ Logic

This page takes the input required for the calculation of storage yard requirement. The page is in a table format having separate section for laden and empty containers. All the fields are mandatory and all the fields should be filled according to units specified against the field.

Exit Criteria

After entering all the mandatory fields click Proceed to go to next page or Cancel to go to previous page.

Error Handling

Error No.	Error Handling / Messages Displayed
18	If any field is not entered "Please enter all the fields"

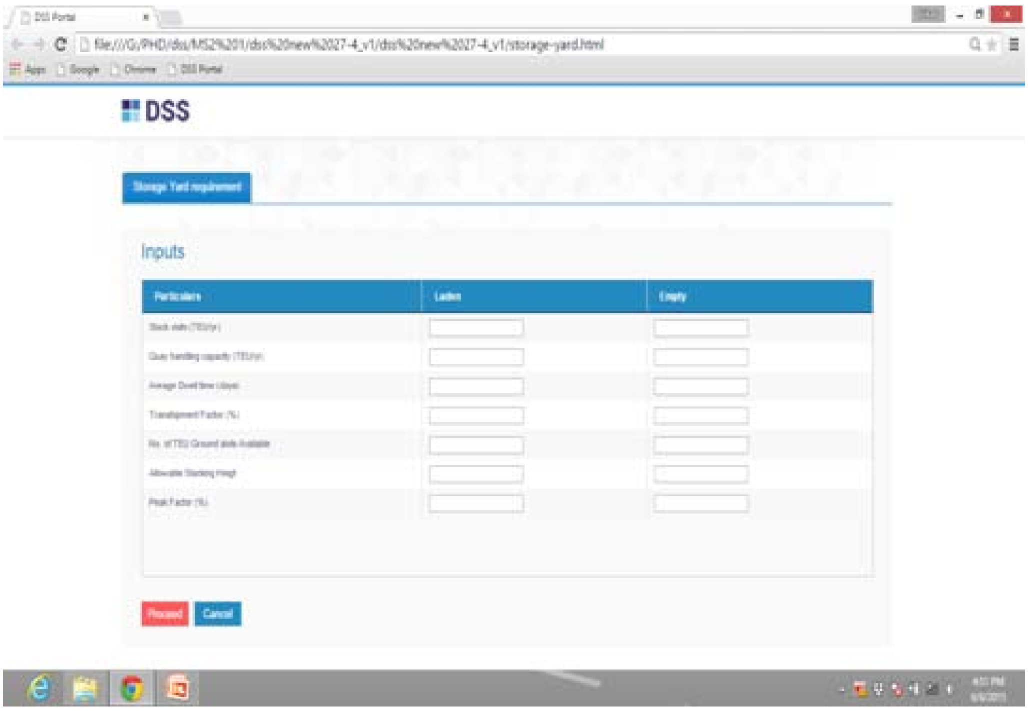

Fig 5.15 Storage Yard Equipment Input Page

5.4.4.5 Dredging Equipment Selection Input Page

Entry Criteria

On choosing to Proceed from the previous page Dredging Equipment Selection Input page is displayed as shown in Fig 5.16.

Business Rules/Logic

This page takes inputs required for dredging equipment design. All the fields are mandatory. The page has two sections one each for new work and maintenance dredging. Each of the section has further subsections of open sea and protected harbour. The page takes values for each of this subsection in the fields of Bottom material present which has drop down values soft, rock and consolidated material. In the case of maintenance dredging only soft and consolidated material option will be available as the hard rock will be present only during initial work. The Accuracy required is the second field which has drop down values as good, moderate and poor and finally pay: non pay over depth ratio which has values 1:2, 1:2.5 and 2:1.

The user has to first select the type of bottom material from the dropdown option provided; all other fields are disabled. Once the material is selected the bottom accuracy required option is activated and this field can be completed as per requirement, the options of accuracy change as per the material selected. After the first two fields are completed the third field of pay: non pay over depth ratio will be activated and the option can be selected from the respective dropdown. The same process has to be followed for all the sections.

Exit Criteria

After entering all the mandatory fields click Proceed to go to next page or Cancel to go to previous page.

Error Handling

Error No.	Error Handling / Messages Displayed
19	If any field is not entered “Please enter all the fields”

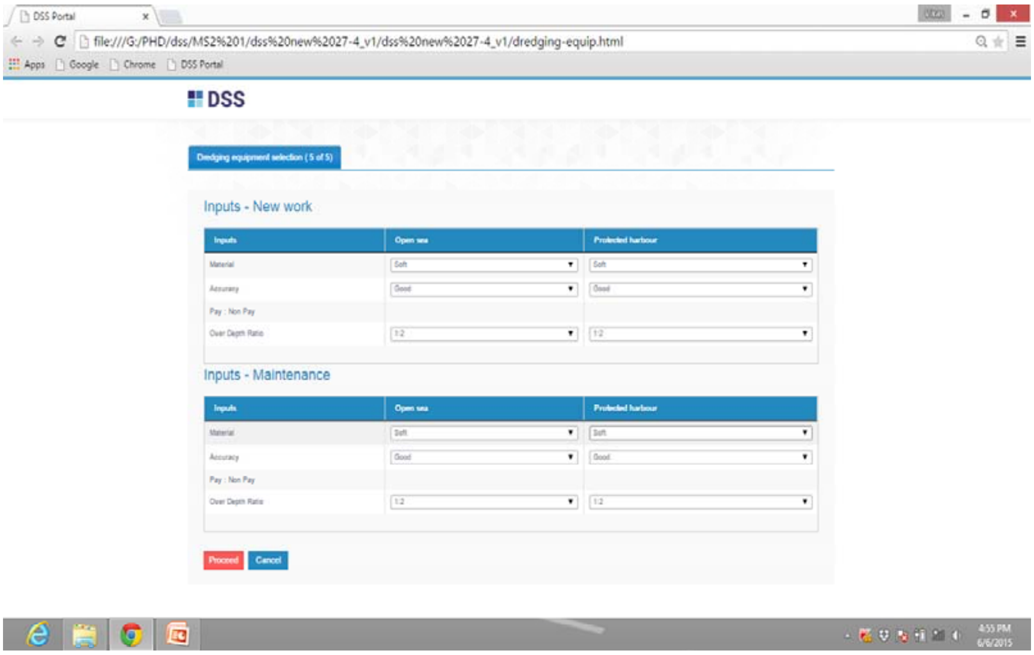

Fig 5.16 Dredging Equipment Selection Input Page

5.4.5 Port Design Output Pages

5.4.5.1 Port Design Output Page 1

Entry Criteria

After completing all the fields in the dredging input page, click Proceed button to display the Port Design Output Page 1 as shown in Fig 5.17.

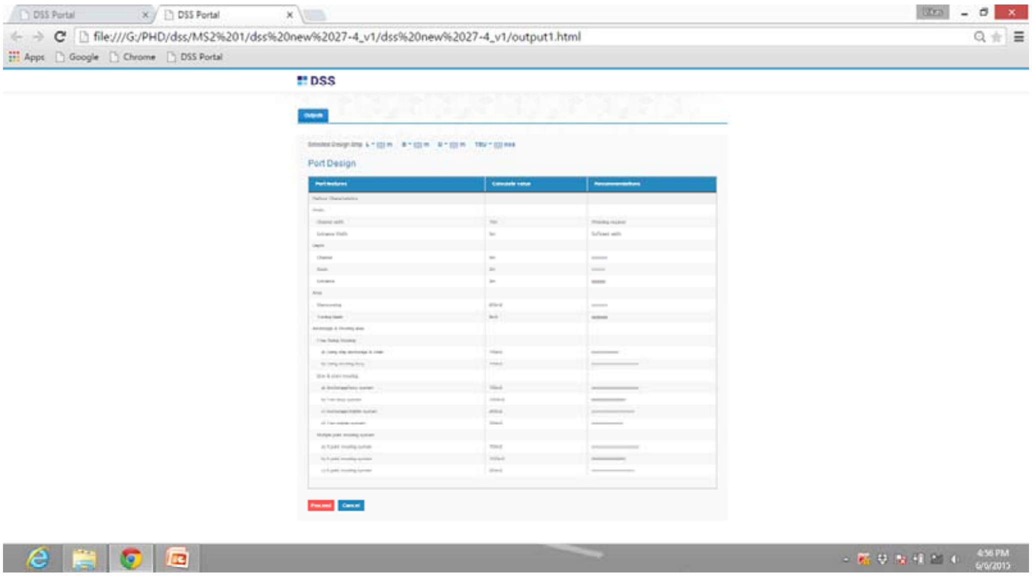

Fig 5.17 Port Design Output Page 1

Business Rules/ Logic

This page in the first section displays the selected design ship dimensions in terms of length, beam, depth and TEU's, after which it displays a table format of various harbour characteristics with calculated values and recommendations.

Width- The first field in the output table is width which will provide the channel and entrance width and the recommendation for the same.

Channel width is calculated by taking inputs; Available bottom channel width and Required No. of channels and taken from port and harbour design input page and beam (B); from the design ship size selection page. Rules of channel width calculation are

If the required no of channel input is 1 then use equation 3.5 to calculate the range of channel width else if the required no of channel input is 2 then use equation 3.6 to calculate the range of channel width and display the channel width as minimum – maximum width in the calculated value field of the output table.

After the calculation of the required minimum to maximum range, the available channel width is compared to this range and if the width available is in between this range then **“Sufficient Width Available”** is displayed as the recommendation and or else suggestion of “**Widening required”** is displayed.

Entrance Width is calculated using the available entrance width and ship classification fields from the port and harbour design input page and Length of design vessel (L) from the design ship size selection page. The entrance width is calculated using the equation 3.7 and the calculated value and recommendations are displayed using the following algorithm

If Ship Classification = “Medium”

Check 0.70*L>100m

Then Display 0.7*L

Else Display 100 to 150 m

If Ship Classification = “Large”

Check 0.70*L>200m

Then Display 0.7*L

Else Display 200 to 250m

After calculating the entrance width, compare the available entrance width field with the calculated value. If the available value is great than calculated required width then display **"Sufficient Entrance Width Available"** else display **"Entrance Widening required"**.

Depth is the second section in the output table shown in Fig 5.17. The depth is calculated for channel, basin and entrance area of the harbour. The depth is calculated using two methods first the depth is calculated for entrance, basin and channel separately using equation suggested by IS code and latter overall depth requirement is calculated using theoretical equation and these depths are compared and the higher value is displayed.

The input fields required for depth calculation from the port and harbour input page are available depth in channel, basin and entrance. The value of squat if entered manually, design vessel speed, exposure allowance, fresh water adjustment, bottom material allowance, maneuverability margin, type of material, depth of transition and tidal allowance. The value of length, beam and draft from the design ship size selection page and channel width dimension displayed earlier in the output page.

Method 1*:* The depth requirement is first calculated at the channel using equation 3.11, at the basin using equation 3.12 and at the entrance using equation 3.13 separately.

Method 2*:* The design depth requirement is also calculated using the equation 3.10, for which the inputs required are; exposure allowance, fresh water adjustment, bottom materials allowance, maneuverability margin, depth of transition and tidal allowance are taken as direct input in port and harbour input page. The others are calculated as below

Squat the user is provided two options either to manually enter the value or the applications calculate using the equation 3.9, the user is asked to make the choice in port and harbour design input page shown in Fig 5.13. For the calculation of squat using the equation the input of draft D is taken from the design ship selection page and the available depth in channel and design vessel speed values are taken from the port and harbour input page.

Trim value required for the depth calculation is calculated using the equation 3.8.

Over Depth allowance is taken as 0.3m if the type of bottom material is selected as hard in the port and harbour design and as 0 if the material is selected as soft.

Once the depth is calculated using both the methods; the depth calculated using method 2 is compared with the individually calculated depth of channel, basin and entrance using method 1 and whichever is greater in the respective field is displayed in the output table against depth of channel, basin and entrance.

After displaying the depth this depth is compared with the available depth in channel, basin and entrance, and if the available depth is found higher than the required depth then **“No Dredging required”** is displayed or else if the available depth is lesser than the required depth then **“Dredging required”** is displayed. This helps the user in identifying the area in which dredging is required.

Area is the final section of this output page and the area of turning basin and maneuvering area requirements of the harbour are calculated and displayed in the output table.

Input required in this section for the calculation of area requirement are the type of berthing arrangement and available diameter of turning circle from the port and harbour input page and length of design ship from the design ship size selection page.

Maneuvering area requirement is calculated depending on the type of berthing arrangement. The user can select 90 degree, 45 degree or parallel. If the user selects 90 degree then the equation 3.14 is used to calculate, similarly equation 3.15 and 3.16 are used to calculate the width requirement for 45 degree and parallel berth arrangement respectively. In the recommendation column the message **"width required to permit design vessel to swing freely into the berth position"** is displayed.

Turning basin dimension depends on the type of arrangement used to turn the ship; values for each of the system are calculated individually and displayed in the table.

On using turning dolphin, the turning basin diameter is calculated using equation 3.17.

On turning by free interplay of propeller and rudder, assisted by tugs in protected location turning basin diameter is calculated using equation 3.18.

On turning by free interplay of propeller and rudder, assisted by tugs in exposed location turning basin diameter is calculated using equation 3.18a.

On turn by free interplay of propeller and rudder, with no tug assistance turning basin diameter is calculated using 3.19.

Each of the calculated value of turning basin diameter is compared with the input value of available diameter of turning basin and if the available value is found to be lesser than calculated value then **"Insufficient turning circle diameter"** is displayed. Else if the available diameter is greater than calculated then **"Sufficient turning circle diameter"** recommendations are displayed.

Exit Criteria

Click Proceed button to move to next page or Cancel to back to the previous page.

5.4.5.2 Port Design Output Page 2

Entry Criteria

Proceed from the previous page will display the second and the final Port design output page 2 as shown in Fig 5.18

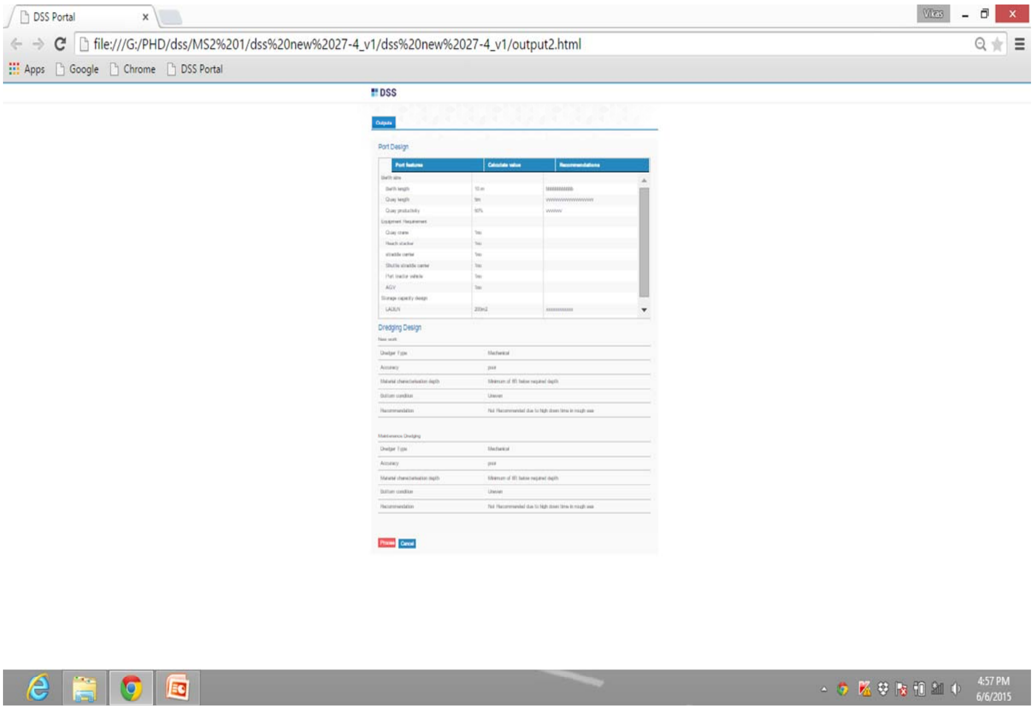

Fig 5.18 Port Design Output Page 2

Business Rules/Logic

This page has four sections displaying output of berth size, equipment requirement, storage capacity and dredging design.

Berth size requirement is the first section and the output parameters are no. of berths, quay length and quay productivity. The input from berth design input page as shown in Fig 5.14 are used for calculations.

First the (un)loading time is calculated using the equation 3.21, for which the fields such as Parcel size, number of cranes per vessel, crane productivity and working crane time are taken as inputs from the berth design input page. Once the (un)loading time is known, the total service time is calculated using equation 3.20 and the (un)mooring time entered by the user in berth design input page.

After this, given the downtime factor, total working hours which is got by multiplying the working hours per day and number of working days per week entered as inputs, the berth working hours per week can be calculated using the equation 3.22.

Next step is calculating berth length requirement using equation 3.23 where total service time calculated earlier, vessel arrival and berthing gap taken as inputs in the berth design input page and ship length taken from the design ship selection page are used.

Once the berth length and berth working hours per week are calculated, using the values of peak factor per week and berth occupancy, the sufficient quay length is calculated using the equation 3.24 and is displayed in the output sheet.

After calculating the quay length and berth length the number of berths is calculated using the equation 3.25, for which the input of length of ship is taken from the design ship size input page. This is displayed in the output sheet against the no. of berth column.

Finally the quay productivity is calculated using equation 3.26, using inputs annual throughput, TEU factor and annual berth working hours from the input page and number of berths calculated earlier. The value of quay productivity is displayed in the output table.

Equipment requirement is calculated using table no.3.2 where the handling equipment requirement is based on the number of quay cranes. So first the number of quay cranes required is calculated. The quay crane is calculated using the thumb rule of 1 crane per 80 to 100 m of quay length. The quay length calculated earlier is divided by 80m to get the number of quay cranes. Once the number of quay cranes is calculated table no 3.2 is applied to get the required number of reach stackers, straddle carriers, shuttle straddle carrier, port tractor vehicle and AGV's. The numbers are displayed in the output table.

Storage yard capacity is calculated in terms of laden and empty containers separately. As shown in Fig 5.15 storage yard equipment input page, the input parameters are also entered in separately. For the calculation of capacity first the stack visits are calculated using equation 3.28, using the input entered for quay handling capacity and transshipment factor. Once the stack visits are calculated this value is used along with inputs entered for average dwelling time and peak factor to calculate the storage yard capacity using equation 3.27.

The output is given in terms of number of TEU ground slots. This is calculated using equation 3.29 and the input of stack height provided by the user in the storage yard equipment page is used in this equation. The process is carried out for both laden and empty containers and the output is displayed separately.

Dredging design output has two section the new work and maintenance dredging. Each section has sub sections for open sea and protected harbour. So totally there are combinations of four working conditions which are new work- open sea, new work – protected harbour, maintenance – open sea, maintenance – protected harbour. The aim of the DSS is to help the user to choose the best dredging equipment for each of the above working conditions. The input is taken in terms of bottom material condition, accuracy and pay – non pay over depth ratio as shown in Fig 5.16 dredging equipment selection input page. The best suited dredging device for a particular input condition is traced using the logical categorization explained in Tables 3.3 and 3.4. The output table gives the best suited dredging device along with recommendation, material characterization depth required and the resulting bottom condition after dredging.

Exit Criteria

The user can click the Proceed button to go back to the home page or Cancel button to go to the previous page.

5.4.6 Green Rating Input Page

Entry Criteria

Green Rating system application page can be accessed from the home page shown in Fig 5.3 by enabling the Green port rating system radio button.

Business Rules/ Logic

The green rating system page shown in Fig 5.19 has been divided into 10 sections and each section has been awarded with sectional points as described in Table 4.2. The sections have green port parameters which are awarded points which will add up to the sectional points as described in Table 4.3 and each parameter is provided with an On-Off switch. All the switches will be by default in Off status. If the green port parameter is satisfied then the user has to press on this switch which slides to On status. The On status is indicated by a green colour for easy identification as shown in Fig 5.19. As the user enables the switches the individual points of the parameter is awarded to the section. The sectional points are shown along with the section heading and the points are added dynamically as more parameters are enabled. The sectional heading is colour coded and the colour changes dynamically with each point getting added to the sectional total. By default all the sectional headings are red in colour and colour changes as the port attains more green port points and the percentage increases. The colour coding system is explained in Table 4.4. At the bottom of the page the total green port rating points are shown which is the total of all the section.

Exit Criteria

After the completion of the report the user has to click Proceed to move on to the next page.

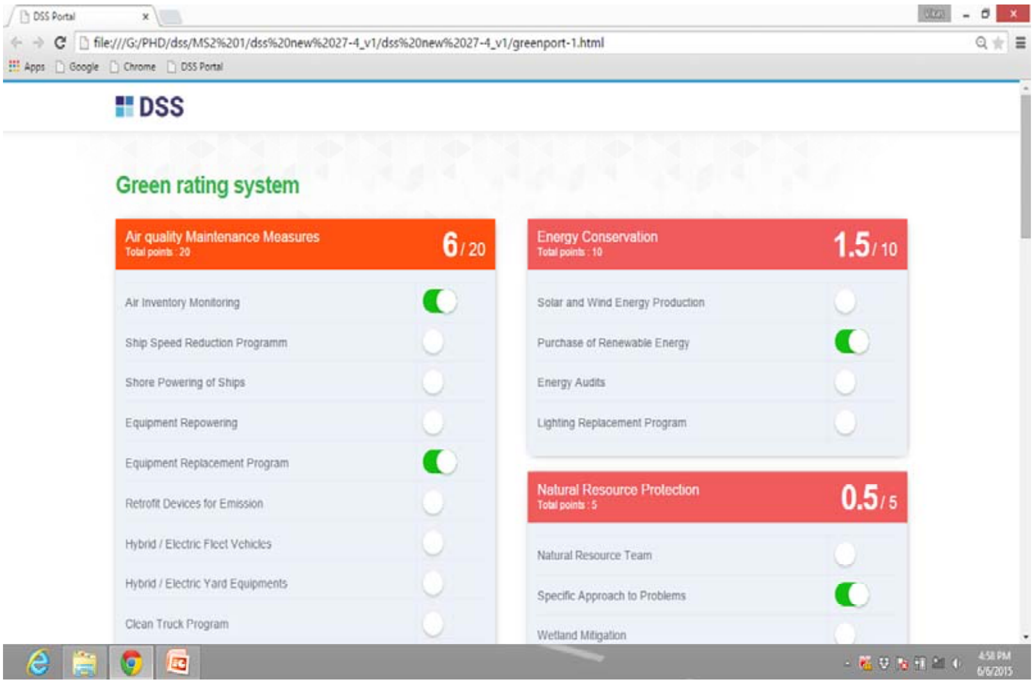

Fig 5.19 Green Rating System Input Page

5.4.7 Green Rating Output Page

Entry Criteria

This is the final page of the application and the entry to this page is by clicking Proceed from the previous page of green rating system input page.

Business Rules/Logic

The page displays a table as shown in Fig 5.20 which shows the 10 different sectional criteria for the green port rating system, the sectional percentage calculated from the points awarded in the previous page and in the comments column the individual rating of the sections. The sectional headings are colour coded. At the bottom of the table the overall percentage of the port is provided which is calculated from the total green rating points awarded in the previous page the overall green rating and colour code of the project is provided as explained in Table 4.4.

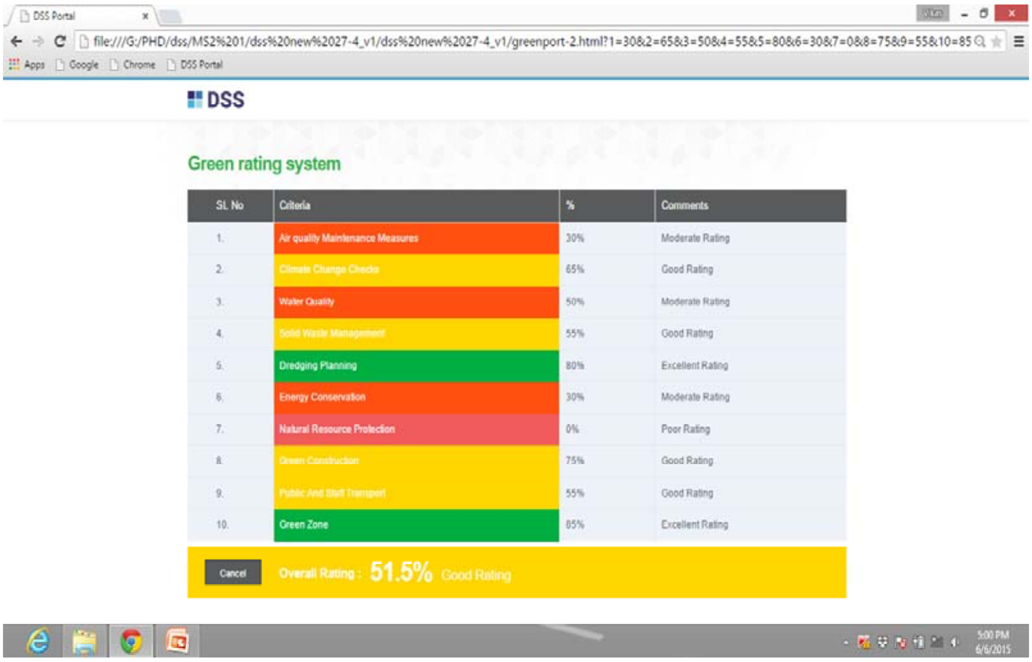

Fig 5.20` Green Rating System Output Page

Exit Criteria

The user can press the Proceed button to go back to the home page or Cancel button to go to the previous page.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Summary

1. Considering the uncertainties and seeking the flexible planning concepts, the various aspects of port planning viz., traffic forecasting, design ship selection, harbour requirement, optimal berth requirement, handling equipment system requirement, storage area requirement and planning for dredging works are identified for present study.
2. The design requirement of traffic volume that the port will handle is forecasted using the linear regression model. The various design parameters of physical characteristics of a harbour like entrance width, channel width, depth requirement of port and area requirement have been adopted from IS code 4651 Part V – 1980. The design of port features such as quay wall, handling equipments, storage area and dredging design have also been adopted.
3. The green rating parameters have been identified and are classified under the features such as air quality maintenance measure, climate change checks, water quality, solid waste management, dredging planning, energy conservation, natural resource protection, green construction, public and staff transport and green zone. Each parameter has been provided weightage according to the environmental impact and a green rating system is devised based on overall and sectional points assigning rating in colour code, percentage and rating.
4. Traffic forecasting methods such as route based, GDP linked and past data have been proposed using linear regression model to forecast the future traffic volume. Further an average forecast method has been incorporated to eliminate the inconsistency during the input data collection.
5. The DSS consists of 17 web pages for performing various functionality of which the first page is the login page that gives access to the software using a valid id and password. This is followed by home page which gives direct access to the various functions of the DSS traffic planning, port design and green port

rating; whichever the user prefers to perform. The rest of the pages are input and output pages for the above functions.

6. The DSS is developed based on MVC architecture with angular JS coding language for the structural framework and HTML5 and CSS3 for UI development, the graphs and tables are presented using high chart library.

6.2 Conclusions

1. From the review of literature and after understanding the complexities of planning and design procedure of port development the need of computerization has been felt.
2. From the case study conducted it is concluded that the DSS developed can be used for green rating of a port.
3. The DSS developed has a consolidated approach towards port and harbour planning, design and green port rating.
4. The DSS developed has formulated an approach for selection of dredging equipment for various harbour conditions and for the selection of handling equipment for a container terminal.

6.3 Significant Contributions

1. The DSS has been developed with a degree of separation between various components and has the advantage of adding more parameters in future without affecting the functioning of the existing code.

2. The DSS is developed as a web based software so as to allow quick updation and customization of newer versions, which is required to be done at the server side without affecting the client side.

3. The web based application developed gives a consolidated approach to the various aspects of port planning, design and green port rating and provides a common platform for addressing the same.

4. Traffic forecasting is the first step towards planning and development of a port. Traffic forecasting methods such as route based, GDP linked and past data

using linear regression model have been incorporated and an average forecast method has been employed to eliminate the inconsistency in forecast.

5. A procedure for dredging equipment and handling equipment selection has been formulated and has been incorporated into the DSS.
6. A questionnaire has been developed for collection of data for green rating of port and document required to be verified for the validation of various parameters have been identified and presented.
7. A qualitative method using various parameters identified has been developed for green rating of port.

6.4 Limitations of the Study

1. The traffic forecasting methods uses linear regression which gives the forecasted data but does not help in improving the quality of the forecasted data like removing inconsistencies. In the present study averages forecast of all the methods used is calculated to remove any inconsistencies in the data, but this cannot be applied when only one method is being used for forecasting.
2. The green rating system developed is only a qualitative study and does not consider what quantity of a particular parameter has been satisfied.
3. The DSS developed does not have a database for storage of data. At present the data is stored in the code and will be lost with each refresh. DSS architecture is designed to plug in a database in the future for the storage of data generated without requiring any changes in the present code.

6.5 Suggestions for Future Works

1. Statistical methods like trend analysis, exponential smoothening or moving averages can be employed to remove the inconsistencies in the forecasting data and to further improve the accuracy of forecast.
2. The green rating parameters can be quantified. It should be studied what percentage of a particular parameter is being satisfied and based on this the marks should be awarded partially or fully.

3. A database for permanent storage of data with a view of further study requirement can be developed and incorporated in the DSS. The database is required for the software to have commercial importance.

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APPENDIX 1

CASE STUDY FOR GREEN RATING OF A SAMPLE PORT

A1.1 Introduction

A case study for green port rating using the methodology discussed in the thesis has been carried out for a sample port in Kerala and the findings are being reported.

A1.2 Methodology Adopted for the Case Study

Qualitative studies of various aspects of the green rating system discussed in chapter 4 have been carried out at the sample port. Interview of various personnel has been conducted to collect feedback on the questionnaire prepared which has been given as Table 4.5 of chapter 4. The answered questionnaire has been given in Table A1 .1. The question answered as yes are marked green and answered as no are marked red as set in the software for easy identification.

Table A1.1 Data Collection Sheet for Sample Port

Sl.No.	Question	Yes	No
1	**Air Quality Maintenance Measures**		
1.1	Does the port have air monitoring stations for testing air quality?		
1.2	Are the ships entering the port asked to reduce the speed to attain better air quality?		
1.3	Are the ships at berth supplied power from the sources on shore?		
1.4	Does the port maintenance department follow an Equipment repowering program for heavy equipment for making them eco friendly?		
1.5	Does the port have an equipment replacement program to replace the existing older and less efficient equipment with eco friendly equipment?		
1.6	Are the existing non eco friendly equipment retrofitted with devices to meet the pollution standards?		
1.7	Does port have hybrid/electric fleet		

Sl.No.	Question	Yes	No
	vehicles?		
1.8	Does port have hybrid/electric Yard Equipments?		
1.9	Does the port have a clean truck program for the trucks entering the port?		
1.10	Does the port have any specific program/schedule to reduce idling time for the various equipments and vehicles?		
1.11	Does the port have any specific scheduling program to reduce rail and road congestion inside the port area?		
1.12	Does the port use alternative fuel like CNG/ biodiesel and USLD?		
2	**Climate Change**		
2.1	Does the port maintain and check green house gas inventory?		
2.2	Does the port calculate the carbon footprints caused by the various port operations?		
2.3	Does the port follow a carbon neutral commitment by offsetting for the carbon footprints caused by the port operations?		
2.4	Does the port have a climate change risk assessment program?		
2.5	Does the port have regular checks to assess the climate change risk caused due to the various operations and does the port make any corrective measures?		
3	**Water Quality**		
3.1	Does the rain water and surface runoff water made to filter into the ground water table using infiltration swales or any other methods?		
3.2	Does the port have pervious pavement to let the rain water filter into the ground water?		
3.3	Does the port use cyclonic devices to improve water quality?		
3.4	Does the port use filtering devices		

Sl.No.	Question	Yes	No
	to improve water quality?		
3.5	Does the port have oil/water separator to improve water quality?		
3.6	Does the port have a water conservation program?		
3.7	Does the port maintenance division use plumbing and irrigation retrofits to conserve water?		
3.8	Does the port have a ballast water treatment and haul fouling program to keep in check water contamination from ship waste water?		
4	**Waste Management**		
4.1	Does the port have an in house recycling program?		
4.2	Does the port have an office waste management program?		
4.3	Does the port have a mechanical waste management program?		
4.4	Does the port have a construction waste management program?		
4.5	Does the port have an electronic waste management program?		
4.6	Does the port participate in the hinterland waste management program?		
5	**Dredging**		
5.1	Does the port have a program to make planned reuse of dredging material?		
5.2	Does the port have a sediment suspension system to avoid settlement of materials?		
6	**Energy Conservation and Renewable Energy**		
6.1	Has the port invested in producing solar or wind energy?		
6.2	Does the port purchase energy from renewable sources?		
6.3	Does the port have energy audits?		
6.4	Does the port have lighting replacement program to replace the existing low efficient system with		

Sl.No.	Question	Yes	No
	LED lights?		
7	**Natural Resources**		
7.1	Does the port have a natural resource team to study the effect on the natural resources due to the operation of port?		
7.2	Does the port follow a problem specific approach while handling the various issues to natural resources due to port functioning?		
7.3	Does the port have a wetland mitigation program?		
7.4	Does the port participate or take initiative in any local program to conserve the natural resources of the hinterland?		
7.5	Does the port fund or take part in conservation of endangered species program?		
7.6	Does the port have an invasive species program to check the effect of invasive species on local species due to hull fouling?		
8	**Green Construction**		
8.1	Does the port promote the use of recycled product?		
8.2	Does the port promote the reuse of material removed to less important areas?		
8.3	Does the port purchase used furniture?		
8.4	Does the port lay strict norms on reducing the use of PVC products?		
8.5	Does the port promote the green certified manufacturers and vendors?		
8.6	Does the port insist on materials with low maintenance?		
8.7	Does the port promote on use of locally available materials for construction?		

Sl.No.	Question	Yes	No
8.8	Does the port do a study of recyclability and reuse of materials used in construction of various components?		
8.9	Does the port insist on use of low VOC paints?		
8.10	Does the port relay on natural air circulation system in office space?		
8.11	Are the office and other work space designed for maximum natural ventilation to reduce the use of electricity consumption due to artificial lighting in the morning time?		
8.12	Does the port promote indoor plant in work space for fresh air circulation?		
8.13	Does the port insist on nonchemical cleaning agents in the office space?		
9	**Public and Staff Transport**		
9.1	Does the port have proper bicycle lane connectivity between various buildings and operational areas?		
9.2	Does the port have separate area for storage of bicycles and special facility for changing and taking shower for the cyclists?		
9.3	Does the port have an employee pick up system?		
9.4	Does the port promote and have a car pooling program to coordinate between the employees?		
9.5	Does the port have transport facility to nearby public transport facility?		
9.6	Does the port promote and have facility for video conferencing to reduce frequent travels for meetings?		
9.7	Does the port have sufficient lane and gate facility to reduce idling and traffic congestion in the port?		
10	**Green Zone**		
10.1	Does the port have a green belt development program?		

Sl.No.	Question	Yes	No
10.2	Does the port have plant a tree program for the employees?		
10.3	Does the port promote the use of recycled materials in landscaping?		
10.4	Does the port promote the use of used materials in landscaping?		
10.5	Does the port have a program for the revival of endangered plant species in the green zone development area?		
10.6	Does the port do landscaping design without cutting down trees?		

A1.3 Green Port Rating Using DSS

The data have been entered into the DSS on green rating input page which is shown in figure A1.1. The output of the study has been given as figure A1.2

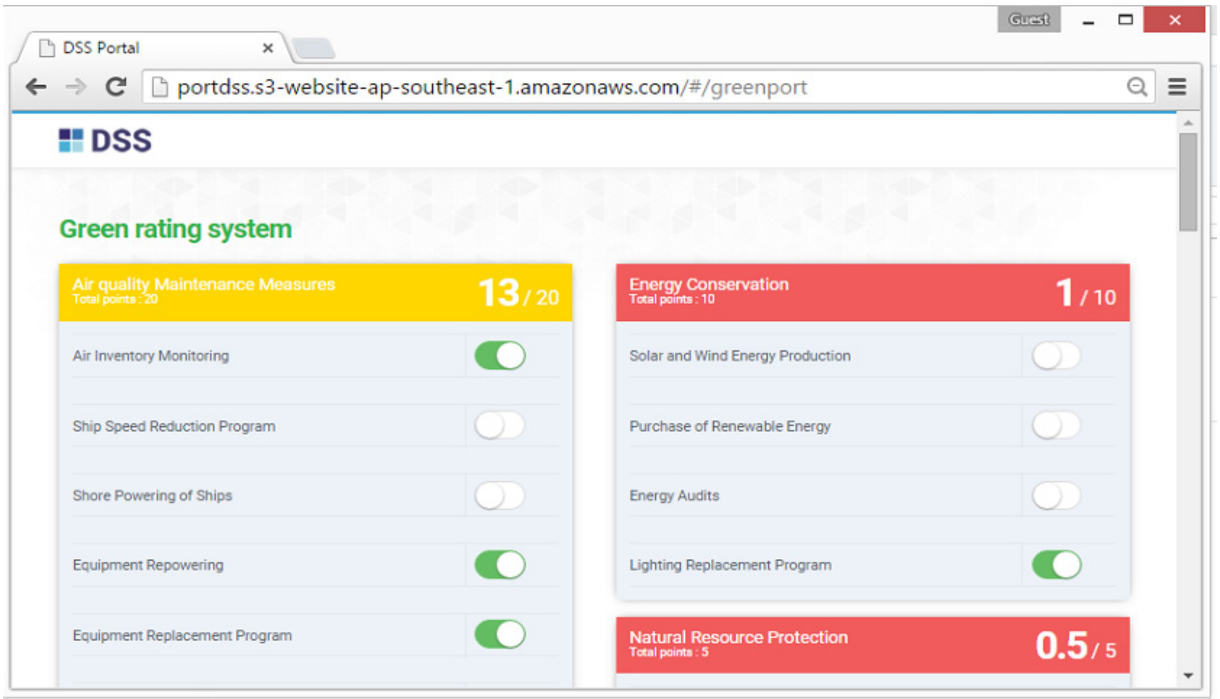
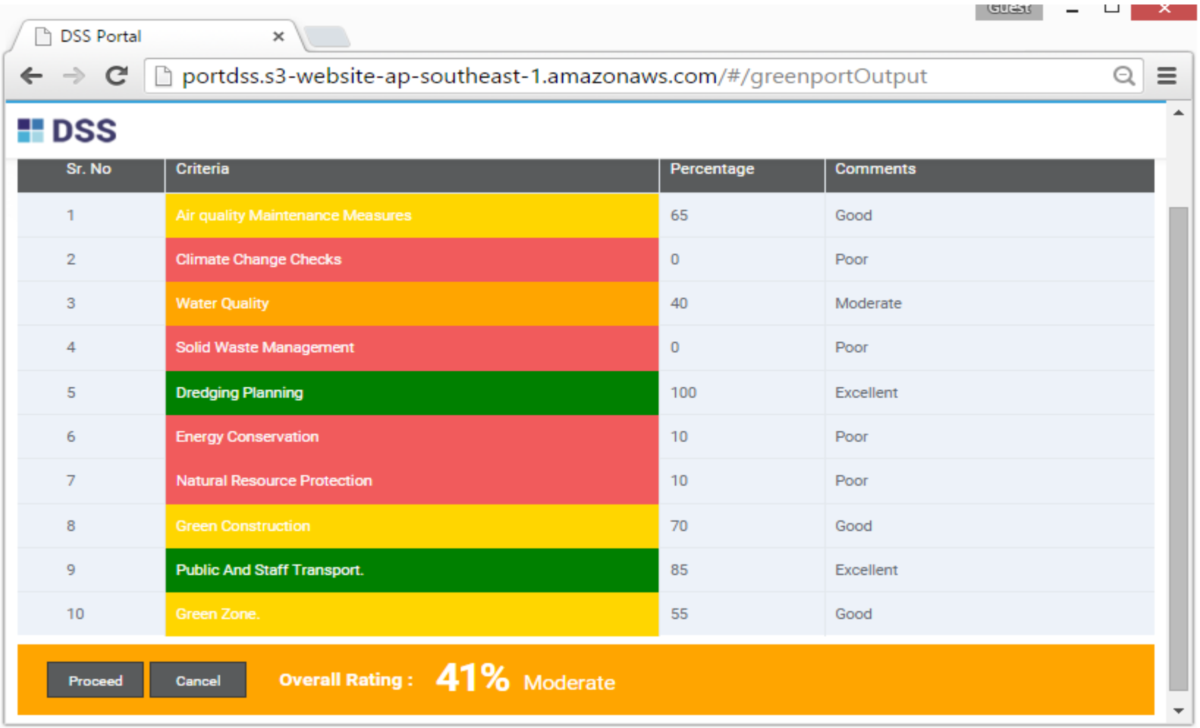


Fig A1.1 Green Rating Input for Sample Port



Sr. No	Criteria	Percentage	Comments
1	Air quality Maintenance Measures	65	Good
2	Climate Change Checks	0	Poor
3	Water Quality	40	Moderate
4	Solid Waste Management	0	Poor
5	Dredging Planning	100	Excellent
6	Energy Conservation	10	Poor
7	Natural Resource Protection	10	Poor
8	Green Construction	70	Good
9	Public And Staff Transport.	85	Excellent
10	Green Zone.	55	Good

Fig A1.2 Green Rating Output for Sample Port

A1.4 Inference of the Case Study

The overall rating of the port can be understood only by studying the individual parameters which add up to the total rating points. The logic of point calculation and sectional rating has been done based on the discussion in Section 4.3 and Table 4.3. The analysis of rating achieved based on the input provided from the study, discussion of output and suggestion for improvement of the rating are further presented.

A1.4.1 Air Environment

The subsections relevant to this parameter are described in section 4.2.1 and the points given to each subsection is shown in Table 4.3 under Sl.No.1. As per the output of the software the following are the rating of the air environment parameter.

Percentage Points = 65%   Rating = Good   Colour Code = Yellow

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port has got a good rating in the air environment maintenance measures, further improvement in this aspect can be done by enforcing the reduction in the speed of the ship in the port area and by shore powering the ships during berth. The speed reduction program can be easily implemented as this does not have any huge monitory implications. But the shore powering of ship will be difficult to incorporate as the shipping company will have to be convinced to add retrofits to take power from the shore to various equipments in the ship. So to improve the rating air environment the port can initially implement the speed reduction program.

A1.4.2 Climate Change

The relevant subsections of this parameter are described in section 4.2.2 and the points given to each subsection is shown in Table 4.3 under Sl.No.2. As per the output of the software the following are the rating of the climate change parameter.

Percentage Points = 0%   Rating = Poor   Colour Code = Red

The rating and colour code has been provided as per the standards provided in Table 4.4.

From the zero percentage points it is understood that the port has not undertaken any climate change check programs. As the port has already got an air quality monitoring system in place it would be easy to incorporate the greenhouse gas inventory program and subsequently this will help in improving the rating in this parameter. The port should also start the carbon footprint calculation as this a mandatory requirement towards the green port commitment. These two points need to be urgently addressed with high priority to achieve overall better green rating.

A1.4.3 Water Quality

The subsections relevant to this parameter are described in section 4.2.3 and the points given to each subsection is shown in Table 4.3 under Sl.No.3. As per the output of the software the following are the rating of the water quality parameter.

Percentage Points = 40%   Rating = Moderate   Colour Code = Orange

The rating and colour code has been provided as per the standards provided in Table 4.4.

It is presently observed that the port allows the rain water to be collected in drains and is left to reach the lake water. The port has got well connected drains which collects rain water and disposes it in to the water body. This needs to be prevented and the rain water needs to be infiltered into the ground for replenishment. It is also observed that the port does not use pervious pavement to allow the rain water to seep in to the ground water. The port policy needs to be changed and in future the port needs to replace its pavements with pervious type.

A1.4.4 Solid Waste Management

The subsections relevant to this parameter are described in section 4.2.4 and the points given to each subsection is shown in Table 4.3 under Sl.No.4. As per the output of the software the following are the rating of the solid waste management parameter.

Percentage Points = 0%   Rating = Poor   Colour Code = Red

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port does not have any waste management program. This is a serious offence and it is observed that the waste from the office and quarters is disposed off in the dumping ground. The port being a government body should immediately reconsider the waste management policy as the nation itself is moving towards Swachh Barath. The port should implement an in-house recycling program. The port should have clear policies and system for waste management program for office, mechanical, construction and electronic waste on the base of recycle, reduce and reuse.

A1.4.5 Dredging

The relevant subsections of this parameter are described in section 4.2.5 and the points given to each subsection is shown in Table 4.3 under Sl.No.5. As per the output of the software the following are the rating of the dredging parameter.

Percentage Points = 100%   Rating = Excellent   Colour Code = Green

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port has received full points in dredging with an excellent rating.

A1.4.6 Energy Conservation

The relevant subsections of this parameter are described in section 4.2.6 and the points given to each subsection is shown in Table 4.3 under Sl.No.6. As per the output of the software the following are the rating of the energy conservation parameter.

Percentage Points = 10%   Rating = Poor   Colour Code = Red

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port is not doing much in the energy conservation section; port having vast land area should invest on solar energy production. The port can also invest in wind farms to get better rating in this section. The port should have energy audit to check for energy neutral commitment by investing in solar and wind energy production.

A1.4.7 Natural Resource Protection

The relevant subsections of this parameter are described in section 4.2.7 and the points given to each subsection is shown in Table 4.3 under Sl.No.7. As per the output of the software the following are the rating of the natural resource protection parameter.

Percentage Points = 10% Rating = Poor Colour Code = Red

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port should have a commitment to the local environment, and should form a natural resource team to study the effect on the local natural resources due to the developments in port activities as well as due to other causes. The port can conduct programs and seminars on the protection of the local natural resource. The port can also take part by funding some of the species conservation programs.

A1.4.8 Green Construction

The subsections relevant to this parameter are described in section 4.2.8 and the points given to each subsection is shown in Table 4.3 under Sl.No.8. As per the output of the software the following are the rating of the green construction parameter.

Percentage Points = 70% Rating = Good Colour Code = Yellow

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port has a got a good rating in the green construction parameter but this needs to be improved as the port area is always engaged with construction activities. It is seen that the port does not adopt the policy of recycle, reduce and reuse, which is the mantra of green construction. The port should adopt this policy wherever possible to achieve better green construction rating.

A1.4.9 Public and Staff Transport

The relevant subsections of this parameter are as described in section 4.2.9 and the points given to each subsection is shown in Table 4.3 under Sl.No.9. As per the output of the software the following are the rating of the public and staff transport parameter.

Percentage Points = 85%   Rating = Excellent   Colour Code = Green

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port has got excellent rating in this parameter with green colour code.

A1.4.10 Green Zone

The relevant subsections of this parameter are as described in section 4.2.10 and the points given to each subsection is shown in Table 4.3 under Sl.No.10. As per the output of the software the following are the rating of the green zone parameter.

Percentage Points = 55%   Rating = Good   Colour Code = Yellow

The rating and colour code has been provided as per the standards provided in Table 4.4.

The port has got vast area dedicated for the port development and it is also observed that the port has maintained the green belt by developing parks and protecting the trees. To improve rating in this parameter the port should start plant a tree program for the employees to bring individual commitment. The port has lost point in this section because it has not adopted the policy ‘recycle, reduce and reuse’.

A1.4.11 Overall Green Port Rating of the Sample Port

The overall percentage points awarded to the sample port is calculated based on the Table 4.2 and the rating and colour code is provided based on Table 4.4.

Percentage Points = 41%   Rating = Moderate   Colour Code = Orange

The overall green rating based on the output from the DSS is as shown in figure A1.2.

It is inferred that the green port rating of the sample port is only moderate. The various green parameters have been individually to be analyzed and corrective measures as described in the above sections need to be implemented to improve the green rating.

A1.5 Summary and Recommendations

1. The port has got excellent rating in parameters dredging and public and staff transport.
2. The port has got good rating in parameters air environment, green construction and green zone.
3. The port has got moderate rating in parameter water quality.
4. The port has got poor rating in parameters climate change, waste management, energy conservation and natural resource protection.
5. The overall green rating of port is moderate.
6. It is observed from the study that for parameter which are immediately affected by the operations and development of port like air quality improvement, green construction and dredging have received better green rating. Along with this the port has also taken care of public and staff facilities and green zone maintenance.
7. It is observed that the port has failed in achieving better rating in water quality, waste management, energy conservation and natural resource protection as the port may feel that it is not in the preview of port operation and functioning.
8. The port needs to follow a structured green port rating system so that it can address all the parameters of green port and achieve better rating.
9. The port needs to invest in solar and wind energy systems to achieve energy neutrality.
10. The port needs to adopt the policy of recycle, reduce and reuse whereever possible to achieve better rating.

11. It can be concluded from the case study that the software can be used to understand the area of improvement required to achieve better green rating for an existing port and in case of a new port, the planner can follow the guidelines provided in the chapter 4 to develop a port with higher green port rating.

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LIST OF PUBLICATIONS

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1. **Vikas V. Shenoy, Sivaprasad K, C G Nandakumar,** Recycling of demolished products of RCC buildings, National seminar on recent advances in civil engineering, Civil Engineering Department, RACE – 08, CUSAT, Kochi, India. 109-112,2008.
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Paper to be Published

1. **Vikas V. Shenoy, C G Nandakumar,** Green Rating System for Sustainable Infrastructural Planning, "Materials for Sustainable Build Environment". Special Topic Volume. Transtech Publication, December 2015.

Papers Communicated

1. **Vikas V. Shenoy, C G Nandakumar,** Decission Support System for Port Planning and Design for Container Terminal. International Journal of transportation Engineering, IJTE, Tarahan Parseh Trasportation research Institute.
2. **Vikas V. Shenoy, C G Nandakumar,** Developing a Web Based Application for Green Port Rating, Journal for Green Building ISSN 1552-6100.