DEVELOPMENT OF BEST PRACTICES FOR SHIP RECYCLING PROCESSES

A Thesis

Submitted By

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Dedicated to my father, late P R Ravi Varma, who introduced to me the ways of Dharma ; the 'mantra' for sustainable development.

DECLARATION

This is to certify that the thesis entitled '**DEVELOPMENT OF BEST PRACTICES FOR SHIP RECYCLING PROCESSES**' submitted to the Cochin University of Science and Technology in partial fulfilment 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

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CERTIFICATE

This is to certify that the thesis entitled '**DEVELOPMENT OF BEST PRACTICES FOR SHIP RECYCLING PROCESSES**' submitted by Sivaprasad K to the Cochin University of Science and Technology in partial fulfilment 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.

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Research work leading to a doctoral degree is a well planned academic exercise which couples intellectual pursuit with social commitment. Any research work which involves studies on ‘Recycling’ is intellectually challenging and has ample social commitment attached to it.

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ABSTRACT

Ship recycling has been considered as the best means to dispose off an obsolete ship. The current state of art of technology combined with the demands of sustainable developments from the global maritime industrial sector has modified the status of erstwhile 'ship breaking' involving ship scrap business to a modern industry undertaking dismantling of ships and recycling/reusing the dismantled products in a supply chain of pre owned product market by following the principles of recycling. Industries will have to formulate a set of *best practices* and blend them with the engineering activities for producing better quality products, improving the productivity and for achieving improved performances related to sustainable development. Improved performance by industries in a sustainable development perspective is accomplished only by implementing the 4E principles, ie.,. eco-friendliness, engineering efficiency, energy conservation and ergonomics in their core operations. The present study has done a comprehensive investigation into various ship recycling operations for formulating a set of *best practices*.

Being the ultimate life cycle stage of a ship, ship recycling activities incorporate certain commercial procedures well in advance to facilitate the objectives of dismantling and recycling/reusing of various parts of the vessel. Thorough knowledge regarding these background procedures in ship recycling is essential for examining and understanding the industrial business operations associated with it. As a first step, the practices followed in merchant shipping operations regarding the decision on decommissioning have been and made available in the thesis. Brief description about the positioning methods and important preparations for the most feasible ship recycling method ie.,. beach method have been provided as a part of the outline of the background information. Available sources of guidelines, codes and rules & regulations for ship recycling have been compiled and included in the discussion.

Very brief summary of practices in major ship recycling destinations has been prepared and listed for providing an overview of the global ship recycling activities. The present status of ship recycling by treating it as a full fledged engineering industry has been brought out to establish the need for looking into the development of the *best practices*. Major engineering attributes of ship as a unique engineering

product and the significant influencing factors on her life cycle stage operations have been studied and added to the information base on ship recycling. Role of ship recycling industry as an important player in global sustainable development efforts has been reviewed by analysing the benefits of ship recycling. A brief synopsis on the state of art of ship recycling in major international ship recycling centres has also been incorporated in the backdrop knowledgebase generation on ship recycling processes.

Publications available in this field have been reviewed and classified into five subject categories viz., Infrastructure for recycling yards and methods of dismantling, Rules regarding ship recycling activities, Environmental and safety aspects of ship recycling, Role of naval architects and ship classification societies, Application of information technology and Demand forecasting. The inference from the literature survey have been summarised and recorded. Noticeable observations in the inference include need of creation of a comprehensive knowledgebase on ship recycling and its effective implementation in the industry and the insignificant involvement of naval architects and shipbuilding engineers in ship recycling industry. These two important inferences and the message conveyed by them have been addressed with due importance in the subsequent part of the present study.

As a part of the study the importance of demand forecasting in ship recycling has been introduced and presented. A sample input for ship recycling data for implementation of computer based methods of demand forecasting has been presented in this section of the thesis.

The interdisciplinary nature of engineering processes involved in ship recycling has been identified as one of the important features of this industry. The present study has identified more than a dozen major stake holders in ship recycling having their own interests and roles. It has also been observed that most of the ship recycling activities is carried out in South East Asian countries where the beach based ship recycling is done in yards without proper infrastructure support. A model of beach based ship recycling has been developed and the roles, responsibilities and the mutual interactions of the elements of the system have been documented as a part of the study Subsequently the need of a generation of a wide knowledgebase on ship recycling activities as pointed out by the literature survey has been addressed. The information base and source of expertise required to build a broad knowledgebase on ship recycling operations have been identified and tabulated. Eleven important ship recycling processes have been identified and a brief sketch of steps involved in these processes have been examined and addressed in detail. Based on these findings, a detailed sequential disassembly process plan of ship recycling has been prepared and charted. After having established the need of *best practices* in ship recycling initially, the present study here identifies development of a user friendly expert system for ship recycling process as one of the constituents of the proposed *best practises*. A user friendly expert system has been developed for beach based ship recycling processes and is named as Ship Recycling Recommender (SRR). Two important functions of SRR, first one for the 'Administrators', the stake holders at the helm of the ship recycling affairs and second one for the 'Users', the stake holders who execute the actual dismantling have been presented by highlighting the steps involved in the execution of the software. The important output generated, ie.,. recommended practices for ship dismantling processes and safe handling information on materials present onboard have been presented with the help of ship recycling reports generated by the expert system. A brief account of necessity of having a ship recycling work content estimation as part of the *best practices* has been presented in the study. This is supported by a detailed work estimation schedule for the same as one of the appendices.

As mentioned earlier, a definite lack of involvement of naval architect has been observed in development of methodologies for improving the status of ship recycling industry. Present study has put forward a holistic approach to review the status of ship recycling not simply as end of life activity of all 'time expired' vessels, but as a focal point of integrating all life cycle activities. A new engineering design philosophy targeting sustainable development of marine industrial domain, named *design for ship recycling* has been identified, formulated and presented. A new model of ship life cycle has been proposed by adding few stages to the traditional life cycle after analysing their critical role in accomplishing clean and safe end of life and partial dismantling of ships. Two applications of *design for ship recycling* viz, recyclability of ships and her products and allotment of Green Safety Index for ships have been presented as a part of implementation of the philosophy in actual practice.

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ABBREVATIONS

ACGIH	American Conference of Government Industrial Hygienists
AEGL	Acute Exposure Guidelines Limit
ASP.NET	Active Server Page. Network Enabled Technology
BAN	Ban Asbestos Network
BOD	Biochemical Oxygen Demand
CAA RMP	Clean Air Act Risk Management Plan
CAS	Chemical Abstract Number
CEC	Commission of European Communities
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Chemical Functional Review
CHRIS	Chemical Hazard Information Response System
COD5	Chemical Oxygen Demand in (5 days)
DNV	Dets Norske Veritas, Norway
DOT	Department of Transport, USA
DOVE	Database of Obsolete Vessels
DSCL	Dangerous Substance Classification List
EHS	Environment Health and Safety
EPCRA	Emergency Planning and Community **Right to know** Act
FPSO	Floating Production Storage and Offloading
ERPG	Emergency Response Planning Guidelines
ESM	Environmentally Sound Management
FRP	Fibre Reinforced Plastic
GMB	Gujrath Maritime Board
HMIS	Hazardous Material Identification System
HTML	Hyper Text Mark up Language
HTTP	Hyper text Transfer Protocol
IACS	International Association of Classification Societies
IARC	International Agency for Research on Cancer
ICS	International Chamber of Shipping
IDLH	Immediately Dangerous to Life or Health
LDT	Light Displacement Tonnes

IIS	Internet Information System
ILO	International Labour Organisation
IMO	International Maritime Organisation
ISO	International Standardisation Organisation
LNG	Liquefied Natural Gas
MARAD	Maritime Administration, USA
MARPOL	Marine Pollution Conference, IMO
MEPC	Marine Environment Protection Committee
MSC	Marine Safety Committee, IMO
MSDS	Material Safety Data Sheet
NIOSH	National Institute of Occupational Safety and Health
NTP	National Toxology Programme
OSHA	Occupational Health and Safety Act, USA
PCB	Polychlorinated Biphenyl
RCRA	Resource Conservation and Recovery Act, USA
SCAPA	Society for Checking Abuse of Public by Advertisement
SRR	Ship Recycler Recommender
TBT	Tributyltin (Anti-fouling paint)
TCP/IP	Transmission Control Protocol/Internet Protocol
TEEL	Temporary Emergency Exposure Limit
TLV	Threshold Limit Value
TRI	Toxic Release Inventory (EPA)
UNEP	United Nations Environmental Programme
WHMIS	Workplace Hazard Material Information System

CHAPTER 1

INTRODUCTION

1.1 GENERAL

There has always been a consistent shift in the terminology used to represent the processes involving ultimate disassembly of ships depending on the prevailing technological focus on the issue. The various terms used in the past include, 'Ship Scrapping", "Decommissioning of Ships", 'Abandonment of Ships", "Ship Breaking" and "Ship Dismantling'. The current state of art of technology combined with other global issues in sustainable development has modified the terminology used to represent the ultimate disassembly of marine vessels as Ship Recycling.

International Maritime Organisation (IMO) has defined ship recycling as the best option for all 'time expired' vessels. A comprehensive definition of ship recycling given by the author as a basis for the formulation of the present study is as follows, "A Systematic engineering process involving dismantling and reusing of hull and machinery parts of an obsolete vessel in a safe and environment friendly fashion, simultaneously focusing on issues such as energy conservation and sustainable development." Ship recycling has been considered as the best means to dispose off a ship either at the end of her operational life or at any point of her life as decided by the owner, regulatory bodies or the classification society. The recycling process should involve careful handling of harmful materials and systems, safer dismantling operations, logical supply chain management, and direct and indirect energy saving activities.

The Second World War produced a different kind of fleet called "obsolete fleet" in countries such as United States, United Kingdom and Germany. Decommissioning of this fleet opened up a new type of engineering industry called "Obsolete Vessel Scrapping." This industry changed it's status according to the prevailing engineering advancement and socio-economic demands in the international scenario. In the meantime, the industry also migrated to various locations around the globe. During the second half of twentieth century the ship scrapping industry was centered on respective home ports of the obsolete fleet. More stringent rules and regulations imposed by the flag states in Europe and by the US administration regarding safety and environmental impacts during the scrapping, forced the industry to move towards the Eastern Europe. The cost advantages and relaxed type of rules and non stringent enforcement mechanism of rules prevailing in the South Asian countries attracted the ship owners to move toward countries such as India, Pakistan and China. The recent trend shows movement of this industry towards Bangladesh, one of the economically most under developed countries in South Asia [DNV 2000].

The so called recycling activities in major ship recycling destinations in the South East Asian countries are done in haphazard way with minimum focus on safety and environmental aspects. Lack of application of ship recycling standards, minimum use of recommended practices in dismantling, handling, storing, transport and disposal activities, absence of use of effective knowledge base and illiteracy among the labourers add fuel to backwardness of this industry. The need of the hour is the use of emerging information technology applications to develop a system which can uplift the standard of the recycling industry from ship scrapping to true ship recycling is envisaged. Also what is more required is to give facelift to the industry from the present day status of “hazardous business” to “modern industry”.

Ever since the reports on tragedies involving human life loss and growing threat on environment from the way in which ship breaking activities are conducted all over the world started flowing in, the international engineering community and the green NGOs have started showing their presence in the scene. The gravity of problems related to safety and environment pollution caused by the ship breaking activities will have to be addressed in detail and immediate initiatives are to be implemented and research projects are to be initiated immediately, otherwise the threat can go to a very dangerous level, even affecting international shipping. More serious, comprehensive and exhaustive studies are to be undertaken in order to evolve more rational and scientific approach in ship recycling. The proposed research aims at analyzing the ship recycling problem in various angles such as engineering efficiency, ecofriendliness and energy conservation and ergonomics.

All physical systems undergo three essential phases in their entire life span. The initial phase is called as creation, the intermediate phase is known as sustenance and the final one is nothing but decay and the system ceases to function as it has been designed. There after components of the system will be converted to some other form and it will be entering to another system and the cycle is repeated endlessly. This is the essence of Recycling. All natural physical systems are found to be following a fine tuned and harmonized life cycle phase transformation. In these systems all the stages simply happen without any external intervention. For some system the span of these life cycle phases is very trivial where as in some it takes millions of years. Ultimately everything vanishes and reappears in another form following a natural recycling plan. The situation is different for manmade systems (products in this context) which fail to deliver the complete natural life cycle. This phenomenon has already sent serious signals to issues in environmental preservation and safety of life on the earth and has provided initiative for the research in recycling studies. Action plans are implemented all over the world in various areas of science, technology and engineering to address issues related to recycling. For a ship the three natural phases of life cycle activities can be identified as, design and construction as creation, shipping operations as sustenance and dismantling as the decay. When a fourth stage of recycling is envisaged here, an opportunity for rebirth in some other form is provided for the ship.

Formulation and implementation of *Best Practices* are essential for all industries to improve the quality and productivity of various activities undertaken. Ship recycling is no exception to this; moreover application of *Best Practices* is an urgent need in ship recycling industry owing to its bad reputation as risky industry causing environmental pollution [IMO 2009]. *Best practices* may not be strictly a part of the stringent rules and regulations, but it should be a set of voluntary measure taken by the industry to contribute to the sustainable development of the maritime industrial sector. These practices offer best possible option to improve the quality standard of ship recycling industry [DNV 2000]. The suggested *Best Practices* in this thesis include the following

- Conceptual model of *Design for Ship Recycling* incorporating Naval Architectural content
- Development of user friendly Expert System for Ship Recycling processes
- Generation of schedule of estimation of ship recycling work content
- Allotment of sustainable development index based on green and safety aspects of vessels.

1.2 SCOPE AND OBJECTIVES

The engineering of ship breaking has to be given a comprehensive formulation of framework as the disassembly and recycling of ship rather than as hull steel recovery. The various aspects of this frame work have been addressed in the present study. The objectives are set as given below:

i. To review the literature available in ship dismantling and recycling and acquire thorough understanding of the current status of the industry.
ii. To identify the parameters in ship recycling processes and assign them in the application of appropriate forecasting models for ship breaking demand forecasting.
iii. To conduct critical analysis of existing methods and yard practices in the ship dismantling industry and to develop Knowledge Based Expert System (KBES) for ship recycling, based on the philosophy of 4 Es, viz, Engineering efficiency, Ecofriendliness, Energy conservation and Ergonomics. Also it is planned to generate the output of the KBES as the *best practices* for ship recycling.
iv. To develop the *design for ship recycling* concepts in shipbuilding based on naval architectural aspects.

1.3 CONTENT OF THE THESIS

Chapter 1 deals with the general introduction to the research topic. Ship recycling processes are given in Chapter 2. In Chapter 3 literature review on ship recycling has been reported. The ship recycling demand forecasting has been given in Chapter 4. In Chapter 5 the development of expert system for ship recycling operations has been described. *Design for ship recycling* is the content of Chapter 6. Chapter 7 deals with summary and conclusions. Detailed information regarding various ship recycling activities undertaken at Alang Ship Recycling Yard, Ship Recycler Recommender (SRR) User Manual, sample report generated by Ship Recycler Recommender and schedule of estimation of ship recycling activities, are given as appendices.

CHAPTER 2

SHIP RECYCLING PROCESS

2.1 OPERATIONS IN SHIP RECYCLING PROCESS

Various engineering activities in ship recycling industry have been viewed as ship recycling processes in the present study. An overview of the processes in ship recycling is presented in this chapter. This is essential for understanding the state of art of this industry. Moreover the recommendations and suggestions for improvement to be proposed by the present study are to be based on the existing operations involved in ship recycling processes.

2.2 BACKGROUND OPERATIONS IN SHIP RECYCLING

Ship recycling being the last activity in the life cycle of a vessel, certain important commercial and engineering operations are to be carried out well in advance to facilitate the objectives of dismantling and recycling. Thorough knowledge regarding these background activities are essential for understanding and realising the ship recycling processes and treating ship recycling as a modern industrial business activity . A schematic representation of flow of related activities has been given in fig 2.1.

2.2.1 Decision on Decommissioning of Ships

At present there are no international regulations, seeking the retirement of a ship from service. Ship classification societies are very active in merchant shipping technical operations and take a lead role in various decision making activities. However, they have little role to play in the decommissioning. There are no ship classification society rules recommending dismantling of an obsolete ship. However the ship classification societies can declass a ship according to their rules and regulations. This decision does not mean that the ship declassed by the ship classification society be scrapped immediately. The owner can change the flag, or can approach other ship classification societies which are not affiliated to International Association of Classification Societies (IACS) which may be ready to register any vessel under their classification survey

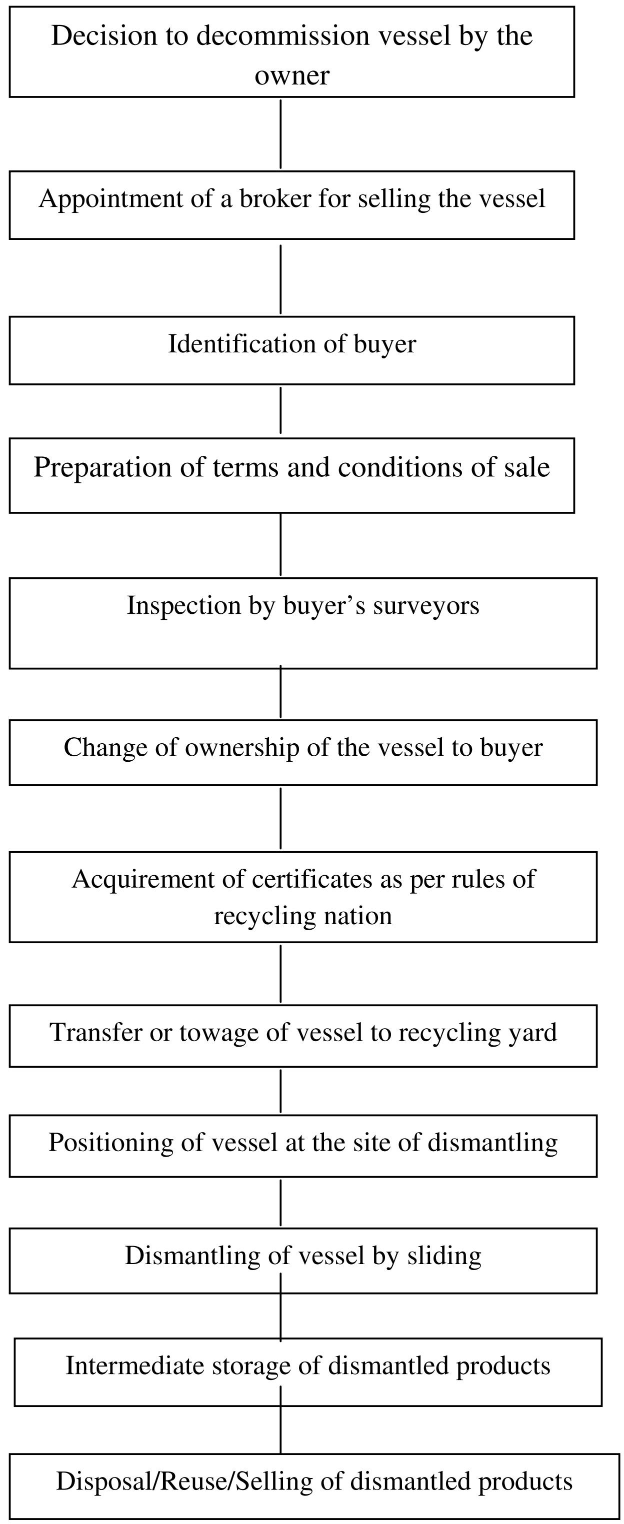

Fig. 2.1 Schematic Diagram of Flow of Activities in Ship Recycling

This will enable the ship owners to extend the life of their vessels. Ultimately, the decision of withdrawing a vessel from service is fully left to the owner of the vessel. Based upon the prevailing returns from shipping operations or scrap ship value the owner decides the fate of his vessel.

2.2.2 Activities Involving Ship Recycling Brokers

Before reaching the last owner (who is responsible for towing the ship to the positioning site for dismantling) the obsolete ship may pass through different intermediate owners. Owners of decommissioned ships are not called ship owners as the ship ceases to be operational and becomes scrap [Basel 2005]. Intermediate owners of such vessels are called as ship recycling brokers. Whenever the ship owners decide to decommission their vessels, information regarding this is made available in global information platforms such as internet websites and maritime publications. Interested ship recycling brokers approach the owners and transfer the ownership by paying advance amount. Then the broker invites quotation from potential buyers. Based on the highest bid offer from the buyers, the broker fixes the buyer and Memorandum Of Understanding (MOU) is signed between the ship owner and the buyer. The MOU clearly states the conditions of transfer of the ship to the dismantling site and other prerequisites. A ship surveyor as representative of the buyer will thoroughly inspect the vessel and give a report. The buyer pays the price to the owner based on surveyor's report. It is the responsibility of the broker to arrange all these activities including arranging relevant certificates for transferring the vessel from a foreign owner to the end buyer or dismantler treating the vessel as imported commodity (or import).

2.2.3 Obsolete Vessel Positioning Methods

The three commonly used positioning methods in ship recycling are the beach method, dry dock method and buoy method.

Beach method is employed at shallow basins with long shelf bed where high tidal variations are available. The main beaching is done during high tide. The beached vessel is progressively slide up, to the recycling yard during successive high tides. Entire dismantling operations are done in the beach area available in the water front of the recycling yard. This method has been employed at Alang Recycling yard, in

Gujrath , Darukhana in Mumbai, Chittagong in Bangladesh and Gaddani in Karachi. Obsolete ships beached in a ship recycling yard for dismantling is shown in fig. 2.2.

Fig. 2.2 Obsolete Ships Beached for Dismantling (Sibal 2001)

In **Dry Dock method or Berth method,** obsolete ship is taken to dry dock facility in a ship recycling yard. This method can be called as disassembly method of ships in ship recycling yards. The major difference between dry dock method and beach method is the presence of a concrete barrier between the dismantled vessel and sea water. Progressive sliding for transporting the vessel within the yard premises is absent in the latter. Western European countries and United States practice this method. Obsolete ship docked in a dry dock ready for dismantling is shown in fig. 2.3.

Buoy method is named after the dismantling process being carried out in floating conditions. Obsolete vessels are berthed in quay side of sea ports and shipyards for dismantling. The dismantling is done by cutting and removing the ship parts in vertical direction. Starting from top of navigation deck and subsequently reaching double bottom. The cutting peripheries do not come in contact with sea water. Most of the recycling yards operating in China make use of buoy method of ship dismantling

Fig. 2.3 Obsolete Ship Docked in Dry Dock for Dismantling (Sibal 2001)

Fig. 2.4 shows dismantling operations using buoy method which uses quay side for mooring the obsolete vessel.

Fig. 2.4 Dismantling of Obsolete Ship by Buoy Method.(Sibal 2001)

2.2.4 Permission for Positioning

On arrival at the outer port, brokers or agents of the ship owner inform the recycling yard/port authorities regarding positioning of vessels at the anchorage. The inspection team of the recycling yard makes a thorough check of various mandatory certificates regarding the import/export shipment and payment of taxes and excise duties to be produced by the owner before beaching the vessel. As per existing practice, one deck officer, one certified marine engineer and the master of the vessel must be present during the check by the yard/ port authorities. A detailed inventory of communication equipment used by the obsolete vessel is prepared. These are to be handed over to the wireless board of the recycler state immediately after completion of beaching. A comprehensive list of marine supplies and safety measures implemented onboard are prepared by the yard/port authorities. After this, permission will be granted and the ship will be allowed to enter the beach either by towing or by its own propulsion.

2.2.5 Preparations for Dismantling

The preparation for dismantling begins with the submission of man entry certificate and hot work certificate from the explosive department to the recycling statutory authority operating from the recycling yard. All kinds of petroleum oils including even inflammable gas in the fuel tank of the vessel have to be emptied and evacuated before starting of the cutting operations. Cutting is started after taking written permission from the local port authority. If the ship is beached away, shore lightening is allowed with the permission of port office.

2.2.6 Dismantling Operations

Major steps involved in the ship dismantling practices in beach method are briefly explained here. Practices involve various engineering activities performed prior to dismantling and during dismantling, buffering, lifting, transporting and disposal.

On the beach, workers use cutting torches and saws to dismantle the ship from the end facing the beach to the end facing the sea. Large blocks are cut and allowed to fall down freely. Further removal is from flat lying block using gas cutting. The cutting operations continue till the dismantled item can be handled by manual labourers or by a small crane to nearby stack location. The handling is done manually as well as using crude mechanical lifting procedures. No weight lifting calculation or lifting analysis is done prior to lifting. Along with the removal of hull steel and other items for the dismantled ship it is towed further inland by teams of men using winches simultaneously. Ship dismantling operations presently undertaken at Alang, state of Gujrath, are analysed compiled in the study [Sivaprasad 2006]. The salient features of the ship recycling activities undertaken at Alang Ship Recycling Yard, Gujrath are given in appendix 1. A schematic representation has been developed and presented in fig. 2.5. Dismantled metal is sorted by material type viz., steel, aluminum, copper, etc.,. Steel plates are often sold to re-rolling mills. Various machinery items are sorted and kept separately in a covered region. If a reverse engineering method of all activities involving disassembly of hull, outfit and machinery of ship is adopted during dismantling, that will improve the overall performance of the dismantling significantly. However, layout constraints, lack of infrastructure and unscientific procedures practiced in recycling yards make the ideal case far from realising.

2.3 GUIDELINES REGARDING SHIP RECYCLING OPERATIONS

Certain codes and recommendations from United Nations conventions, court ruling, codes and regulations framed by various agencies are acting as governing rules in ship recycling activities. Legally binding statutory rules and regulations are seldom seen in the field. Almost all regulations are still operating in a qualitative level and these can be collectively called as guidelines in ship recycling. Major agencies and bodies involved in making of codes and guidelines in ship recycling field include the following,

a. International Maritime Organisation,(IMO)

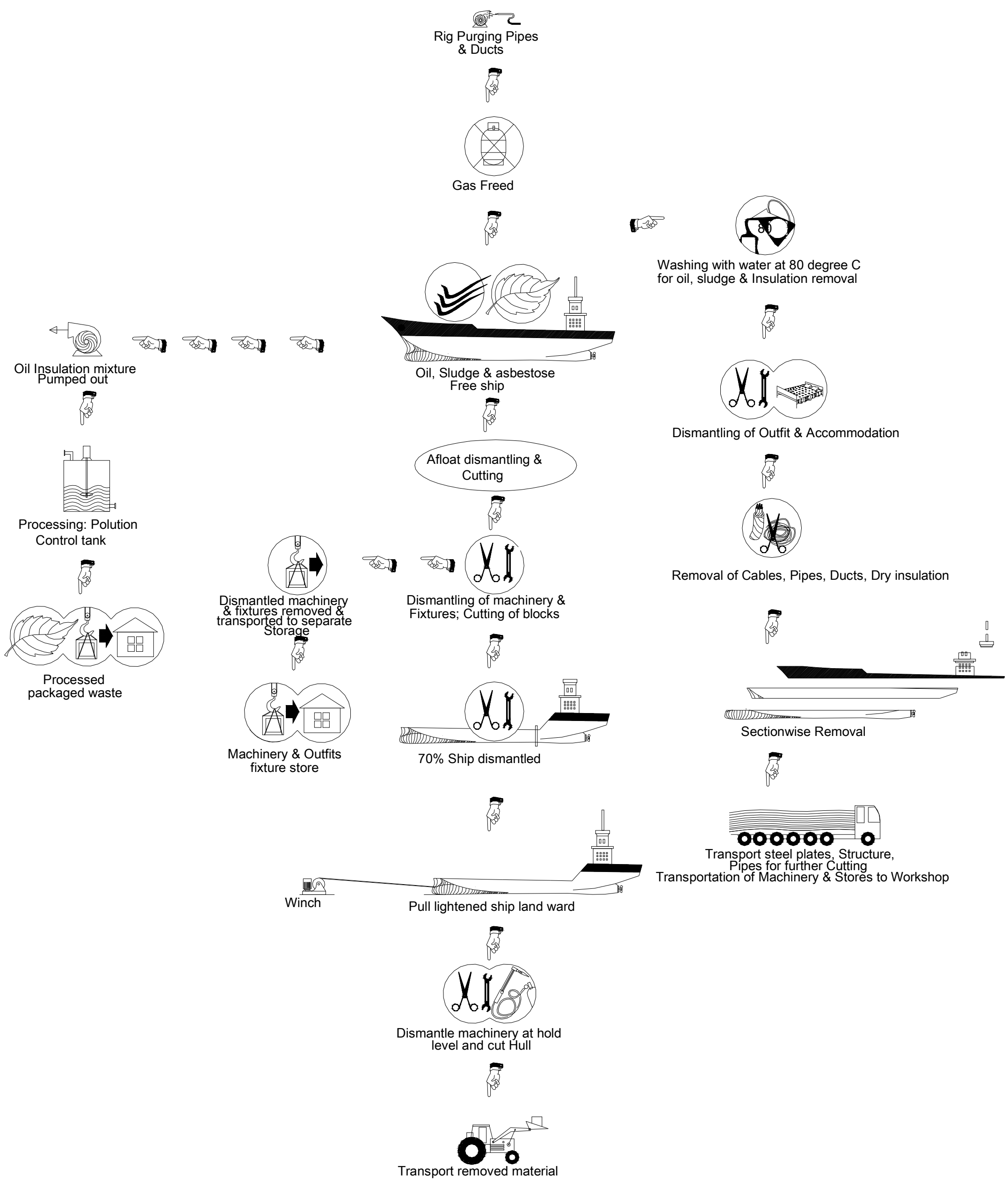

Fig. 2.5 Beach Based Ship Recycling Activities at Alang Ship Recycling Yard

b. International Labour Organization (ILO)

c. Department of Trade and Industry (DTI), UK

d. Secretariat of Basel Convention (BC)

e. Environmental Protection Agency (EPA), USA

f. Dets Norske Veritas (DNV), Norway

g. United Nations Environment Programme (UNEP)

h. Regional Rules and Regulations – Gujrath Maritime Board regulations

The guidelines provided by bodies differ slightly both in focus and direction. Most of these guidelines and directions are in the qualitative level and not very concrete. The focus of the guidelines has been summerised and is provided in table 2.1 that has been used in the generation of expert system in the present study. These deal with the aspects like sea, air and land pollution, operational and occupational safety, hazardous and non-hazardous waste, working practices and seaworthiness. The focus of these guidelines has been identified as the consequence of ship recycling.

Table 2.1 Focus of the Guidelines in Ship Recycling Industry

	Focus of the Guidelines in Ship Recycling Industry								
Guidelines ↓	Sea Pollution	Air Pollution	Land Pollution	Safety Operation	Occupation Safety	Hazardous Waste	Hazardous Material	Working Practice	Sea Worthiness
IMO	√					√	√		√
ILO				√	√			√	
BC						√	√		
S.C (India)	√	√	√						
E P A (USA)	√	√	√					√	
DTI (UK)						√	√		
GMB (India)	√	√	√	√	√	√	√	√	
DNV						√	√		

The guidelines of ship recycling procedures by the Gujrath Maritime Board cover all the ship recycling factors except seaworthiness of vessels. However modifications are required to make it the guidelines as mandatory rules and regulations covering entire ship recycling processes.

2.4 SHIP RECYCLING PROCESSES IN VARIOUS GLOBAL LOCATIONS

South East Asia contributes to more than ninety percent of global ship recycling activities. Countries such as Pakistan, India, Bangladesh and China are the major ship recycling centres of the world. Fig. 2.6 shows the statistics of world ship recycling volume up to 2008. Besides Turkey in Asia, ship recycling activities are reported from isolated locations of Europe including UK. Ship recycling activities carried out in these destinations are discussed briefly on the following subsections.

2.4.1 Bangladesh

Very steady growth is reported in ship recycling volume from ship recycling yards in Bangladesh during the last five years. Chittagong is the major ship recycling location in Bangladesh. Sixteen kilometers stretch available at Fauzdarhat, a city 16 km southwest of Chittagong where 8 square kilometers area is available for the recycling related activities. Due to high tidal difference available these yards are suitable for dismantling of big tankers and bulk carriers. The recycling yards in Bangladesh follow minimum safety standards for recycling. The yards seldom follow recommended ship recycling practices given by leading international ship recycling agencies. Pre-beaching and beaching activities are done without proper routine checks [DNV 2000].

2.4.2 China

Chinese ship recycling yards are located in Jiangmen and Jiangsu provinces and are situated in Pearl and Yangtse river deltas. There are more than 50 ship recycling yards located in these provinces. There are a few inland recycling yards which are operating exclusively for inland vessels. Chinese ship dismantling yards are using buoy (wharf based) method. The dismantling is done using vertical lift off method with concrete support base. Chinese authorities claim that beaching method of dismantling of ship is forbidden in China [Xie 2007]. Most of these yards have either acquired ISO 14001 or OHS 180001. Fully developed asbestos treatment and ballast water treatment facilities are present in these yards. The hull paint removal is done using advanced Rough Paint Treatment (RPT) facility. Chinese government has included ship recycling industry in the environmental industry category. Special policy on energy saving and environmental protection has been envisaged very recently. Cooperation between stakeholders of ship recycling is identified by the government as key to clean and efficient ship recycling. Advanced dismantling facilities, futuristic vision based recycling policy, stringent laws and regulations and "stakeholders cooperative working model" are reported to be the four pillars of enterprising ship recycling industry in China.

2.4.3 European Union

U.K has only recently joined the ship recycling nation group. Very stringent environment ship recycling regulations based on principle of sound management are implemented in UK. ABLE group a pioneer in decommissioning works of other

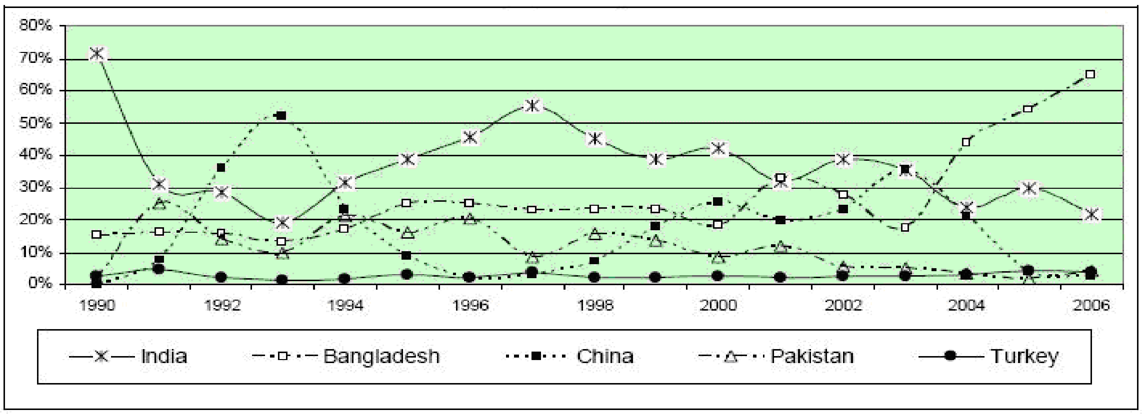

Fig. 2.6 Global Ship Recycling Statistics (Nikos 2007)

industrial plants is the major establishment in UK involved in ship recycling [Stephenson 2005]. In ABLE, ship recycling is carried out in dry docks. Environmental Protection Agency and Maritime Administration of the US government have audited the recycling yard owned by ABLE and they have qualified the yard enabling dismantling of ships by US owners. ABLE ship recycling yard works in tune with control of Major Accidents for Health regulation act of UK government [Stephenson 2005]

2.4.4 India

Major Ship dismantling centres in India are given in table 2.2. The modes operating remains the same as other neighbouring countries like Pakistan and Bangladesh. Gujarath Maritime Board has an exclusive wing for monitoring ship recycling in Gujarath region whereas other states do not have any such administrative or technical mechanism to manage ship recycling activities in the centres coming under their geographic limits.

Table. 2.2 Major Ship Recycling Centres in India

No.	State	Locations
1	Andhra Pradesh	Vishakapatnam
2	Gujarat	Alang
		Sachna
3	Karnataka	Tadri
		Mangalore
		Malpe
4	Kerala	Baypore
		Cochin
		Azhikkal
5	Maharashtra	Mumbai
6	Tamilnadu	Tuticorin
7	West Bengal	Kolkatta

2.4.5 Pakistan

Major ship recycling yards are located near Karachi, the largest port entry of Pakistan. The yards are under the control of Baluchistan Development Authority situated in Gaddani. These yards use mainly beaching method to position the obsolete ships arriving at Gaddani. The yards here have the capacity to dismantle large ships. More than 50 large ships can be dismantled at a time. The recycling yards are underdeveloped and they are using combination of manual and mechanical method for dismantling activities. The beaching is done by experienced hands in this field and no statutory inspection is carried out during beaching. Environmental impact survey and safety system are seldom done. The yards use deck lift - winch lift combination for lifting operations. No concrete flooring is provided where cutting and removal TBT based paints are carried out. There is no inspection and control over the down stream industries which collect the waste and pre- used items from the dismantled ships. The government control over ship dismantling is not very effective, though few agencies are working in tandem with the ship recycling industry [Shahid 2005]

2.4.6 Turkey

Ship recycling industry was established in Aliaga and Itmir regions of Turkey during early Seventies. The industry got recognition and the ship recycling was declared as a legal industrial activity in 1986. Now the industry has capacity of producing 1million tones recycled steel per year [CEC 2007]. Turkish ship recycling facilities use beach based ship recycling. Environmental and occupational controls are being exercised rigorously by the concerned government authorities. Turkey is placed 4th in the current ranking of world ship recycling output [Nikos 2007].

2.4.7 Comments on Ship Recycling Practices at Various Global Locations

From the above mentioned facts and figures it can be observed that beach based ship recycling method is being followed in all the major ship recycling countries except China. Ship recycling becomes economically viable in the developing countries only when the actual operations are carried out in beaches. There are number of guidelines in ship recycling which, when applied to the respective fields would improve the status of the industry as safe and environment friendly. Considering these two observations, ie., operations in beach based activities and guidelines , a set of *best practices* for the industry can be formulated. If these *best practices* are implemented through a user friendly knowledgebase system, like computer based expert system, it will serve as the stepping stone to make ship recycling effective, efficient and sustainable.

2.5 SHIP RECYCLING AS AN ENGINEERING INDUSTRY

The various aspects involved in treating ship recycling as an engineering industry have been analysed under the following subheadings.

2.5.1 Engineering Perspective

2.5.1.1 Engineering Project Management Tool

By looking at the man made chaos in product design and development, the process of recycling can be explained as the following;
"Recycling is an engineering project management tool used to plan and control the process abandonment of manmade products strictly according to the underlying principles of sustainable development. Recycling should be considered as an

engineering philosophy which tries to incorporate the essence of sustainable development mantra in all product design and development undertaken by all the industries in the world". This concept is applicable to ship recycling industry as well. The sustainable development is to be considered and emphasized in the ship recycling process. It is this philosophy which differentiates ship recycling from "making steel scrap and managing that".

2.5.1.2 Elements of Sustainable Development

A comprehensive recycling plan should envisage the following points in the ship recycling processes which is catering to the spirit of development with some control and quality, viz.,

- Environmental orientation
- Energy consciousness
- Safety focus
- Technological soundness
- Economical viability
- Ergonomics

These elements have a very critical role to play in the sustainable development of marine industry sector. To implement sustainable development concept in ship recycling, characteristics of each of these elements has to be separately analysed. A suitable index has to be assigned taking into consideration the strength of each of these elements present in a vessel.

2.5.1.3 Trends in Global Ship Recycling

India, Bangladesh, China, Pakistan and Turkey are the main ship recycling destinations in the world. China during the shipbuilding boom (year 2005 onwards) had less focus on ship recycling industry and hence went down in recycling output. Similarly due to stringent control by the government and local bodies, Indian ship recycling industry is also on a slow down process now. Bangladesh with very loose regulation and very relaxed government control on the industry is flourishing at present [Nagarsheth 2008]. European Union has taken some initiation to develop sustainable ship recycling facilities in European countries [Karpowicz et al 2006]. Ship recycling facilities in Turkey is likely to get maximum benefit out of these attempts undertaken by the European Union.

2.5.2 Attributes of the Products from Marine Sector for Recycling

Marine structures such as Air Defense Vessels, Very Large Crude-oil Carriers and Oil Rig Platforms are probably the most complex man made industrial products which have to undergo the recycling process along with the conventional ships. The unique features of ships and marine structures call for special attention and focus on a systematically planned and technologically executed recycling activity. Fig 2.7 shows the steps in ship dismantling. The special attributes of the products for recycling and conditions existing in the marine sector are discussed in detail in the following sections.

2.5.2.1 Situations in Global Ship Recycling Locations

The major points of attraction for the owners of the obsolete vessels for the selection of destination for breaking of their ships include flexible and relaxed rules and regulations, cheap labour, minimum investment on infrastructure, abundant coast line unaffected by severe weather, heavy demand for used parts, and advantageous geographical features. These factors prevailing in the dismantling yards have been a case for degradation in the quality recycling of ships. The ship recycling sites are not well managed as these are planned to be. Environmental impacts and risk levels are two major areas of concern of these ship recycling locations. Some of the original fleet nations and green NGOs have been successful in setting a right course for ship recycling activities in the current recycling locations.

2.5.2.2 Complexity of Ship Structures

The weight, tonnage/displacement, shape and size of ship and her components individually as well as in combination, demand an additional technology focus on various activities undertaken during beaching, dismantling, handling and marshalling. This unique complexity generates scope for more comprehensive analysis of the recycling process for finding out the *best practices*.

2.5.2.3 Presence of Non-ecofriendly Materials

Toxic and hazardous materials like asbestos based insulation, oil traces etc., which can be termed as hazardous and / or non eco-friendly elements may be present in large quantities in as contaminants in ships. All types of protective coatings, insulation coverings and laggings, paneling components, glues and deck covering materials and various types of waste oil pollutants contributes to this. Extremely hazardous stuffs such as radioactive substances and asbestos are rarely seen whereas less dangerous materials like oil, coatings etc., are found in almost all types of ships. During the recycling process these heavy pollutants emerge out and become a potential environmental threat. Handling of these environmentally hazardous elements is quite

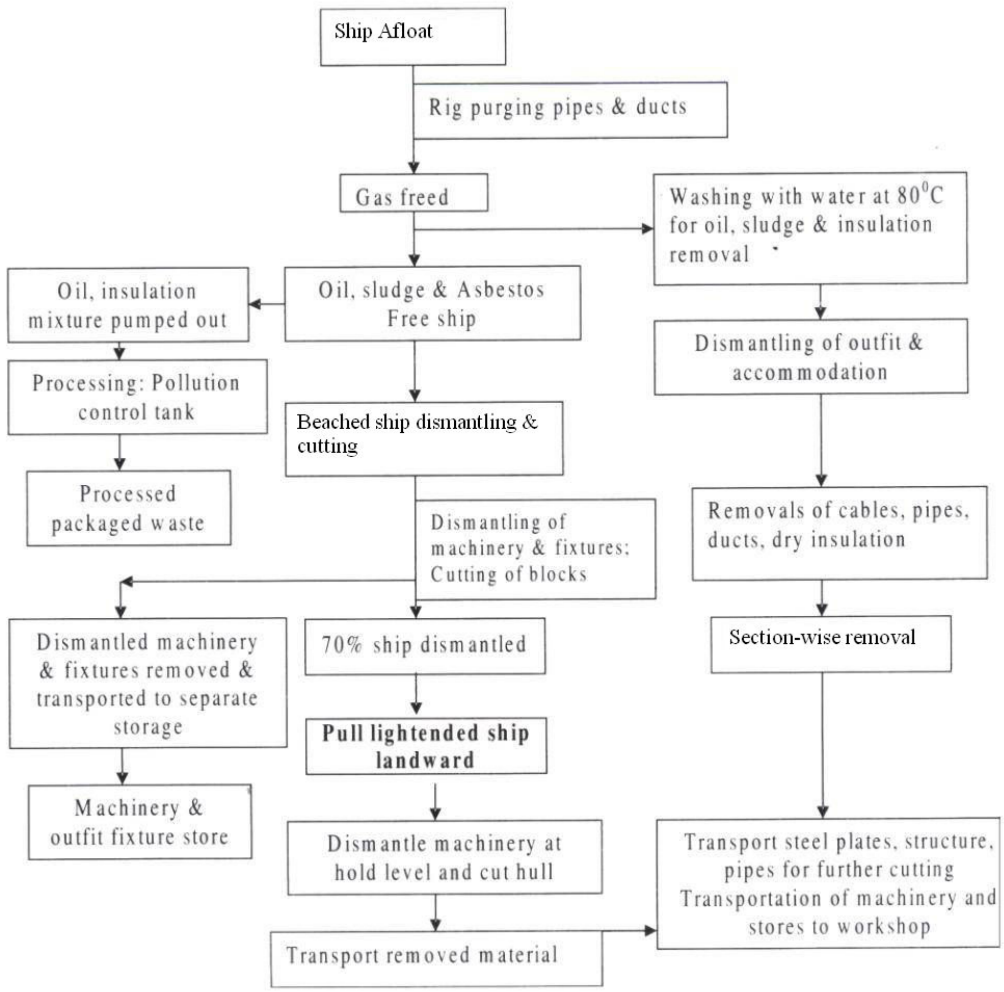

Fig. 2.7 Steps Involved in Ship Dismantling

dangerous since the quantity to be handled is quite high and all the yards are located in relatively heavily populated coastal zone. Besides, these non-ecofriendly pollutants are likely to contaminate sea water.

2.5.2.4 Involvement of Naval Architects

At present recycling of ship and offshore structures is not treated as an entity in shipbuilding. Recycling yards do not employ naval architects and almost all the ship dismantling is carried with minimum guidance from an engineer who knows total technology of ships and offshore structures. The disassembly and subsequent recycling activities, which are integral parts of life cycle of ship, have to be guided by the basic principles of naval architecture and shipbuilding. Very limited number of naval architects and offshore engineers take part in ongoing research and training programmes in ship recycling at global level. Environmental scientists, chemical engineers, structural engineers, production engineers and safety engineers usually steer such projects.

2.5.2.5 Lack of Rules and Regulations

There exists a very solid frame work of rules and regulations pertaining to shipbuilding and ship operations. Various agencies are actively involved in framing and implementing these rules like ship classification societies, flag state administration, local governmental bodies, ports, canal and inland authorities and coastal protection agencies.

Individual as well as combined operations of these agencies accomplish relatively safe shipping and shipbuilding activities around the globe. IMO has a lead role in bringing about changes in modifying existing rules and introducing new rules as situation demands. But a similar type of situation does not exist in dealing with the last phase of life cycle of the product. From among the ship classification societies, only DNV has come forward with concrete and well documented plans. Though the other ship classification societies are entering to this arena, their presence is felt only at various discussion platforms convened by IMO and similar agencies. Team work of responsible agencies is yet to be take place effectively and the mechanism to implement the guidelines as rules and regulations are not that much effective.

2.5.3 Benefits of Ship Recycling

The benefits of ship recycling have been described, by considering it as a modern industrial activity, under the subheadings.

2.5.3.1 Effective Removal of Obsolete Vessels

The global marine industry is facing a tough situation, regarding decommissioning and physical dismantling of its obsolete fleet. The situation is much worse than that prevailed after the Second World War. Number of vessels and other marine structures destined towards the dismantling yards of India, China, Bangladesh and Pakistan in the coming years will be uncontrollably high and unmanageable. Ships built during the economic boom during the last decade may not remain in the active service due to certain technical and commercial reasons. This may also cause an increase in the number of obsolete vessels in the global shipping sector. Both the delay in decommissioning of obsolete vessels and dismantling conducted in haphazard manner are likely to introduce adverse problems in the international marine industry. Implementation of sustainable development oriented ship recycling is the only solution to get rid of the adversities creating this massive problem.

2.5.3.2 Global Sustainable Development Tool

The idea of sustainable development surfaced in the international scene after some of the major global summits which deliberated some of the burning issues related to earth's ecosphere. The hot issues which compelled the international development policy makers to think in the direction of sustainable development included hazardous gas emissions from industries and automobiles, ozone depletion, global warming and green house effects. These were mainly pertaining to atmospheric pollution and their impact on global environment. Sustainable development issues connected with land and water pollution have been taken up in different view points and one of the practical solutions is pointed towards the concept of recycling. The major thrust areas identified by the present study
on sustainable development of water and land include the following.

a) Minimizing impacts of environmental pollution due to industrial products and by-products.
b) Preserving energy sources
c) Maximization of renewable energy utilization
d) Minimization of cost of manufacture by the use of more productive techniques
e) Minimization of risk levels by improving safety standards in work places
f) Partial replenishment of depleted resources by products from recycling

Ship recycling methodology addresses these thrust areas in an integrated approach within a common platform of product life cycle activities. So ship recycling acts as an effective tool implementing sustainable development action plans. More coordinated efforts from academic and industrial research agencies are required to formulate a master plan for accomplishing the major objectives set by the individual thrust areas identified

2.5.3.3 Generation of Employment

Like ship and offshore production industries, ship recycling industry also offers massive potential for direct employment generation including skilled and unskilled manufacturing tradesmen, ship brokers, transporters, recycling plant workers, recycled goods traders and trading agents. Application of more mechanised methods and systematic approach will certainly have a negative impact on employment potential. However this can be partly solved by attracting more business due to improved quality and productivity attained using the modern techniques.

2.5.3.4 Creation of 'Recycling Role Model'

Consumption essentially creates the unwanted and unusable material termed as waste or scrap. Recycling aims at re-engineering of these wastes and scraps and bringing back their re-usability. It is the massive consumer population that makes unmanageable waste and scarp in major cities of the world. Disposal of these wastes is a headache for the concerned authorities and recycling is most effective remedy. The marine industrial sector is also going to experience a similar kind of situation in the near future. The hostile environment in which the structures are operating is one of the major issues related to this. Corrosion of hull and machinery parts makes the structures obsolete in a faster rate than their land counterparts. Ship owners are more concerned about availability of their vessels for operation and due to this their approach towards maintenance and refitting of ships has changed. Any decision to short cut the routine and scheduled repair and maintenance of vessels operating in the hostile marine environment will have a significant effect on age and health of the vessels. Usually ship operation management policies influence the rate of obsoleteness of marine vessels, and thereby decide the future of ship recycling industry in terms of capacity, standards, productivity etc. For finding everlasting solutions to these complex situations, a comprehensive interdisciplinary recycling approach based on various factors involving engineering, economics, environment, ergonomics and energy and management issues should be formulated. The stake holders in global maritime industrial sector should take important steps towards this by supporting academic and industrial research in sustainable global ship recycling.

2.5.4 State of Art of Ship Recycling Industry

The present status and capacity of ship recycling as an engineering industry is presented in the following subheadings. The analysis can provide some fundamental information on the development of *best practices* in ship recycling.

2.5.4.1 Undefined Industry Status

Even today the activity involving removal of obsolete vessels are not defined as to which branch it belongs to. It is not clear whether recycling is a manufacturing activity or a re-engineering process or all together a new branch of engineering. This confusion is prevalently seen in various attribute which define the process. Still debates are on how to lay down common international rules and regulations in this field. The West and the South Asia are divided on various aspects of implementation recycling norms, as evident in the case of issues related to dismantling of obsolete French Air Craft Carrier Clemenceau [Nagarsheth 2008].

2.5.4.2 Limited Global Recycling Capacity

Ship recycling industry which has been treated as dirty industry by the West has very takers in the developed countries. Even the leading shipbuilding nations backtrack while dealing with setting up of ship recycling facilities within their geographic territory. The reason behind this policy of avoiding building up a very profitable industrial base, can be attributed to the following reasons.

a) Pollution from the scrap material from dismantling of ships
b) Unsafe dismantling operations and the risk factor involved in it
c) High cost of labour, transportation and yard area
d) Stringent rules regarding safety and environment pollution
e) Inactive used product market
f) Prevailing modern rich / wealthy consumer culture which does not show interest in buying and using recycled products.

Other regions where ship recycling is carried out, the industrial climate support the recycling activities. Some of the characteristics of this industrial climate do not promote ship recycling industry like unavailability of re-processing technology for recycling, lack of naval architecture/ shipbuilding tradition, lack of effective involvement in international maritime trade, minimum governmental support and unsuitable geographical features. These are true with respect to African and South American countries. The Middle East Asia has not come up with any policy on ship recycling, though the region has become world's capital of ship repair and conversion.

In this context it is evident that the international marine industrial sector has no other option than to destine their vessels and structures to South Asia for dismantling. This way the capacity for ship recycling is limited to the facility available in countries such as India, China, Pakistan, Bangladesh and Sri Lanka.

2.5.4.3 Beach Based Low Technology Industry

As on today ship recycling is graded as low technology industry with limited infrastructure and facilities to support. This will continue to remain in the same status unless and until some major policy change occurs in the marine business and stringent measures from the flag state administrations. Since the dismantling operations in the yards make use of low level technology gadgets combined with unskilled labour, implementation of flow line production concept is not possible. The yards are overcrowded and the area is restricted due to over allocation of plots in the major facility location of conducting ship dismantling operations resulting in lack of scope for an efficient engineering layout. Absence of proper flow line will lead to haphazard way of getting things done resulting in a combination of low productivity, higher risk rates, potential pollution source and poor quality output.

The ideal tidal and other oceanographic conditions of some of the coast lines are the main driving factor for the creation and development of ship recycling sites. These advantages provided by such beaches can not be replaced by any other facility as on today. However these advantages are marred by many critical drawbacks which include remote location, unsuitable conditions for civil constructions and infrastructure development like covered dismantling sheds and cranes and other supporting facilities, hostile environment like occasional severe environmental factors such as waves, wind, humidity and salinity.

2.5.4.4 Market Features of Recycled Products

Numerous products and byproducts of ship recycling can be generally classified, according to their re-usability as, readily reusable, (without additional dismantling, spare parts) recyclable, scrap and hazardous elements and parts.

Information regarding the route through which these dismantled marine components and parts are moving out to reach the pre owned market elsewhere is not properly studied and documented so far. It is unofficially known to all that these dismantled items some how manage to enter the new building sites. The prevailing rules and regulations in ship recycling and maritime activities do not cover this aspect of re-entry of used items to fresh and new building.

The very presence of active "used marine industrial goods market" determines the degree to which ship recycling extends. If one region or a country is having very live market for used goods trade, dismantled goods will reach the nook and corner of that country and those items will come back into the product market. In this situation there will be high chance of manipulation in the condition of the products. Possibilities for unauthorized preowned trading where the traders will somehow manage the deployment of used products, labeling it as brand new exist. The market will flood with these items and that will generate a new threat in new building and repair sector of the maritime industry.

2.5.4.5 Presence of Unskilled Labor

A low technology industry which is remotely located with low safety standards can attract only semi-illiterate and unskilled workforce. To train and educate the work force for developing various skills for accomplishing safe and environment friendly ship recycling with some engineering orientation is an uphill task. The common disadvantages associated with this workforce are the lack of general engineering orientation, unawareness about safety and environmental issues and high standard of rules and regulations.

CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

Publications available in this field have been reviewed and classified into five subject categories viz., Infrastructure for recycling yards & methods of dismantling, Guidelines, codes &regulations regarding ship recycling activities, Environmental & safety aspects of ship recycling, Application of information technology and Demand forecasting. The review and comments are given under various subheadings subsequently.

3.2 SHIP RECYCLING OPERATIONS

Bailey [2005] has elaborately dealt with the prerequisites for recycling of any marine structure by exhibiting a list of provisions in the proposed *certificate for dismantling*. According to the author this certificate which contains the essential and critical information needed to carry out safe and productive ship dismantling must be made mandatory. A good picture of common occupational hazards and major causes leading to casualties both in terms of loss of life and environmental deterioration has been presented. It has also spoken on an effective legal framework recommended by International Labour Organisation giving duties, responsibilities and rights of various stake holders involved in the business. Some techniques on assessment of risk during disassembly of heavy parts, while handling poisonous chemicals and during storing of dismantled products have been covered. Various protection, control and welfare measures required for smooth functioning of the process have been touched in the last part of the paper.

Neil [2006] has given account of various disposal options before the recycling business. He has mentioned that once a ship has reached the end of her service life, there are a number of methods of disposal ranging from being laid up, sold on, reefing or converted for recreational purposes. However, with the advent of ever increasing safety and environmental standards associated with the costs of upkeep and upgrades, together with the potential requirement to remove hazardous or restricted materials, there comes a time when the best option is to recycle it. The necessity for a comprehensive ship recycle plan to identify the costs and manning requirements, and to demonstrate the environmental safety and project risks have been highlighted by him. The methodology also has presented the merits of utilizing Green Passport and an onboard Safety and Environmental Management System (SEMS), both of which will facilitate the smooth handover of the obsolete vessel to the recycling yard. This may be the first citation where recycling of ship at the end of its life time has been termed as a best practice.

An authentic statistics on activities of Alang-Sosiya ship recycling yard located in Gujarat which is the biggest recycling site in the world has been given by Winjgarden [2005]. The data including the dimension of the plots, output of recycled products, turn over, revenues and even death rates are available. On this background the paper has precisely presented the content of the safety manual followed at various operations at Alang yards. It has also spoken about setting up of an oil recovery facility consisting of combination of facilities at sea as well as onshore which will have dual applications like better environmental protection and safer handling operations. The paper has thrown light on formulating integrated Health, Safety and Environment management (HSE) system for better productivity in the dismantling line. A new proposal for early vessel separation, i.e., disassembly of scrap hull while floating has also been discussed.

Stephenson [2005] has discussed dock based dismantling facilities in a UK based recycling yard owned by ABEL group of companies. It has provided deeper technical input in the criteria of selection location of recycling yards and the major requisites leading to access for ships to enter the yard and the access out of the recycling area entering the supply chain. The capacity requirements environmental adaptability and legal attributes such as license, consents and handover in the business have been nicely dealt with in the flow of discussion. The controversial outcomes of recycling such as asbestos, PCB, mercury and radioactive traces also appear in the course of discussion in the paper. Invasive presence and threat from biological microorganisms from ballast have also been projected with due importance. Some valuable tips regarding reuse of components and reuse the same after proper conversion have been also touched very briefly. A detailed account of the contract from MARAD given to ABEL recycling yard has been given towards the end of the paper.

Karpowicz et.al [2006] has described one of the objectives of the EU funded FP6-506606 SHIPMATES project, which has been designed to review the technology of ship repair to identify potential for application in ship recycling. This paper has given the list of all industrial partners of the project, the potential in the foreseeable future, to diversify their product-mix towards ship recycling. This paper has also presented some early results of the project to inform the potential users of it regarding sustainable recycling in Europe. In this paper the author has suggested the idea of the establishing an academic level European Union knowledgebase on ship recycling. At the macro level, key management and organization issues of the future standard ship recycling yard have been discussed. In particular, the fundamental role, significance and tasks of the R&D function within the organizational structure of a competitive ship recycling yard of the future have been investigated and highlighted. The continuously growing importance of the successful performance of the organization function has been strongly emphasized not only from the point of view of the needs of the future ship recycling yard, but for the continuous and systematic improvement of productive and functional performances of the project participants within the frame of their existing product-mix as well.

Shahid [2005] has given, detailed account of ship breaking activities in Pakistan, one of the major ship recycling centers of Asia. The paper has clearly depicted a comprehensive domain of ship breaking processes followed in a site near Karachi, with the help of neat layout of the yard and its organizational structure. Various associated manufacturing activities, handling operations and storing procedures have been discussed in a basic level. The author has explicitly pointed out the important roles and responsibilities of some of the participating agencies, such as governmental bodies, ship-breakers associations, and local bodies, in the day-to-day running of the business. Predictions, based on simple logic, ship breaking scenario in Pakistan and available data, have been provided for the coming years with respect to number of ship ready for recycling and the employment and skill requirements. The role of classification societies as a leading force in setting the course of ship recycling towards environmentally sound and risk free industrial business has also been addressed. The simple and scientific forecasting methods have been used in the ship breaking activities by the author and this may be given a pioneer status in this regard.

Various options regarding recycling of different types FRP in the ship industry have been discussed by Kostopoulos et al [2006]. The paper has also thrown enough light on the potential reuse of recycled FRP products. The last action before landfill, according to waste hierarchy, is energy recovery. According to the findings recorded by the author the efforts made by the maritime community and other interested groups towards a sustainable global ship recycling would not be effective if adequate attention is given for recycling of fibre reinforced composite materials that are increasingly used in the ship building industry the last decades. Some of the viable concepts for the recycling which are essential for the FRP industry over the coming years, as per the European Waste Directives, have also been included in the discussion.

Chaturvedi et al [2006] has critically evaluated the water budget for a typical ship breaking yard and characteristics of waste water from a ship breaking yard in Alang, India. This paper has explained the details regarding the requirement of fresh water and disposal of waste water. The paper has described two important methods employed in waste water treatment. In this research, it has been highlighted that natural waste treatment systems have now been emerging as alternate and appropriate and the application of the same has been suggested as the best practice in waste water treatment for ship recycling yards in India. The authors have put forward various arguments on sustainable wastewater management strategy which includes water recycle and reuse opportunities in premises of the ship dismantling yard.

Mahindrakar et al [2006] presents the major environmental problems faced by Indian ship recycling industries with regard to disposal of anti-corrosive and anti-fouling paints in recycling yards and in steel rolling mills. The major threats to the environment from heavy metals and resins have been discussed by analyzing a ship of average size. More serious effect of handling of sand blast paint mixture has been presented separately. It has also proposed new methods to study the leaching characteristics of various hazardous coatings used in ships. Comparison with provision of Environmental Protection Agency [EPA), USA standard in this field has also been highlighted. Need for strict measure to stop the contaminations from marine paints has been listed as the concluding remark.

Asolekar [2006] has overviewed the present ship dismantling methodologies adopted in India along with environmental, health, and safety related issues. It has also included a very comprehensive list of all solid waste items produced in the recycling process and has classified the same into hazardous and nonhazardous category. An integrated approach dealing with the potential threat from pollution, health hazards and accidents has been given in this paper. The human resources development part has separately been dealt in the background of these three major issues present in Indian ship recycling locations. The content of this paper can be considered as a major input to the knowledgebase on land filling and solid waste production management.

Kinigalakis et al [2006] in their paper have dealt with the necessity of designing risk analysis methods useful for various ship recycling processes. The emphasis has been given for individual ship recycling process conducted in a specific location. The paper has given an analysis of the influence of technical trade skills of the personnel, complexity of ship structures, dismantling procedures and other technical factors on the safety of dismantling operations. A review of established risk analysis methods has been provided within the frame of the ship dismantling project, aiming to develop a modified method suitable for application for ship recycling.

Hedlund et al [2006] have stressed the need and importance of comprehensive information about the constituents of polymer materials found in ships. The author has developed and included a model for assessing various waste disposal techniques especially for polymer composite materials. In this model nine influencing internal factors have been identified. These are closely associated to the generated wastes and the processing of them. Necessity of developing an integrated information handling system for productive ship recycling has been put forward by the author

3.3 GUIDELINES, CODES AND REGULATIONS IN SHIP RECYCLING

Throughout the life cycle stages, ships are subjected to application of various guidelines, codes and regulations. Most of the important guidelines are formulated by expert committee working groups of International Maritime Organization which is the maritime agency working directly under the United Nations. Only exception to this is ship recycling, where till recently no concrete rules and regulations have been implemented. The Marine Environment Protection Agency (MEPC) meeting, MEPC 59, 2009 has made significant progress in developing draft guidelines for safe and environmentally sound ship recycling intended to assist with the voluntary implementation of all important IMO, Hong Kong Convention, 2009. Outcome of this convention is considered as the pioneering guidelines for formulation of rules in ship recycling field. Some of the ongoing and past attempts in this area have been explained in the subsequent subheadings.

3.3.1 General

Dimakopoulose [2005] has referred to the major contributions of International Maritime Organisation in formulating a frame work of rules for ship recycling industry. This paper has projected the essence of the efforts carried out in ship recycling industry by considering recycling as one of critical stages in the life cycle of ships. The issue of Green Passport as a tool to develop an efficient reporting system for ships destined for recycling has been elaborated. It has also tried to lay-down a concrete, fool proof and standard approach of reporting the developments in ship recycling.

Parkinson [2005] in his paper has recommended a code of practice to be developed in order to improve the quality standard of ship recycling. The paper has stressed on elevation of existing ship recycling activities mainly scattered over South East Asia to an international level engineering industry. The author has emphasized the need of developing and implementing rules and regulations in ship recycling industry as in international shipbuilding. He has also pointed out some of the basic issues leading to the definition of a ship as scrap or ready for recycling by pointing out the differences in approach of agencies such IMO, MARPOL on one side and declarations approved in basic charter of agreements like Basel Convention on the other side.

Anderson [2005] has critically analysed the concept of *Green Passport* and its essentiality in the ship-breaking scenario. The paper has been critical on non-conformity of rules framed by various UN bodies such as IMO, ILO and UNEP (Basel Convention), but very firm on the stand adopted by Dets Norske Veritas in implementation ship inventory Dossier Environment and subsequent issue of Green Passport clearance. According to the author, ships are queuing up before DNV to acquire the Green Passport as this certificate has been foreseen as a must in the business in the years to come. Detailed methodology adopted by DNV teams on systematic surveys to arrive at the hazardous content in a ship has been categorically listed in the second half of the paper. The preparations and procedures of awarding Green Passport have been nicely narrated.

Watkinson [2006] has thrown light on new developments in the issue of management of marine environment, initiated by IMO, in order to standardize the ship recycling operations in various countries. The paper has done a detailed debate on the role of Environmentally Sound Management (ESM) put forward by IMO. Key requirements for the sustainable development of ship recycling facilities, conforming to the principles and practice of recycling have been taken up for analysis. The paper has also described the relevance of guidelines prepared by three UN bodies, the I M O, the Basel Convention and the I L O which are to be followed very strictly by the recycling industry worldwide.

Ahluwalia [2006] in his paper, has listed the guidelines developed by Basel Action Network (BAN) and I L O for safe dismantling and disposal of obsolete vessels. The paper has envisaged effective implementation of the guidelines to identify hazards present on board ships, to help control environmental pollution, to control workers' exposure to hazardous substances, to build a healthy work environment, and most of all to comply with international standards. It has also dealt with the benefits for the business community due to implementation of these guidelines.

3.3.2 Marine Environment Protection Committee and IMO Resolutions

IMO Resolution A962 (23) IMO guidelines on Ship Recycling., adopted on 5 December 2003 (Agenda item 19) is the most significant document prepared by IMO regarding ship recycling. Resolution A.981(24), 2005 is another resolution adopted by IMO regarding legally binding regulations to be implemented in various life cycle stages of the ships, ship recycling yards and enforcement of ship recycling reporting and certification. These resolutions are outcome of deliberations made during the meetings of Marine Environment Protection Committee, working group of IMO on global environmental issues. MEPC 42, 1998 to MEPC 61, 2010 has discussed the ship recycling issue with proper importance and seriousness.

IMO Resolution A962 (23) has envisaged the process of recycling in general, as one of the basic principles of sustainable development. The document has mentioned that for the disposal of all 'time-expired' ships there are few alternatives to recycling. This can be considered as a well focused extension of the proposals put forward by the London convention 1972 (Dumping of waste and marine pollution) regarding recycling of steel by converting into other utility structures. The resolution has categorically stated that recycling is the best option for all time-expired tonnage and firmly assert that in the process of recycling ships, virtually nothing goes as waste. The resolution has identified ship recycling as green industry if the guidelines are followed in its true spirit. However, the guidelines have recognized that, although the principle of ship recycling may be sound, the working practices and environmental standards in the yards often leave much to be desired. The resolutions have affirmed that the ultimate responsibility for conditions in the yards has to lie with the country in which these are situated and other active stake holders.

IMO [2009] has pointed out the need for preparing ship recycling plan by the concerned ship recycler performing the assigned operations and the basic issue of Green Passport extended over the life cycle stages by the ship owners. IMO has mentioned the importance of implementing *best practices* for ship recycling process for the first time in this convention. Also the active collaborative efforts by the relevant United Nations agencies and conventions dealing with ship recycling have been reasserted in the convention report.

3.3.3 UNEP – Basel Convention Guidelines

Basel [2005] has dealt with identification of potential hazardous material onboard and method to prevent the haphazard handling of these materials. The Basel convention [2005] recommendation stresses the need of *best practices* to be followed in ship recycling process. The recommendations have focused more on environmental control procedures at ship dismantling yards by picking each and every potentially hazardous material present onboard.

3.3.4 Environmental Protection Agency (USA) Recommendations

US EPA [2000] has prepared a very comprehensive document regarding regulatory measures to be implemented in the United States ship dismantling yards. This document is the most extensive document dealing ship recycling issues related to pollution and hazards. The content of guidelines has dealt mainly with handling of hazardous materials onboard. Identification, handling and management of main hazardous wastes such as asbestos, PCB paint bilge and ballast water , waste water and oil and fuel have been described in a very detailed manner. This document has also thrown light on practices involved in metal cutting, managing scrap and removal and disposal of ships machinery.

3.3.5 International Labour Organisation (ILO) Guidelines

[ILO 2004] has provided guidelines on ship recycling which has focused mainly on worker safety and health during ship dismantling. The ILO documents on ship recycling mainly have dealt with the health and safety of the labour work force employed in ship recycling yards. The guidelines have covered general safe ship breaking operations, involving manual labour, safety requirements for tools, machines and equipment.

3.3.6 Regional Rules and Regulations

3.3.6.1 Gujrath Maritime Board

Gujarath Maritime Board (GMB) is the governing body of world's largest ship recycling destination. GMB has its own rules which can be considered as local rules. GMB has formulated certain rules regarding handling and disposal of asbestos and waste oil. The transportation and disposal of solid waste also has been brought under the preview of these rules.

3.3.6.2 Supreme Court of India

Supreme Court of India has given historic ruling in connection with denial or permission for infamous French Aircraft Carrier, Clemenssau, to Alang Ship Recycling Yard. The Supreme Court of India has given some strict guidelines regarding ship recycling activities in India. These guidelines are very general in nature and more specific rules have to be formulated for actual implementation at the recycling yards.

3.3.6.3 Departments of Trade & Industry and Environment, Food and Rural Affairs, U.K

Rules and regulations related to decommissioning of offshore installations, ships and pipelines in the United Kingdom have been started by the end of last millennium.[UK 1998] Two different government departments have prepared separate guidelines regarding ship recycling in UK. These documents prepared by the Department of Trade and Industries, United Kingdom and though these guidelines prepared are for dealing with offshore structures, the same can be very useful in ship recycling context also. Separate guidelines have been provided for heavy and light structures. Notes have been provided for concrete structures used in offshore installations considering special characteristics associated with it. Another UK government body, Department of Environment, Food and Rural Affairs has prepared a similar ship recycling document [UK 2007]. This has spoken about the UK ship recycling strategy in detail.

3.3.6.4 MARISEC, London

Industry Code of Practice on Ship Recycling [MARISEC 2001] is general purpose ship recycling guidelines. These guidelines have been prepared by the Industry Working Party on Ship Recycling working under Marisec which is a consortium of number of international maritime agencies, operating from London. The working group on ship recycling is under the coordination of International Chamber of Shipping (ICS). The ship recycling in codes are given in the book titled "Industry Code of Practice on Ship recycling". European Union council regulations No.259/93 has been referred in this as the supporting document. Content of this code is of promotional nature and the code calls for voluntary kind of participation by the ship recycling and other interested maritime industries in clean and safe recycling activities in recycling destinations of the world. It is the only document which strongly speaks about necessity for an efficient and concrete 'Industry Policy on Ship Recycling'.

3.4 APPLICATIONS OF INFORMATION TECHNOLOGY

Karpowicz et al [2005] have elaborated the need for a proper and efficient Knowledge Base support for healthier ship recycling activities all over the world. The paper has drawn the attention of various engineering professionals and practicing managers, technocrats and other interested groups in the process of initiating a common information platform by which the prospects of the recycling industries can be made brighter. It has presented an interesting matrix depicting very clear roles and responsibilities of various participating elements in the recycling engineering system. The paper has categorically suggested that if any recycling industry has to survive, especially that from the EU nations, they will have to turn toward implementation of an effective knowledge base support mechanism in the day to day activities.

Sibal.P, [2001] in her project work, has described the process of development of a software tool and associated databases to show various information available such as , ship name, type, year built, ship status, light ship displacement, length, beam, changes made, dead weight, number of propellers, propulsion type, dismantling site of ship(s).This work has dealt in detail the development of a Database for Dismantling of Obsolete Vessels (DOVE) by providing total towing cost for a selected ship based on the total tow distance, the light ship displacement of the ship, the unit tow cost/mile-ton and the tow preparation cost. A cutting technology database is discussed which was developed and populated to provide information about the various cutting technologies, decontamination technologies and waste processing methodologies. It has included yet another database system in the work which gives the account of recycled metals and alloys is successfully integrated to the DOVE system. Information links to all the regulations by the OSHA and the EPA regarding the hazardous chemicals have also been listed in thesis.

Gramann, [2006] has provided an overview on the background of data management and development of an appropriate tool incorporating the needs and requirements related to the new legally binding instrument on ship recycling, which is currently under development at IMO. The paper has nicely projected the need of a high computing database system allowing different approaches by creation of technical and logical data relations.

Koumanakos et al [2006] have considered various factors involved in ship recycling, and propose an information support framework that supports decision making for the dismantling of obsolete vessels. The proposed framework has integrated a dynamic simulation tool with decision support features and functionalities to address the individual needs of the different stakeholders involved. Framework presented in this paper highlights points such as support decision making concerning the design and execution of the dismantling process of a vessel, the suitability of a dismantling yard for a specific vessel, the recycling of the vessel's materials, the economic feasibility of a dismantling yard to undertake a dismantling process. In addition, the proposed framework integrates a set of well-structured databases that maintain data concerning vessels, dismantling yards and processes, associated technologies and equipment, customers, as well as directives and regulations concerning occupational health and environmental sustainability.

3.5 ROLE OF NAVAL ARCHITECTS AND CLASSIFICATION SOCIETIES

Alkaner et al[1] [2006] have referred to the point of development of industrial facilities as a process which involves extensive interaction among numerous layout design parameters. This paper has also stressed the need of re-engineering the current processes and facilities to suit environmentally friendly solutions for the "product's funeral". In this paper, a systematic approach to the facility development problem for a generic ship dismantling yard has been presented. A comparison is made between the current layout and facility types used in ship dismantling and shipbuilding, emphasising the similarities between both industries. Current ship dismantling practices and facility formations from the main ship dismantling countries have been critically evaluated and presented. Departing from abstract and broadly defined facility components, this study has focused on selected stages of the processes and has introduced a detailed and streamlined modeling approach for critical facility components. A series of layout alternatives is systematically generated at the concept development stage, based on the variants of the primary and secondary phase dismantling processes. A set of performance criteria for ship dismantling facility layouts has been developed in order to compare and evaluate the performance of each layout alternative. Performance indices have also been used to determine the input data and systems modeling needs of the study. A simulation model for each layout variant is developed to evaluate the performance of each alternative under various operating and environmental conditions. The stochasticity of real-life cases has been introduced into the model to analyze the dynamic nature of ship dismantling processes and systems. Integrated fuzzy multiple-criteria multiple attribute decision support systems for facility design evaluation for ship dismantling has also been presented for selecting the best alternative.

Alkaner et al[2] [2006] have done a comparative analysis of ship dismantling with ship production. Moreover, ship dismantling has occasionally been referred to as "reverse" shipbuilding. The paper has investigated both activities from the point of view of process characteristics and key performance indicators for both processes are listed. It has highlighted the Health and Safety rules and regulations in both processes and later has brought out comparison of facilities management in ship production and ship dismantling. Another area touched by the authors is the environmental impact of yard operations, i.e.; emissions and handling of hazardous materials. In this paper, "design for disassembly (DfD)" concepts have also been discussed in the ship lifecycle performance improvement context. DfD activities consider the end of life stage of the product as early as possible during the initial stages of design and construction. Among the subjects discussed under that section are design aspects, material inventories and reusability issues.

3.6 SHIP RECYCLING DEMAND FORECASTING

Bruce et al [2005] have presented a model for assessment of future market for ship dismantling. The authors have been successful in arriving at a reasonable prediction using time series over a ten year period. The method used in the prediction is a Free-Forward Neural Network which has been trained for logic of interaction between the identified parameters affecting ship recycling demand. The authors have expressed doubts over the prediction accuracy of their model in the event of sudden and unexpected developments in the international shipbuilding sector. This is one of the very few technical papers available in ship recycling dealing with demand forecasting of ship recycling.

3.7 INFERENCE

It has been observed that most of the works are of promotional nature and reflect concerns regarding issues related to Safety, Environment and Pollution. The reported works by Winjgarden [2006], Stephenson [2005], Shahid [2005], Asolekar et al[1] [2006] and the like in ship recycling field deal with only peripheral issues with shades of regional aspects. The active role of IMO in the ship recycling industry has been elucidated in IMO [2003]. There are more guidelines than the actual recycling activities and these guidelines still remain as recommendations. The ship recycling nations have not yet made it mandatory, though there are some concrete move in this direction initiated by IMO and some member states. 'Rules' remain as a Black Box yet to be decoded by the industry for implementing them in a real situation. The efforts undertaken by the ship classification society, Det Norske Veritas [DNV, 2000] are reflected at many places in the literature. The Green Passport issue put forward by the DNV has got a good coverage and IMO is referring to this in its reports.

Though ship recycling has been accepted as one of the main life-time-activities of ships, the presence of naval architects is felt seldom. The literature presented in this report has only one technical deliberation in a field which connects naval architecture and ship recycling viz, Das et al [2006]. Experts representing mechanical, chemical, safety and environmental engineering are more active in this filed now. The reported studies in ship recycling are more in terms of industrial projects than academic research. Database creation for obsolete vessels has been dealt by Sibal [2001]. The necessity of developing knowledgebase has been proposed by Karpowicz et al [2005]. Database creation of rules and regulations in ship recycling has been emphasized by Gramann [2006] and creation of dynamic decision support tool for planning operations in ship recycling h as been proposed by Koumanakos et al [2006]. Bruce et al [2005] have touched a small part of vast area of demand forecasting in ship recycling.

CHAPTER 4

SHIP RECYCLING DEMAND FORECASTING

4.1 SCOPE OF DEMAND FORECASTING IN SHIP RECYCLING

Demand forecasting is an essential analytical procedure executed through mathematical tools or otherwise by any modern industry and ship recycling industry is no exception to that. Ship recycling demand in general means the number of vessels ready to be dismantled during a specific period of time. The parameters that are involved in the ship recycling demand forecasting can be of cost aspects or regulatory aspects. The cost aspects include scrap steel prices, condition in freight market, cost of dismantling, price of fuel oil and shipbuilding cost. The regulatory aspects include implementation of rules and regulation and option for conversion. The interdependence of these parameters and their influence on demand for ship recycling vary among different ship types. Also this is applicable only to cargo ship recycling demand forecasting as other type ships do not have any relation with freight rate.

4.2 PARAMETERS OF SHIP RECYCLING DEMAND

Demand forecasting of ship recycling volume for a specific period of time depends on various financial and non financial factors. The financial factors which has got direct influence in the demand forecasting are,

a) Price/ton of shipbuilding quality steel in the international market
b) Price/ton of scrap steel in the regional market
c) Prevailing freight rate/ ton of commodity shipped
d) Price/barrel of fuel oil and
e) New shipbuilding cost/ ton of steel

The non financial factors influencing volume of demand of recycling are identified and listed below;

i) Recycler friendliness (situation yielding maximum profit) of the prevailing dismantling and recycling rules and regulations enforced on or prevailing for the recycler.

ii) Rules and regulations regarding ship operations and maintenance which decide on the availability of the ship for recycling.

iii) Prevailing ship conversion options.

The first five parameters are quantitative where as the last three are qualitative. These are suggested in the present study to serve as the input for demand forecasting of ship recycling volume using some commercial software.

4.3 FORECASTING METHODS AND TOOLS

Before going into the details of ship recycling demand forecasting, the need for a critical evaluation of the existing methods and tools for forecasting is felt. The general methods and tools for forecasting have been described subsequently, followed by a critique of that.

4.3.1 Qualitative Forecasting Methods

The qualitative forecasting methods are based on executive opinion, market research or Delphi method. Executive opinion is one approach in which a group of managers meet and collectively develop a forecast. Market research is the approach based on surveys and interviews to determine customer preferences and assess the demand. Delphi method is one in which a forecast is the product of a consensus among a group of experts.

4.3.2 Quantitative Forecasting Methods

Quantitative forecasting methods can be divided into two categories viz., time series models and causal models. Time series models look at past patterns of data and attempt to predict the future based upon the underlying patterns contained within those data. Causal models assume that the value/characteristics being forecasted is related to other variables in the environment. Causal models try to predict after establishing those associations between value being predicted and the influencing factors.

4.3.2.1 Time Series Models

The various time series models and their prominent features are shown in table 4.1. The time series models tend to show some specific patterns such as level or horizontal, trend, seasonality and cycles. When the data are relatively constant over time, with no growth or decline, the series is called as “Level”. “Trend” is term used to describe the steady growth or decline of the analysed data over a period of time. If the collected data show upward and downward swings in a short to intermediate time frame (most notably during a year) then the data type is called as “Seasonality” and if the data exhibit upward and downward swings in over a very long time frame, it is called as “Cycles”. “Random” is a set of data which show erratic and unpredictable variation over a period of time.

Table 4.1 Prominent Features of Time Series Models

Model	**Description**
Naïve	Uses last period’s actual value as a forecast
Simple Mean (Average)	Uses an average of all past data as a forecast
Simple Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving the same emphasis (weight)
Weighted Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving a different emphasis (weight)
Exponential Smoothing	A weighted average procedure with weights declining exponentially as data become older
Trend Adjusted Exponential Smoothing	An exponential smoothing model with a mechanism for making adjustments when strong trend patterns are inherent in the data.
Seasonal Indexes	A mechanism for adjusting the forecast to accommodate any seasonal patterns inherent in the data.
Linear Trend Line	Technique that uses the least squares method to fit a straight line to the data

4.3.2.2 Causal Methods

Causal models assume that the variable being forecasted (the dependent variable) is associated to other variables (independent variables) in the environment. This approach tries to project demand based upon those associations. In its simplest form, linear regression is used to fit a line to the data. That line is then used to forecast the dependent variable for some selected value of the independent variable.

4.3.3 Critique of the Methods

Time series models in demand forecasting mainly focus on the averages of the demand over the years. The external factors affecting the demand are not considered while the analysis done for forecasting the future trends. In fact as explained in section 4.2, few quantitative and qualitative factors influence the demand of ship recycling. Causal methods which take into consideration various external influencing factor for prediction is found suitable for demand forecasting of ship recycling.

4.4 IMPLEMENTATION OF DEMAND FORECASTING METHOD IN SHIP RECYCLING

Ship recycling demand forecasting follows theoretical formulations and at the same time shows highly unpredictable nature of occurrence. The later characteristic of the ship dismantling volume is due to the fact that the scrapping volume does not solely depend on the economic state variables. The recycling volume is influenced by various strategic decisions by the ship owners and their individual preferences too. These features make forecasting of ship recycling volume more of a practical field of analysis than a pure theoretical prediction based on various related economic data

As there are many type ships in the international shipping sector and each type has a set of unique domain of operations. Even within a type ship group wide variation are seen in the life cycle stage management leading to a totally dismantling prospect. For example, Very large Crude oil Carriers (VLCCs) are entirely different from a coastal tanker as far as design, construction , survey and repair functions and operations are concerned. This makes it practically impossible to have a common platform for forecasting dismantling volume of type ships. Separate forecasting models based on salient life cycle features of the identified class of vessels have to be formulated.

The Stochastic methods applied to the demand forecasting of recycling of obsolete vessels have several limitations such as influence of rules and regulations on various life cycle operations of vessels, effects of prevailing economic conditions in international shipping field, impact of technological developments in ship design&

construction and vessel operation or creating alternate options and policy taken by various countries to protect their own shipping business. Stochastic methods can be applied to find an initial estimate of the dismantling volume only. Better statistics can be further found out by using iterative methods which use past data, their inter relations and effect of various qualitative influencing factors on them. Application of computer based iterative methods like neural networks and genetic algorithms can be more useful in this regard. Since the main issues addressed in this thesis is not demand forecasting of ship recycling, further efforts are not attempted in this regard.

CHAPTER 5

DEVELOPMENT OF KNOWLEDGE BASED EXPERT SYSTEM FOR SHIP RECYCLING

5.1 INTRODUCTION

Any interdisciplinary or multifunctional engineering activity requires the help of experienced professionals for its execution. In a problem-solving situation there may be an additional requirement of an expert as well. An expert is a person with immense and in-depth knowledge in any branch of studies. Expert system is regarded as the embodiment, within a computer of a knowledge based component, from an expert skill, in such a form that the system can offer intelligent advice or to take an intelligent decision about a processing function. [Yazdani,1988]

Practically it is very difficult to find a person who is equally expert in all the disciplines. Interdisciplinary approaches are commonly seen in managing industrial activities where involvement of many engineering, technology, science and other related disciplines are involved. When many such disciplines come as part of a problem or solution of a problem, the problem solving becomes multifunctional. In this situation, it may be difficult for a person to intervene effectively and solve problem using only his expertise. In this context computer based expert system offers a better solution to such problems.

Information flow in a computer based expert system suitable for an engineering problem is shown in fig. 5.1. The investigation domain is the field of activity in which the expert system is applied. This field of activity should be well defined and a definite domain has to be assigned to it. Problem chart in this domain refers to any specific problem that the research aims to address. Various problems are to be listed in the beginning itself to identify the issues related to that. After having listed the problems in the domain the expert system should acquire data input related to the problem through a mechanism called system dialogue. Dialogue is the process of acquiring input through interactive sessions. Other means of input include data work sheets and value added data. Data sheets are raw data collected directly (other than interactive modes) and value added data are raw data modified to suit the functioning of the expert system. Decision points and available rules are the other set of input through which the first set of data are analysed. The data collected and compiled are systematically screened and compared with the stored decision points and available rules. Decisions regarding the answers to the problems are derived out of the screening and comparison. Heuristics and weightages are applied at this stage to further analyse the data to arrive at feasible solutions. The solutions to the problems are given as recommendations which constitute the output of the expert system.

Ocean going ships are massive in size and complex in its constitution. The basic construction commodity for ships is 'harmless' steel, but the ship related activities involve dealing materials ranging from hazardous chemicals to radio active items. Generation of an accurate and comprehensive knowledgebase of the materials, regarding quality, quantity and location onboard is very critical for a risk free, environment friendly, energy conserving and economical ship recycling process. Interestingly, the knowledge base is essential for effective implementation of any computer-oriented expert system. This makes application of computer based expert system most supportive and suitable for developing an efficient and productive ship recycling process. Identification and classification of technology and science involved in ship recycling which has not been thoroughly undertaken till now, is one of the useful outcome of this exercise.

5.2 FEATURES OF EXPERT SYSTEMS FOR DECISION SUPPORT

An expert system is a computer code designed to carry systematically organized knowledge of a specific set of human expertise. This is used to simulate the functions and contributions of a subject expert in that field. Expert system in general possesses symbolic representation of knowledge and inference, heuristic search, reasoning ability, generation of self knowledge and use of this knowledge to provide explanations or justifications.

5.2.1 Fundamental Elements of Expert System

Input-output module of the expert system gives platforms for communication between user and the expert. The problems given by the user is processed and reasonable solutions are forwarded by the expert system. The results are displayed as output on the screen.

The prime modules of an expert system are the knowledge base and the inference mechanism. All available knowledge in a particular subject domain can be the part of the knowledge base which can be raw or processed.

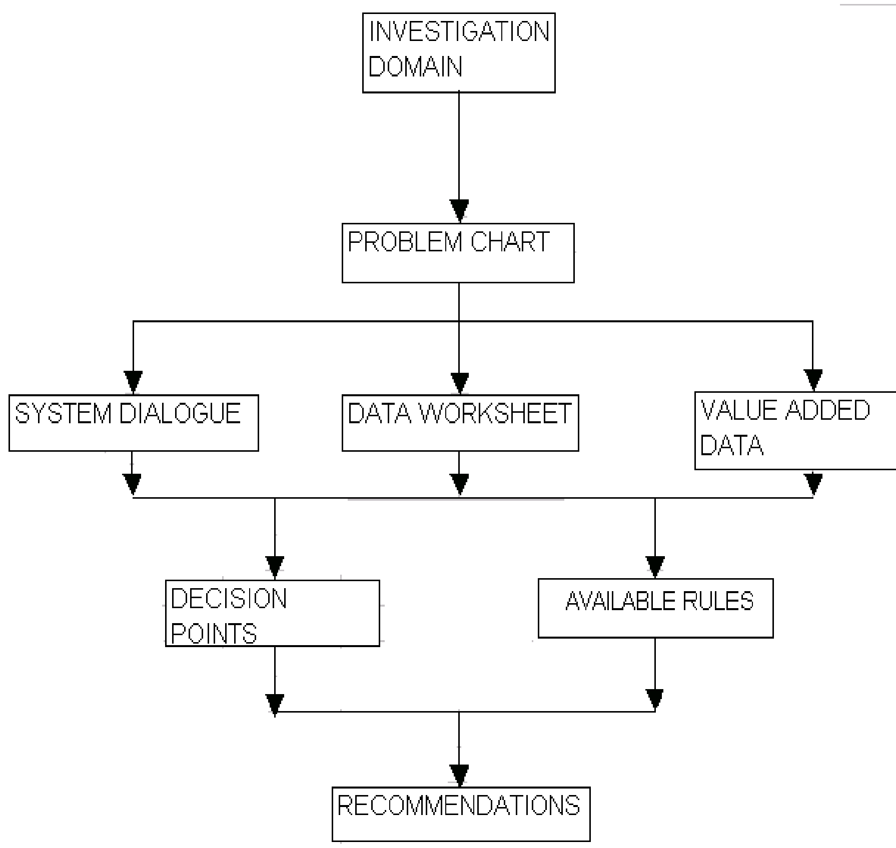

Fig5.1 Flow Chart of Information Flow of Computer Based Expert System

Knowledge base is a collection of data pertaining to a subject for which an expert system is developed. The main facilities for representations of knowledge are rules, object definitions, relationships and procedures. Among these components rules are the most common element of an expert system. The rules appear as IF…. THEN… statements, which when applied to a particular situation, gives an answer corresponding to "if this is the situation then this should be the "reaction". Object definitions are used to identify and differentiate various types of knowledge building blocks. The relation between these blocks express dependencies and connections among the blocks. Procedures written as codes specify the sequence of preferential operations to solve problem.

Inference mechanism is applied over the knowledge base to produce the result, solution or output and the knowledge is modified and altered during the process mechanism. Common inference mechanism can be used to solve variety of problems. The main inference mechanism contained in the knowledgebase is known as forward chaining and backward chaining. Real systems use both of them separately and sometimes in combination too. Pattern recognition based inference systems are also used as inference mechanism for solving certain problems. Forward chaining mechanism uses the reasoning from knowledge base to reach a conclusion. The rules consist of a condition part and an action component. If the conditions match the appropriate parameters given in the knowledge base then the action component is activated. IF…THEN type of forward chaining inference system will check, if X value is true, and then deduce a new fact Y. As these changes, the current set of facts changes and new rules come into force.

Backward chaining is another method employed to find a set of data to prove or to project a hypothesis by considering it as a goal. Proper conditions are found out which satisfies the requirements of the set goal. The backward chain mechanism then finds a set of conditions, by examining the database to see whether they are true, or not true, by treating the false value as goal. The main goal is divided into various sub goals until a basic space is reached or the attempts to prove the goals fail.

5.2.2 Characteristics of Practical Expert System

Expert systems are applied to problems in which a specialized knowledge domain is present. Efficient expert systems can be developed only when experts and knowledge base are available and the domain knowledge can be formulated in computer based system. The experts systems are often employed to special problems in which experts have difference of opinion as far as the end and means are considered. Problems which are of general interest and comparatively massive in nature are effectively handled by expert system which has the capacity to analyse huge database. Also problems with no algorithmic solution and which can be solved with pure heuristics can easily be tackled by an appropriate expert system.

5.2.3 Effectiveness of Expert Systems

The level to which the database is a correct representation of the expert knowledge required to undertake the problem solving is the most important measure of effectiveness of an expert system. The correctness of the system depends on the quality of knowledge representation and inference mechanism applied. The easiness which the operator can handle the system and the scope of improvisation of the system are two major evaluation points applied to find out the effectiveness. Reliability is yet another factor which contributes to the correctness and effectiveness of the system. Reliability of an expert can be defined as the degree to which the expert system can give consistent results with required level of accuracy.

5.2.4 Knowledge Acquisition

Traditional knowledge sources such as books and technical journals, in-house technical documents of industrial establishments, experience capture notes by individuals can be of good use in acquiring required knowledge for development of an expert system. The process involves collection and compilation of specialized theoretical and practical data, the rule of thumb and experience based information available with experts in the field. These raw data have to be improvised to fit into coded type of knowledge. This process is usually done by a knowledge engineer who has working knowledge in the problem domain as well as expert system development. Special purpose intelligent editing program can also be used to convert the raw knowledge to a readily usable type of computer knowledge database.

5.3 BEACH METHOD IN SHIP RECYCLING

Detailed discussion regarding the recycling activities in beach based ship recycling, the roles of major stake holders and the interaction between them are given in the following subheadings.

5.3.1 System Representation of the Beach Method

Proper definition of the system and its detailed representation depicting the mutual interaction of the participating elements is an essential requirement for developing a proper knowledgebase of the problem domain. The major elements of the beach based ship recycling system have been identified and their roles and responsibilities have been listed in the subsequent subheadings.

5.3.2 Elements of the System

Ship recycling has been conceived as the reverse engineering process of modern shipbuilding and some efforts have been made in the present study to connect the missing links between ship recycling and modern shipbuilding. The major elements in the ship recycling system are described in the subsequent paragraphs. A proposed system analysis of ship recycling depicting close interaction between the identified elements is shown in fig. 5.2.

In order to establish a system of ship recycling process (as a reverse engineering process of modern shipbuilding) as it is practiced today, the major elements of the system are to be identified. Well defined roles and responsibilities assigned to these identified elements of ship recycling system will consequently be useful for developing a knowledge base regarding ship recycling. An ideal system of ship recycling should contain the following major elements,

i. Ship Owners
ii. Ship Recycling Brokers
iii. Ship Classification Societies
iv. Ship Recyclers
v. Ship Recycling Subcontractors
vi. Statutory Maritime Bodies
vii. Ship Recycling Promotion Agencies
viii. Pollution Control Bodies/Safety Councils
ix. Re-rollers of Dismantled Steel
x. Supply Chain Brokers
xi. N.G.Os Involved in Green Issues
xii. Worker Forums

Ship Owner is either an individual or a firm who has got the legal ownership of the vessel just before she is dismantled. As on today the ship owner has no role and responsibility in the issues related to ship recycling. Once he sells the vessel to the ship breaking broker, he simply vanishes from the turbulent scene to be followed. It is interesting to note that the green NGOs such as Green Peace and Ban Asbestos Network of India (BANI) always argue that these ship owners are the real culprits in the ship recycling controversies. Role of obsolete ship owners ends with selling of the ship and the owner is not a party to any of subsequent ship recycling activities, for the time being in the ship recycling industry.

Ship Recycling Brokers are international agents who participate in the auction bid and take over the charge of the ship before it is delivered to the recycling site. Ship recycling broker is yet another intermediate owner of the obsolete ship and his role is limited to negotiation of bids in the early stages of ship recycling activity. These brokers are, just agents seen in these business ventures and are not concerned about any issues related to ship recycling other than profit.

Ship Classification Societies are very active and authoritative in other life cycle activities of seagoing vessels since their inception. However at present their role in ship recycling is limited to preparing proposals, attending meetings and conducting research studies. Declassing of ships with respect to ship recycling concept is so far neither developed nor implemented. A few codes or rules have been framed regarding some other major issues like environmental protection, safe working condition etc., The proposed system envisages greater responsibilities for ship classification societies in aspects such as rule making and surveying. They have a key role to play in decision on de-classification of ships leading to recycling. They have to work in tandem with other elements including statutory maritime authorities, local maritime boards, ship recyclers and pollution control authorities.

Ship Recyclers who are supposed to provide all infrastructural facilities with regard to safe and eco-friendly dismantling of vessels constitute a strong link in the ship recycling chain. They work closely with other promotional and statutory bodies to deliver safe and smooth ship recycling. At present most of the ship recyclers are just providers of plot and basic infrastructure to the next element in the recycling chain. Since they have to take the blame of any untoward incidents that may occur during ship recycling, they have to be more vigilant and involved in the process. The ship recyclers attain key role in the proposed ship recycling system with a major thrust on their responsibilities leading to clean and safe ship recycling. Ship recycler is responsible for implementation of statutory and classification guidelines on ship recycling. They also have to ensure that the recycling subcontractor is undertaking the ship dismantling activities following international, national and local rules on environmental pollution, quality and occupational safety of workers. The proposed system representation of the ship recycling process has clearly indicated this concept as the ship recycler is placed in its centre.

Ship Recycling Subcontractors provide manpower and machines for the actual dismantling. The contractors are the people who implement prevailing rules regarding safety and environment. They are responsible for employing trained personnel for dismantling operations involving risk and hazard. Subcontractors are not generally considered to be responsible for any ship recycling related issues occurring in the yard. However, it is always their negligence, incompetence, and inexperience that are reflected in most of the mishaps involving loss of life or spread of pollutants. The proposed recycling system envisages the ship recycling subcontractors as the core element in the system for which *best practices* in ship recycling are to be implemented urgently.

Statutory Maritime Bodies, which have otherwise lot of statutory powers, are not actively involved in the ship recycling issues at present. Basel Convention organised by United Nations Environment Program (UNEP) considers obsolete ship as a hazardous waste. The vessel becomes a steel scrap as it becomes obsolete. The obsolete ship loses the status of a seaworthy vessel and comes out from the purview of maritime regulatory bodies. These bodies will have to participate in the ship recycling activities in a fashion similar to other maritime activities such as ship design, ship production, operation and repair of ships. Statutory bodies should take superior role in implementing the rules through the agencies such pollution control boards, maritime promotional bodies, ship classification societies and local and regional statutory bodies. Unless the maritime statutory bodies take more participating role in this regard, the real issues may become more severe. In the new ship recycling system more emphasis is given for more active and regulatory type of role for the statutory national maritime departments.

Promotional Bodies provide land, expertise, infrastructural facilities, provisions, training, transport, logistics support to the ship recyclers and the subcontractors. They are the custodians of important statistics regarding ship recycling activities including productivity figures, the accident rates, pollution effect, health hazards etc.,. Such agencies have to be dedicated to play a major role in development of port and maritime sector of the country. Along with the major duties, they have to undertake promotional activities in ship recycling as a subsidiary work. Services of experienced naval architects and marine engineers are essential for more effective functioning of these bodies. The necessity of providing business support activities in ship recycling industry is becoming more relevant when viewed in conjunction with the acute problems faced by the industry today. The ship recycling system proposed for improving the efficiency of ship recycling locates this element at the helm of the system. Unless modern infrastructural facilities are offered the efficiency of the system is not going to show remarkable changes. The platform for development in ship recycling industry is to be set up by these promotional bodies.

Pollution Control Boards/Safety Councils work as advisory bodies at present in the ship recycling field. Their roles and responsibilities are limited as far as safe and clean ship recycling is concerned. These agencies can work in tandem with the promotional bodies to create a clean, safe and productive ship recycling system and can attain active partner status at par with statutory maritime departments or institutions. These agencies can act as the representatives of various United Nations agencies such as International Labour Organisation (ILO) and Basel Convention supervising enforcement of the respective guidelines on clean and safe ship recycling.

Steel Re Rollers mills enjoy maximum benefit out ship recycling in all the major ship recycling countries. These re rollers usually set the agenda for ship recycling of these countries. This is the case with almost all major recycling nations. They do not seem to contribute back to the development of ship recycling infrastructure and support. Re- rollers are one of the powerful links in the chain and current information regarding their role is yet to be defined clearly. This will be advantageous for the re rollers also. Ship classification societies can play a role in accrediting these down stream industry for improving the quality of their products. Maritime industry can also use the re rolled products helping sustainable development of maritime sector of nation. If *best practices* in ship recycling are rigorously followed, quality of the used products can be improved a lot.

Supply Chain Brokers include the agents who purchase various equipment and other onboard items which are kept for auction by the recycler/subcontractor after dismantling. These auctioned items are sold out as pre-owned or pre-used items. Most of these item and equipment re-enter the domestic and industrial market through shop/shelf. Sometimes brokers get shipyard people to take main machinery back to shipbuilding. There exists no mechanism to identify the recycled product, code them and mark the quality of the item depending on the worthiness and status of these items. The pre-owned dealer market is mainly for small items and scrap. Pre-owned items and scrap dealing are potential threat for the future as these are likely to cause major disposal problems. Statutory bodies will have to check the status of the used items and formulate a mechanism to code them. This is essential as the classification societies have been reporting the appearance of used item in the fresh industrial products market.

Green Non Governmental Organizations (NGOs) are the international organisations involved in green issues and are active in ship recycling. There is a constant pressure from these NGOs on ship recyclers. They are now targeting ship owners than the ship recyclers for the lack of eco-friendliness in related issues in ship recycling. The presence of these NGOs has in fact significantly affected the style of functioning of ship recyclers, government authorities and promotional bodies. The effect has been highly positive so far. They have a very significant role to play in ensuring clean and safe ship recycling activities around the world by providing accurate and reliable statistics on happenings in ship recycling and providing positive reporting on the serious issues.

Worker Forums are the trade unions and similar association working in this industry. They are actively participating in all the issues related to improving the status of present day ship recycling from the point of view of worker welfare and green issues. However their voice is not powerful. These workers forums couple their activities with stronger international NGOs working in ship recycling and gain stronger position in bargaining. These organizations should get more positive empowerment to participate in meaningful bargaining with ship recyclers to grab more opportunities and better job conditions for the workers. Their role is very significant in ship recycling which has been stamped as most unsafe and hazardous industry by ILO [2004]. They should always work in tandem with the Green NGOs and represent their demand before the promotional bodies and other statutory bodies for ensuring occupational health and safety of the workers. Another additional role that they can take up is that to participate in the collective effort to convert the present day status of ship recycling as ‘scrap industry’ to ‘sophisticated industry’.

The important activities of beach based ship recycling system have to be integrated with the expert knowledge base for making a comprehensive model of beach based ship recycling. A system for beach based ship recycling has been developed in the present study. The basic elements of the ship recycling system have been identified and their roles and responsibilities have been presented. Fig. 5.2 shows the interaction of the elements of the beach based ship recycling system. The major interaction routes and lines of the system have been studied for the purpose of developing the knowledge base of ship recycling.

Identification of the system elements their roles and responsibilities and the mutual interaction will serve as the basis for generation of a knowledge base for processes involved in beach based ship recycling. This knowledge base thus generated would help in developing an expert system meant for decision support in accomplishing various ship recycling activities. It is envisaged that the implementation of the system will open a wide corridor for effective application of *best practices* in ship recycling.

5.4 EXPERT SYSTEMS IN MARINE APPLICATIONS

Katsoulakos et al [1989] have listed application of expert systems in various marine technology fields. The important categories of expert system application in marine technology are as follows;

i) Classification type of expert system which is used for fault diagnostics, communication and ship classification.

ii) General advice category is useful in implementing international convention guidelines in life cycle activities of ships, operation costing of ships and generation shipping information

iii). Design oriented expert systems are used to develop decision support in ship machinery designs.

iv) Planning and scheduling type of expert systems are implemented in voyage planning and scheduling and planning of maintenance and surveys.

v) Monitoring category type of systems is the best suitable method for fleet management and equipment monitoring.

vi) Simulation and prediction based expert systems are helpful in predictive maintenance programmes and freight rate predictions.

vii) Identification oriented systems are applied in weather monitoring and surveillance, navigation and position control.

viii) Control based systems are widely used in ship management, bridge integrated control and dynamic positioning.

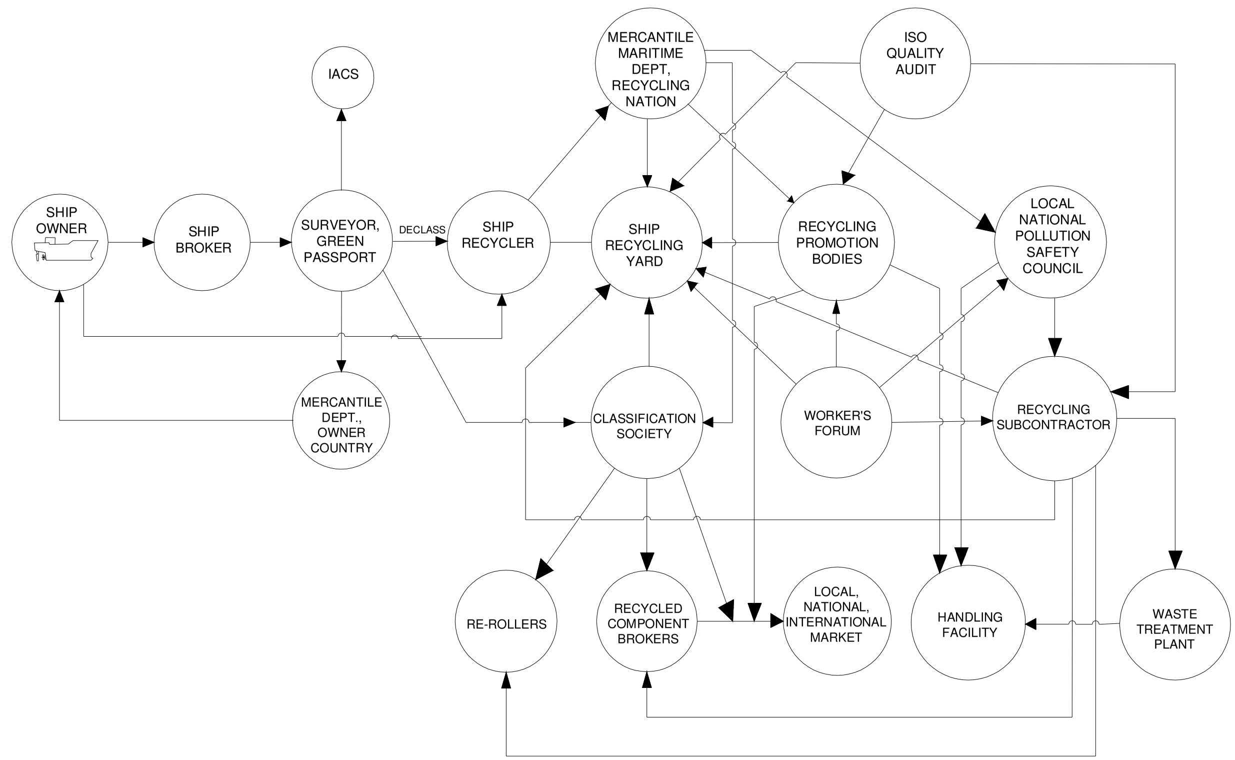

Fig 5.2 Proposed Systems Analysis of Ship Recycling Activities

Out of these types of expert system applications, General Advice type has been identified as the most relevant and suitable type having good scope of application in ship recycling. The need of the hour in ship recycling field is to implement the guidelines issued by various international conventions such as Marine Environmental Protection Committee, Marine Safety Committee, ILO and Basel. These conventions have put forward various important recommendations regarding safety of personnel working at site, environmental protection, safety of machines and systems supporting the ship recycling activities and occupational health. Vast amount of information available in this connection have to be well presented to various stake holders in the ship recycling industry for making it more clean and safe. One of the best ways to implement it is to introduce this into a computer based knowledge base system and then by using an expert system(which arranges the relevant information readily accessible to the various stakeholders) effectively address the requirements of ship recycling industry and this has been followed in the present study.

5.5 KNOWLEDGE BASE OF THE SHIP RECYCLING SYSTEM

Ship recycling is an engineering industry where various branches of knowledgebase such as science and technology, engineering, management, law, economics, commerce and political science have been involved. Information base of these branches of knowledge as applicable to the development of a comprehensive expert system for ship recycling has been identified developed and presented in table 5.1.

Computer based expert system helps to provide recommendations for improving the situation in an identified investigation domain by collecting and analyzing data from the investigation area.

The expert system, which is developed for the ship recycling practices has three major elements. viz, data base regarding ship (Ship Data), recommended practices and codes (Guidelines) and disassembly processes in ship recycling (Practices). The information model for the expert system which is developed for ship recycling as a part of the present study is given fig. 5.3. Recommendations for *best practices* in ship recycling have been envisaged as the output from the expert system. Ship data and rules on ship

Table. 5.1 Knowledge Base Identified for Comprehensive Expert System for Ship Recycling

Information Base	Knowledge	Expert
Innovation	R&D	Naval Architects, Production Engineers, Structural Engineers
Environment	Pollution and Hazards	Ecologists
Safety	Human /System factors	Safety Engineers and Production Engineers
Production Technology	Technology of Dismantling	Naval Architects
Information	Knowledge Base Engineering	Naval Architects and IT Specialists
Recycling	Energy	Production Engineers
Management	Recycling, Planning and Plant Layout	Naval Architects
Marketing	Demand Forecasting	Market Research Analysts
Finance	Cost and Accounts	Economists, Accountants
Regulation	Rules, Acts and Laws	Lawyers
Green Topics	Socio-environmental Impact	Green Activist

recycling are very much dependent on the specific vessel that approach the yard for recycling. However the disassembly process in recycling is yard dependent and such yard dependent ship recycling activities are explained subsequently.

5.6 SHIP DISMANTLING PROCESSES IN BEACH METHOD

Production processes associated with dismantling of obsolete vessels in beach based ship recycling industry have been identified and these processes have been analysed for their influence in overall performance of ship recycling activities. Important ship recycling performance parameters and their influence in the identified dismantling

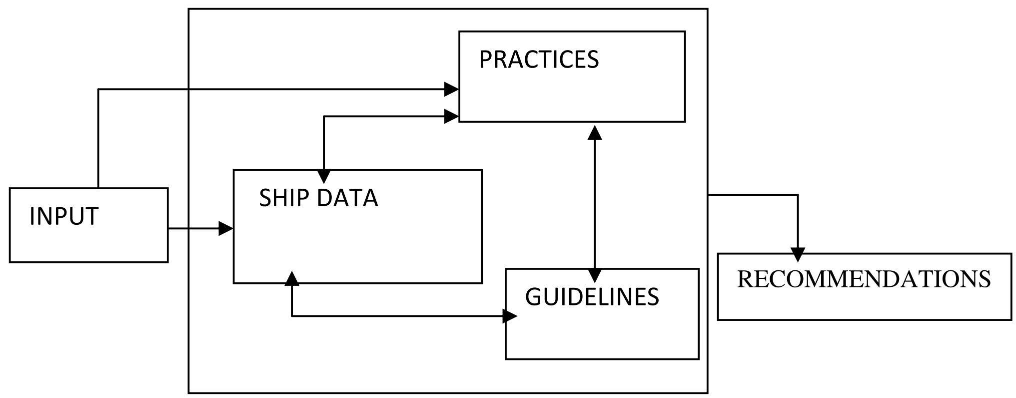

Fig. 5.3 Information Model of the Proposed Expert System

processes are provided in the analysis. This will eventually help the naval architects and other engineers to develop *best practices* for each these processes. These *best practices* are the major output of the expert system software developed here in. The identified dismantling processes and their associated ship recycling parameters are discussed in the subsequent subheadings and influence of these parameters on the identified ship recycling processes is given in table 5.2.

5.6.1 Towing

Some of the ships destined for recycling reach the beach side of recycling yard with towing assistance. Towing of big vessels in shallow water of the recycling yard is associated with some risks including grounding of the vessel or the tug or both. Towing can be considered as the first engineering operation in ship recycling. All obsolete ships are not towed to the recycling destination. Only dump ships or ships with non- operational power plants are taken to the recycling site with the help of tugs. Towing operations are carried out in deep sea or in shallow water. Different types of tugs are to be employed in these two conditions. Both of these operations involve certain amount of risk. Technical specification regarding towing equipment power, stability and maneuvering characteristics of the tugs are to be specially noted as the towing is carried out on aged and declassed vessels. Apart from this the basic minimum stability requirements, stipulated by IMO for ocean going vessel are also to be considered. Database regarding the capabilities of world wide specialist towing service operators are useful for implementation of *best practices* ship recycling. Before beaching the vessel the obsolete ship broker or his agent has to produce documents regarding the transfer of the vessels that is going to be beached to the ship recycling yard authorities. The main particulars of the ship, special information on condition and seaworthiness of hull, and the method of towing/ sailing are to be provided in this document. This document is called as Physical Delivery Certificate.

5.6.2 Beaching

Beaching is the process of transferring the weight of a floating vessel to the beach soil by sliding the vessel. Beaching is done when maximum water depth is available, at the site ie., during the high tide condition. Fig 5.4 gives photograph of a vessel beached in a ship recycling yard. Obsolete vessels having self propulsion capacity are beached by surging directly into the beach. Beaching of the vessels, without onboard propulsion unit is done with the help of tugs and shore pulling mechanisms. Bottom plates of the vessels come in direct contact with the beach soil during this operation. The condition of bottom hull plate of the ship is important as far as pollution prevention during beaching is concerned. There is a possibility of structurally week plates getting damaged causing spilling of fuel or cargo oil from the inside hull tanks. This operation involves certain amount of risk for non flat bottom ships like warships, patrol vessels etc.,. Possibility of capsizing of ships due grounding effect of ships can not be ruled out. This situation calls for analysis of stability of ships during the beaching operation. The entire operation which depends on high tide and tidal condition is very time consuming. The heavy and massive structure is moved and the movement is to be slow so as to prevent any bottom damage. Ship dismantling operations start after the ship is beached safely and evenly supported by the mooring mechanisms.

Fig. 5.4 Beaching of Obsolete Ships (GMB)

5.6.3 Mooring /Sliding /Securing

Due to insufficient tidal difference available in some recycling locations only small portion of the obsolete vessel will be available for dismantling operation immediately after beaching. Other portions will be still under the shallow water part of the beach. The vessel has to be secured well so that even during high tide condition, it will not be floating freely causing movement of the structure causing discomfort to the onboard dismantling workers. The vessel which is usually a massive structure, has to be moored and secured properly for safe dismantling operation. During available high tide water level, the partially dismantled structure has to be slide up facilitating further dismantling of parts of ships that have emerged out of water. Fig. 5.5 shows a photograph of the sliding process in ship dismantling. Improper mooring of the vessel results in unwanted movements which will hamper onboard dismantling operations. This will affect the safety of personnel engaged in marking, cutting and lifting operations.

5.6.4 Gas Freeing

Gas freeing is the method used for removal of oil and inflammable vapour of oils so that the dismantling of ship's parts using 'hot works' can be undertaken without any fire hazard. Inflammable materials remaining in tanks or piping such as fuel, lubricating oils, hydraulic fluids, cargoes and their residues and grease are removed and the vessel is cleared off gas and oil residues. Gas freeing is mandatory operation prior to the ship dismantling operation. Without proper gas freeing, the 'hot work' clearance certificate will not be issued.

Fig. 5.5 Sliding of Beached Vessel (GMB)

Drummed, tanked, or canned liquids or gaseous materials should be removed from the ship before the cutting of plates and stiffeners have commenced. All materials removed should be managed in an environmentally sound manner like recycling and in certain cases, onshore incineration. Incomplete or careless gas freeing causes safety hazards in the later stages of ship dismantling. Gas freeing, if attempted during dismantling will lead to productivity loss.

5.6.5 Removal of Paint

Prior to ship dismantling, paint removal is done along the marking for cutting of blocks and pieces. This will enable fire hazard free cutting operation. All paints are highly inflammable and any trace of paint present in the cutting line can cause fire hazard. Man Entry Certificates are to be obtained before entering any compartment for the purpose of paint removal and marking. The compartment should be properly ventilated and made gas free and offered for inspection by the ship recycling yard and statutory authorities. Proper access, lighting and drinking water provisions are to made before the compartment is offered for getting Man Entry Certificate. Poisonous paints such as Tributylin (TBT), if handled without proper care can cause heavy pollution of sea water and beach sand. Painting has to be removed from the entire cutting length of plates, stiffeners and other structural members and the total length of cutting may depend on the main dimensions of the ship to be dismantled. In the case of a medium sized ship the total cutting length will be in the range of few kilometers. Painting has to be removed from the entire cutting length and the amount of effort spent on paint removal will be considerably high. Paint removal operation in inaccessible onboard spaces is a very tedious process and highly time consuming. In ship recycling productivity perspective, paint removal is a significant activity compared with other activities such as cutting, lifting and handling. Hot Work Certificate is yet another mandatory certificate which is issued after necessary preparations are done to make the cutting areas (paint removed from the cutting lines) and the compartments gas free.

5.6.6 Marking and Cutting

This is the most important part of ship dismantling work which includes designating, marking and preparing hot work areas, and other areas of potential risk. Fig. 5.6 shows oxy-acetylene cutting operations done during dismantling of hull parts. There are many risk factors associated with cutting and the risk factors can be due to fire, structural failure, generation of poisonous gases and lack of ventilation or access.

Application of a proper marking plan will improve the efficiency of subsequent dismantling operations. Cutting means dismantling of parts of ships either using thermal or mechanical type of cutting. Cutting is done along a line of cut on the plates or stiffeners. After cutting the part or the component, the dismantled item is detached from ship's hull. Ship dismantling safety, productivity and overall quality depend largely on cutting operations.

Strict adherence to well designed cutting plan for dismantling operations reduces safety issues and ensures quick and trouble free ship dismantling. Cutting operations should be carried out in conjunction with lifting and handling operation onboard.

5.6.7 Handling

The term handling is used to describe the process of supporting, moving, and releasing of dismantled products. Shipwright is a similar term used in actual ship

Fig 5.6 Oxy-Acetylene Cutting of Hull Parts (GMB)

assembly process. In a beach based dismantling method, bigger parts such as hull blocks and units are allowed to fall face to beach after they are dismantled from the main hull. This is not the case with equipment and smaller assemblies which are dismantled separately and prior to removal of big assemblies. In this case handling operations are to be well planned and their execution should be supervised properly. Additional set-up in terms of scaffolding, fixtures and supports are to be provided prior to and during dismantling. Photograph of manual handling operation is given in fig.5.7. The dismantled parts are to be handled as per the pollution control instructions

Table 5.2 Influence of Performance Parameters on Ship Recycling Processes

Ship Dismantling Processes	Ship Recycling Performance Parameters					
	Safety	Hazard	Pollution	Productivity	Energy	Quality
Gas Freeing	√	√	√	√		√
Towing	√					
Beaching	√		√	√		
Mooring/sliding	√		√	√		
Paint removal	√	√	√	√		√
Marking				√	√	√
Cutting	√	√		√	√	√
Lifting	√	√				√
Handling	√		√	√		√
Buffering				√		√
Sorting and Coding				√		√
Transport			√	√		√
Disposal	√	√	√		√	√

in such away that leakage and other forms of spilling do not occur causing land, sea and air pollution. Strict adherence to the safety instruction is a must for hazard free handling of dismantled parts and equipment.

5.6.8 Lifting

Removal of dismantled hull, outfit and machinery of the dismantled ship either using a frame, chain pulley block and or using crane is considered as lifting. The lifting arrangement and procedures should be taken into account in the cutting plan. The lifting operations include vertical and horizontal movement of dismantled products within the dismantling yard.

Lifting operations become more significant and critical in an obsolete ship dismantling site than in a ship yard. Aged and declassed ships may possess hull parts with inadequate strength and lifting of dismantled items without proper strength analysis may prove the operation very dangerous. Conditions of lifting accessories such as lifting blocks, chains, shackles and winches, capstains and lifting frames made out of the recycled products may add to the risk in lifting operations. Safe lifting operations not only reduce risk while handling but it also reduces chances of environmental pollution. Hence lifting operations can be treated as one of the major constituents of quality ship recycling.

5.6.9 Buffering and Secondary Cutting

Buffering and secondary cutting activity involve stacking the dismantled parts of the ship and preparation of these for further cutting into smaller components such as plates, stiffeners, brackets and cut pieces. In this stage cutting of plates, stiffeners are done to the actual size required for transportation in trucks. Handling and lifting operations find an important place within this activity also. Manual handling is very common in this stage of ship dismantling and more stringent safety measures are to be adopted. Separate buffering zones provided for different types of components such as hull part, outfit equipment, machines, cables, sheet metal, pipes will improve the efficiency of the subsequent operations. Separate storage zones must be provided for different types of plates such as mild steel, stainless steel and high tensile steel which are commonly used in hull construction. A well planned ship recycling layout is essential for efficient buffering and related activities. The photograph showing buffering of dismantled products is shown in fig 5.8.

5.6.10 Sorting and Coding

Sorting and coding are done, if required, after buffering and final dismantling. The dismantled products can be sorted according to the Green Passport content in it, or it can be sorted to any convenient classification. After sorting, dismantled products are stored in its designated locations and suitable coding is given to each product.

Fig.5.7 Manual Handling of Dismantled Hull Parts (Sibal 2001)

Sorting and coding are considered to be very critical for effective ship recycling process as these operations set the course of dismantled products outside the yard. Coding can be based on recycling, reuse, reselling and landfill.

5.6.11 Transport and Disposal

The products according to the classification make their way out and proceed to a safe disposal unit, a recycling plant, or merge with the vast supply chain of dismantled products. In this stage as well some safety and environmental concerns are involved.

Though this part of recycling process is done away from the recycling site, it is still a part of the master recycling plan. Disposal activities are to be undertaken by the considering the fact that ensuring safe and environmental friendly disposal is the ultimate duty of the recycling industry. Fig 5.9 shows photographs disposal of dismantled items using trucks.

Fig 5.8 Buffering of Dismantled and Removed Items from the Vessel

Fig 5.9 Disposal of Dismantled Products

These important operations involved in ship recycling have been analysed for their respective focus in development of *best practices* and the same is presented in table 5.2.

5.7 STRUCTURE OF EXPERT SYSTEM IN SHIP RECYCLING

The knowledge based expert system developed in the present study is named Ship Recycler Recommender (SRR). Schematic diagram of the structure of Ship Recycler Recommender (SRR) is shown in fig. 5.10. It has three components viz., knowledgebase, processor and output system. Inputs are analysed and processed to generate ship recycling process recommendations as the output. This output will be in form of two reports which are '*Best Practices* for Ship Dismantling' and 'Extended Green Passport'. Detailed discussions regarding the expert system are given in the subsequent subheadings.

5.7.1 Description of Expert System in Ship Recycling

Ship Recycler Recommender (SRR) is a General Adviser type expert system. It deals with issues associated with beach based ship recycling. Though the expert system shell is capable of handling any ship type, the recycling processes associated with recycling of obsolete ocean going vessels in Bulk Carrier is attempted here.

5.7.2 Identification and Classification of Stages in Ship Recycling Activity

The recycling activities of a ship, after it has been decommissioned, can be divided into the following four stages, based on the location of the activities: These activities are described with process classification starting with B.

B.1 In Offshore- quay side
B.2 In Inter-tidal zone
B.3 On the beach
B.4 In land

The various processes and sub processes involved in each of the above stages have been identified and a sequential order numbering has been assigned to each of the process. The main processes and sub processes under each stage are given as an assignment in table 5.3. Some of the identified processes given in the ship recycling activity listing may be carried out during more than one stage depending on the availability of time, accessibility to compartments/spaces, usability of equipments and convenience in performing the work.

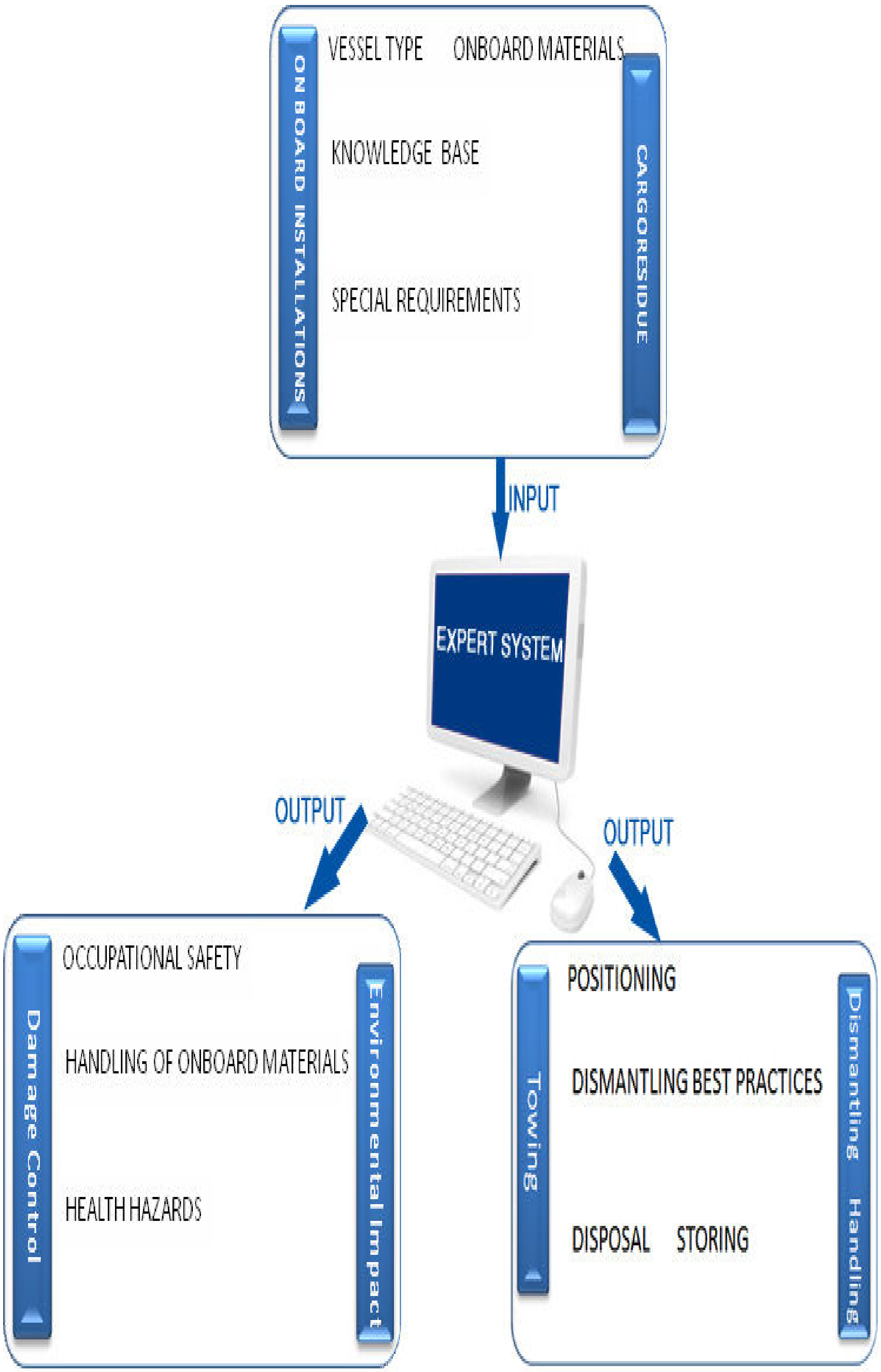

Fig. 5.10 Schematic of S R R (Expert System for Ship Recycling)

Table 5.3 Activity List of Processes Involved in Ship Recycling

Sl. No	Activity Classification	First level Activity	Second level activity	Third level activity
1	B.1.1	Decommission and sale of ship		
2	B.1.2	Transportation of the ship to the yard and keep afloat in shallow water		
3	B.1.3	Gas Free the compartments/ spaces for entry purpose		
4	B.1.4	Conduct an inventory survey		
5	B.1.4.1		Identify, quantify and locate the types of hazardous materials such as fuels, oils, asbestos, PCBs & hazardous wastes onboard	
6	B.1.4.2		Prepare inventory list of hazardous wastes and other wastes.	
7	B.1.4.3		Conduct preliminary sampling of Green Passport items, starting in the compartment that will be cut first	
8	B.1.5	Dismantle small motors		

Table 5.3 contd..

Sl. No	Activity Classification	First level Activity	Second level activity	Third level activity
9	B.1.6	Dismantle pumps		
10	B.1.7	Dismantle navigation equipment		
11	B.1.8	Dismantle Life Saving Appliances		
12	B.1.8.1		Dismantle Lifeboats	
13	B.1.8.2		Dismantle lifeboat davits	
14	B.1.8.3		Dismantle rescue boats	
15	B.1.8.4		Dismantle rescue boat davits	
16	B.1.8.5		Dismantle life rafts	
17	B.1.8.6		Dismantle other buoyant apparatus, if any	
18	B.1.8.7		Dismantle lifebuoys	
19	B.1.8.8		Dismantle life jackets	
20	B.1.8.9		Dismantle Life Saving Appliances other than those listed above	
21	B.1.9	Dismantle furniture		

Table 5.3 contd..

Sl. No	Activity Classification	First level Activity	Second level activity	Third level activity
22	B.1.10	Dismantle electrical cabling		
23	B.1.10.1		Dismantle end connections of cables	
24	B.1.10.2		Dismantle insulation on cables, if any	
25	B.1.11	Remove uncontaminated oil-products		
26	B.1.11.1		Remove uncontaminated heavy fuel oil	
27	B.1.11.2		Remove uncontaminated marine diesel oil	
28	B.1.11.3		Remove uncontaminated high speed diesel	
29	B.1.11.4		Remove uncontaminated lub oil	
30	B.1.11.5		Remove uncontaminated hydraulic oil	
31	B.1.12	Remove onboard consumables		

Table 5.3 contd..

Sl. No	Activity Classification	First level Activity	Second level activity	Third level activity
32	B.1.13	Remove saleable (loose) equipments such as electronic equipment		
33	B.1.14	Washing of cargo tanks		
	B.2 In Inter-tidal zone			
34	B.2.1a	Beach the vessel by its own propulsion power at high tide		
35	B.2.1b	Tow the vessel to recycling yard		
36	B.2.2	Secure the vessel		
37	B.2.2.1		Provide safe access to all areas, compartments, tanks etc.,. ensuring breathable atmospheres	
38	B.2.3	Remove remaining fuel, if any left out after removal in stage B.1, from fuel oil tanks		
39	B.2.4	Remove lub Oil, if any left out after removal in stage B.1, from lub oil tanks.		

Table 5.3 contd..

Sl. No	Activity Classification	First level Activity	Second level activity	Third level activity
40	B.2.5	Remove oil sludge & used/waste oil (& spent lubricants)		
41	B.2.6	Remove oil sludge at bottom of fuel oil tanks, cargo hold of tankers and bilge		
42	B.2.7	Remove combustible liquids and materials other than those listed above		
43	B.2.8	Removal & treatment of bilge water		
44	B.2.9	Removal & treatment of ballast water		
45	B.2.10	Washing of tanks, if not done in stage B.1.14		
46	B.2.10.1		Washing of cargo tanks	
47	B.2.10.2		Washing of bunker tanks	
48	B.2.10.3		Washing of fuel tanks	

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
49	B.2.10.4		Washing of bilge & ballast compartments	
50	B.2.10.5		Washing of sewage tanks	
51	B.2.10.6		Washing of tanks other than those listed above	
52	B.2.11	Proper containment & treatment of waste water & any used solvent from cleaning station		
53	B.2.12	Remove fire hazards other than those listed above		
54	B.2.13	Arrange safe conditions for hot work		
55	B.2.13.1		Cleaning/ venting	
56	B.2.13.2		Removal of toxic or highly flammable paints from areas to be marked	
57	B.2.13.3		Removal of toxic or highly flammable paints from areas to be cut	
58	B.2.14	Certification for hot work permit		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
59	B.2.15	Recheck of tanks before start of cutting operation		
60	B.2.16	Dismantle stern aft of the propeller		
61	B.2.16.1		Divide stern into 2 parts along Centre line	
62	B.2.16.2		Drop down the stern into the sea	
63	B.2.16.3		Pull stern to shore at high tide using winches	
64	B.2.17	Removal of propeller		
65	B.2.18	Cut & dismantle side shell plate, except outer hull plates at the bottom to avoid water intrusion		
66	B.2.18.1		To gain access to engine room & adjacent areas	
67	B.2.19	Dump the plates on the floor/mud and transfer to shore using winch		
68	B.2.20	Dismantle bulkhead structure		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
69	B.2.21	Dismantle bow - collision bulkhead to forward; free from the rest of the hull		
70	B.2.21.1		Lift and free the cut bow part from the rest of the hull to gain access to components of value	
71	B.2.21.2		Transfer bow ashore using winch	
72	B.2.22	Remove equipments/items, using skilled workers from the relevant trade of downstream industry		
73	B.2.22.1		Boilers	
74	B.2.22.2		Separators	
75	B.2.22.3		Pumps	
76	B.2.22.4		Engine room equipment	
77	B.2.23	Transfer of items to shore		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
78	B.2.23.1		Lifting through deck	
79	B.2.23.1.1			Transfer items from their location onboard to top deck using deck lift.
80	B.2.23.1.2			Transfer items ashore using winches
81	B.2.23.2		Taking out through hull openings	
82	B.2.23.2.1			Dump or lower down items through hull openings.
83	B.2.23.2.2			Make the items afloat using air filled oil barrels or by boats on high tide ashore.
84	B.2.24	Break down of larger components of equipment, engines/generators & send for re-melting		
85	B.2.24.1		Engine components	
86	B.2.24.2		Generator components	

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
87	B.2.25	Remove Anchor		
88	B.2.25.1		Lower down anchor using windlass, if there is power available from ship. Otherwise carry out the removal in the following steps	
89	B.2.25.2		Change weight of anchor to a crane	
90	B.2.25.3		Remove D shackle of chain from anchor shackle	
91	B.2.25.4		Lower down anchor through hawse pipe	
92	B.2.26	Remove Chains		
93	B.2.26.1		Release bitter end of chain	
94	B.2.27	Remove Furniture		
95	B.2.28	Dismantle glass		
96	B.2.29	Dismantle wood		
97	B.2.30	Dismantle fibrous insulation/ glass wool		
98	B.2.31	Dismantle pipes		
99	B.2.32	Dismantle ducts		
100	B.2.33	Remove rock wool		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
101	B.2.34	Remove thermocol		
102	B.2.35	Remove PVC & plastic wastes		
103	B.2.36	Remove fiber glass		
104	B.2.37	Remove linoleum		
105	B.2.38	Remove mica		
106	B.2.39	Remove cementing material		
107	B.2.40	Remove ceramic tiles		
108	B.2.41	Dismantle construction with AC sheets		
109	B.2.42	Remove rags and sacks		
110	B.2.43	Remove broken ceramic ware, glassware, paper, wood, all sorts of junk		
111	B.2.44	Remove Human excrement		
112	B.2.45	Remove concrete slabs used as ballast.		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
113	B.2.46	Remove Gas Bottles		
114	B.2.47	Remove fire detectors		
115	B.2.48	Remove Waste Electrical and Electronic Equipment (WEEE)		
116	B.2.49	Remove fluorescent lights		
117	B.2.50	Dismantle small equipments		
118	B.2.51	Remove rubber gaskets and isolation mountings. Remove waste rubber sheets, gaskets & liners		
119	B.2.52	Wash with water at 80° C for oil, sludge and insulation removal		
120	B.2.53	Remove accumulated water (this is through out the dismantling process)		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
121	B.2.54	Treat of oil contaminated sand, generated from cleaning of oily surfaces before cutting		
122	B.2.55	Treat contaminated paint contaminated sand		
123	B.2.56	Remove materials containing asbestos		
124	B.2.57	Remove the electrical components		
125	B.2.57.1		Remove the cables (left out after removal in offshore quay side)	
126	B.2.57.2		Removal of batteries	
127	B.2.58	Removal of materials containing PCBs		
128	B.2.59	Removal of other hazardous liquids such as refrigerants		
129	B.2.60	Removal of other hazardous liquids such as fire suppression substances		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
130	B.2.61	Remove paints, adhesives & antifouling compounds (surface preparation for cutting)		
131	B.2.61.1		Mechanical removal / using hand hammer	
132	B.2.61.2		Chemical Stripping	
133	B.2.61.3		Grit blasting	
134	B.2.62	Treat the scrapped paint chips		
135	B.2.63	Remove the paint chips.		
136	B.2.64	Remove canvass with chemical coating/chicken mesh / rexin / card board		
137	B.2.65	Collect onboard oil remains and dirty bilges into oil-drums and transfer to liquid waste area of the yard.		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
138	B.2.66	Cut super structure horizontally in large pieces & allow free fall to shallow water		
139	B.2.67	Cut upper decks horizontally in large pieces and allow free fall to shallow water		
140	B.2.68	Cut Main deck horizontally in large pieces & allow free fall to shallow water		
141	B.2.69	Cut lower decks horizontally in large pieces & allow free fall to shallow water		
142	B.2.70	Move structural blocks using winch to the Panel yard.		
143	B.2.71	Dismantle the ship from the end facing the beach to the end facing the ocean (using cutting torches & saws).		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
144	B.2.72	Pull bottom portion of hull ashore using winch with extreme care		
145	B.2.73	Lift dismantled structural parts by crane to land		
146	B.2.74	Further disassemble and sort dismantled structural parts by metal type.		
147	B.2.75	Final stage of the ship cutting process; cut large sections into smaller pieces using torch cutting and mechanical or saw cutting.		
148	B.2.76	Handle, transport and dispose hazardous wastes, produced during cutting process, according to regulations and local environmental laws and ordinances.		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
149	B.2.77	Remove scales generated during gas cutting of steel from shore as well as onboard		
	B.3 On the beach			
150	B.3.1	Dismantle machinery at hold level		
151	B.3.2	Transfer structure blocks from Panel Yard to Cutting Yard		
152	B.3.3	Removal of stiffeners, brackets and other projections from plate by torch cutting		
153	B.3.4	Cutting of plate, to size, for grading and sale		
154	B.3.5	Transport different parts and components of hull and various equipment from beach to temporary storage sites		
155	B.3.6	Sort materials in different piles in the scraping yard		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
156	B.3.7	Unify materials into the same "standard" sizes, cut if necessary, in the scrapping yard		
157	B.3.8	Store "standardised materials" in separate piles like plates of different thickness, pipes of different diameter etc..		
158	B.3.9	Disassemble all equipment components like valves, flanges and gaskets from the pipelines in the scrapping yard		
159	B.3.10	Disposal of hazardous materials		

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
	B.4 In land			
160	B.4.1	Sort scrap metals by metal type, composition and grade for selling to re-melting firms or to scrap metal brokers.		
161		B.4.1.1	Steel	
162		B.4.1.2	Aluminium	
163		B.4.1.3	Copper	
164		B.4.1.4	Cu-Ni Alloys	
165	B.4.2	Separate metals which are mixed with other materials like copper in electrical cable using shredders & separators		
166	B.4.2.1		Produce fluff using shredders, a mixture of metal and other materials that resemble gravel.	

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
167	B.4.2.2		Separate the metals from the other materials, so that they can be sold using separate air floatation separator columns or shaker tables	
168	B.4.3	Load the items on truck for transfer to market using crane or fork lift.		
169	B.4.4	Transport/export of materials and substances		
170	B.4.5	Transportation of sorted materials to nearby markets or reprocessing facilities like disposal and recycling centre.		
171	B.4.6	Sell things, which need no reprocessing, directly		
172	B.4.6.1		Pumps, Valves, Motors, Machines	
173	B.4.6.2		Navigational equipments	

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
174	B.4.6.3		Life-saving equipment like rafts, life buoys, life-vests, survival suits etc.,.	
175	B.4.6.4		Personal protection equipment like helmets, work boots, gloves, goggles, overalls etc.,.	
176	B.4.6.5		Chemicals and paints	
177	B.4.6.6		Steel components like anchors, chains, grills, ventilation components, pipe assemblies etc.,.	
178	B.4.6.7		Sanitary equipment like toilets, sinks, bathtubs etc.,.	
179	B.4.6.8		Furniture	
180	B.4.6.9		Intact electrical cabling and batteries	
181	B.4.6.10		Insulation materials	
182	B.4.6.11		Oil products for manufacturing industries	

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
183	B.4.7	Sell things, which need reprocessing, as scrap		
184	B.4.7.1		Ferrous scrap metal to re-rolling mills	
185	B.4.7.2		Non ferrous scrap	
186	B.4.7.3		Minerals	
187	B.4.7.4		Plastic	
188	B.4.7.5		Liquids & Chemicals (included under different heading)	
189	B.4.8	Re-manufacturing/ re-processing		
190	B.4.8.1		Steel re-manufacturing	
191	B.4.8.1.1			Undamaged plating (by cutting, grinding & hot work), Anchors, chains, engine structures etc

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
192	B.4.8.1.2			Reprocess steel to make reinforcing rods for use in construction industry
193	B.4.8.1.3			Reprocess steel to make corner castings and hinges for containers
194	B.4.8.2		Oil re-manufacturing	
195	B.4.8.2.1			Used (dirty) oils (lubricating oils) are re-processed and offered for sale
196	B.4.8.2.2			Use hydrocarbons onboard as reclaimed oil products to be used as fuel in rolling mills or brick
197	B.4.8.3		Mineral re-processing	

Table 5.3 contd..

Sl.No	Activity Classification	First level Activity	Second level activity	Third level activity
198	B.4.8.3.1			Insulation material (asbestos) is in some facilities reprocessed by manual crushing and sold to manufacturing industries
199	B.4.8.4		Copper reclaim	
200	B.4.8.4.1			Damaged cabling or non-saleable cabling is stripped for insulation either by mechanical stripping (sometimes also carried out at the scrapping site).
201	B.4.9	Send materials/components that could be reused to the revised items.		
202	B.4.9.1		Use ship's generators ashore	
203	B.4.9.2		Use ship's batteries ashore	
204	B.4.9.3		Use ship's light fittings " "	

5.7.3 Identification and Classification of Onboard Materials

The list of hazardous materials, being considered for the preparation of properties and characteristics of onboard materials have been taken from the Appendices 1, 2 and 3 of IMO 'Guidelines on Ship Recycling' which is part of IMO Resolution A.962 (23), 2003. The list has been named as Green Passport [Anderson 2005] in the guidelines. These hazardous materials have been grouped under the following two main categories as operational substances & consumables and toxic materials (as part of ship structure) Cargo residues and other materials present onboard which are not listed in the Green Passport have been incorporated in the comprehensive material list prepared as a part of the present study.

There are thirty subgroups under the first category of onboard materials ie.,. operational substances and consumables.. There are three subgroups under the second category which include the toxic materials. Each subgroup consists of a number of materials. The present study has modified the existing Green Passport concept and prepared an onboard material safety data record, and named as Extended Green Passport. Extended Green Passport that has been prepared for each of the above mentioned material groups, will give additional information on composition, ingredients, hazards, first aid measures, fire and explosion data, accidental release measures, handling and storage, exposure controls/personnel protection, chemical stability and reactivity data, toxicological information, disposal considerations, possible locations onboard ships etc.,. which may be useful while handling with the onboard materials identified Extended Green Passport will provide very exhaustive and comprehensive information as compared to the existing Green Passport which is a mere listing of on board materials according to certain hazard/pollution. A sample Extended Green Passport prepared for Asbestos is given in Appendix 3

5.8 IMPLEMENTATION OF THE EXPERT SYSTEM

5.8.1. Perspective of SRR Software

SRR is one of its kind web based software. It is an expert system in its role of suggesting how things need be done in a complicated scenario. SRR allows users to generate ship specific recommendations accurately using a intuitive web based Graphical User Interface.

When a ship is required to be beached, SRR will generate ship specific recommendations considering Economical, Environmental and Health & Safety Aspects. It would also generate recommendations for reusing / adding value to the scrap generated. These recommendations will be based on the particular ship type, age, any specific equipment and data from the Extended Green Passport (EGP) and from also all relevant applicable rules and regulations. SRR will have provision to incorporate the updates in the guidelines and regulations in ship recycling implemented by various agencies.

Very detailed engineering specifications on dismantling are not in the purview of SRR. The ways and means to accomplish the tasks are the responsibility of the supervising engineers and foremen. Local rules and practices are not included SRR as it is not commonly available. However the users can incorporate these guidelines and codes and regulations with the help of the administrator of SRR.

Ship Recycling Yards, Owners and Ship Classification Societies can use this software; which will run off a web server. This means stakeholders around the world can have a piece of the action. Users will have usernames and passwords for logon and by log in they can generate reports for a specific ship. User interacts with the SRR through a series of predefined QUESTIONNAIRE. The QUESTIONNAIRE constitutes the major web interface mechanism of the software. The entire ship recycling processes and information onboard materials are moulded into a QUESTIONNAIRE form and presented in the main web interface input. Apart from this main particulars of the vessels are included in the interface. Each QUESTION appearing in the input format either represent main particular of the vessel or a related activity associated with ship recycling. For example presence of mercury as an onboard material is noted by a QUESTION, “Is mercury present in any of the equipment onboard?’. If the answer is “yes”, the data is accepted and the same is connected to RULE(S) regarding handling of mercury, material data record of mercury, spread sheet containing possible locations where mercury can be present as a component/part in equipment. RULES constitute the main decision support database of Ship Recycler Recommender. They are a set of information and recommendations as guidelines which contain the *best practices* part of ship recycling activities included in the report. Fig 5.12 shows set of RULES applied to a sample SRR ship recycling report generation exercise on the extreme left side of the SRR main page screen dump.

Effective implementation of the expert system will be useful to the ship recycling industry. Effective implementations of the recommendations provided by SRR in the form of ship recycling reports will certainly benefit the performance of the ship recycling yards. SRR is not production version and has some limitations, which can be resolved in later revisions.

5.8.2 References for the SRR Software

The following documents have been used as reference for SRR software.

i. ILO - Safety and Health in Ship Breaking : Guidelines for Asian Countries and Turkey (October 2003)
ii. The Basel Convention Recommendations, 2005
iii. Marine Environmental Protection Committee (MEPC) Recommendations , 1999-2010
iv. Environment Protection Agency, USA
v. Science Lab.com Inc, Texas, US: Material Safety Data Sheets
vi. Hands-on Science (H-Sci) Project, Oxford, UK: Chemical Safety Data Sheets
vii. Paton Fertilizers Pvt. Ltd, New South Wales, Australia: Material Safety Data Sheets
viii. Acros Organics N.V., New Jersey, US: Material Safety Data Sheets
ix. Science Stuff Inc., Austin, US: Material Safety Data Sheets
x. Mallinckrodt Chemicals, New Jersey, US: Material Safety Data Sheets
xi. Wynyard Technologies Inc, Canada: Material Safety Data Sheets
xii. Sherritt International Corporation, Canada: Material Safety Data Sheets
xiii. Gary Williams Energy Corporation, Oklahoma, US :Material Safety Data Sheets
xiv. International Maritime Organisation Guidelines on Ship Recycling 2003

5.8.3 Interfaces

5.8.3.1 System Interfaces

SRR software interfaces with the web server software as well as the database engine at the system level. User actions on the website are passed on to the web server which in turn relays the result of the action to the web browser of the user. The SRR leverages the Dot Net platform and JET database engine to serve requests through a Microsoft Windows based Web Server.

5.8.3.2 User Interface

All pages of the system are following a consistent theme and clear structure. The occurrence of errors are minimized through the use of checkboxes, radio buttons and scroll down in order to reduce the amount of text input from user. Java Script implement in HTML in order to provide a Data Check before submission.

5.8.3.3 Hardware Interface

In the server side the web application is hosted on windows based web server called Internet Information Services 6.0 and connecting to a local Microsoft Access database. The web server shall be listening on the web standard port, port 80. The system being a web based application; clients shall be able to use the software on Internet Explorer 6 with cookies enabled. The client computer should have an Internet connection in order to be able to access SRR.

5.8.3.4 Software Interface

A windows PC which runs IIS 6.0 is the minimum requirement for the server in which SRR runs. This server will accept all requests from the client and forward SRR specific requests to the Container with ASP.Net 2.0 hosting SRR.

5.8.3.5 Communications Interfaces

The HTTP protocol will be used over TCP/IP to facilitate communications between the client and server. For about 5 simultaneous users, server shall have at least 1 GB RAM & Client shall have at least 512 MB memory. This shall be revised when number of users increase. Data backup to be performed as per standard IT policies. Usual procedures involved in hosting any website on IIS including but not limited to creating folders, assigning permission to users on folders and files, enabling access logs / stats are applicable in case of SRR also.

5.8.4 Functions of the Software

The functions available in SRR are described in the following sub headings.

Login / Member Registration

Provisions are made in the program such that the input details can be provided by the user as well as the administrator. SRR web site administration is done by the site "administrator". The 'administrator uses the login 'admin" and only one user can have access to SRR website as the "administrator" SRR is hosted in http://knengg.com/sd-dss/ and the current password is **'admin321'**. The user with "admin" login can make changes to the existing structure of SRR. In order to generate reports for ship recycling, one has to register in the site as a "user" and log in with the user name and password. Administrators in addition to being able to create reports, can also modify the report generation RULES as well as add or delete new QUESTIONS and are able to modify user interface. Ship recyclers, ship classification societies, ship recycling promotional bodies can be treated as administrators of the software, whereas ship recyclers, their contractors, pollution control bodies and dismantled product logistic providers can be its users. Figure 5.11 shows the login page of SRR.

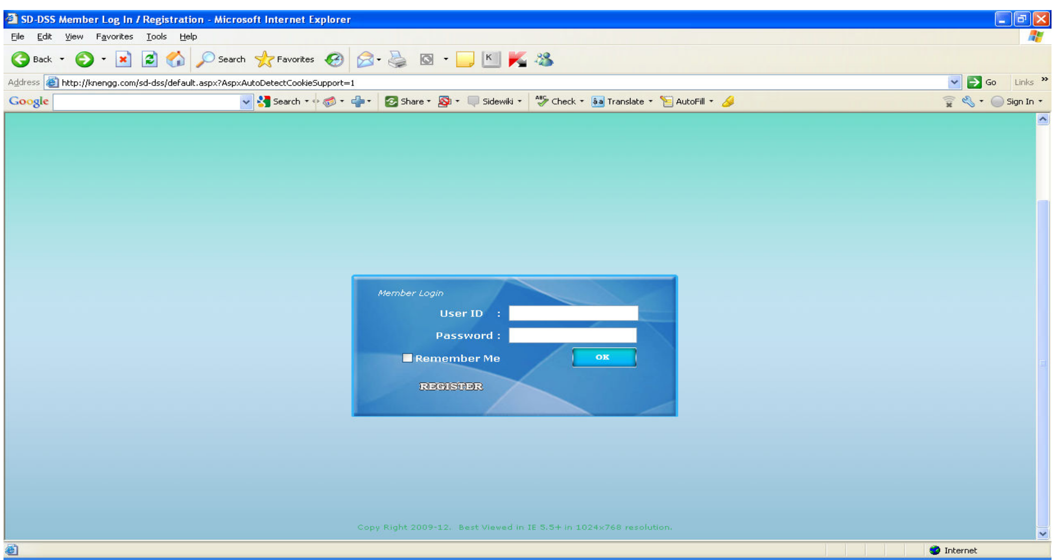

Fig 5.11 Login Page of SRR for Users

After log in the users can either generate a ship recycling report, continue with an inconclusive session of creating a report or they can refer to an already generated report. In addition to creation of ship recycling reports and related activities the administrator can modify the QUESTIONNAIRE and RULES of SRR. After login, the main page of SRR will appear. The main page which appears after login is given in fig 5.12

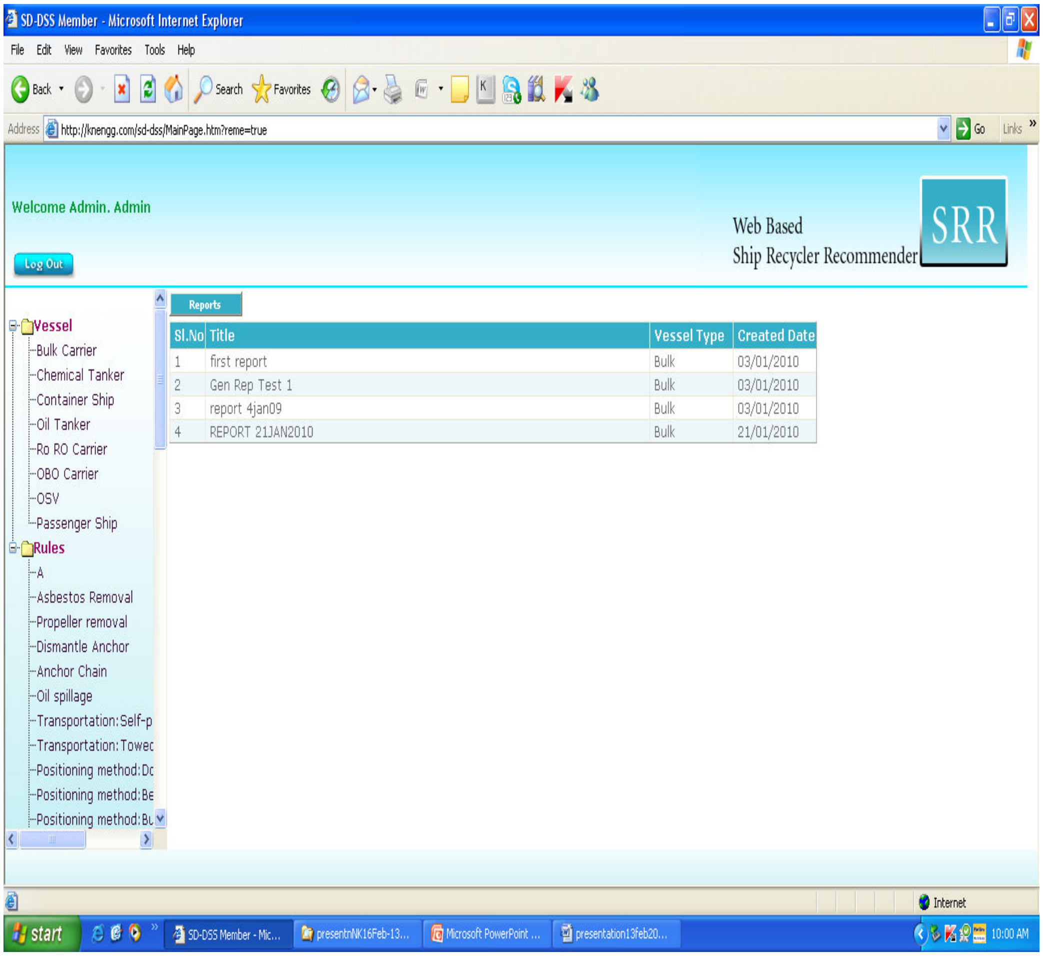

Fig. 5 12 Main Page of Ship Recycler Recommender (SRR)

Generation of New Reports

After the log in to the website of SRR, the user has to click on the desired ship type for which he needs a ship recycling report. The user can create a report for a new vessel by entering relevant answers in pre-defined QUESTIONS available in the SRR input interface. A detailed ship recycling activity report consisting of *best practices* for ship recycling, activities for which input have been entered, and the Extended Green Passport will be generated. This report can be used as the basic reference document for the recycling activities to follow on that particular ship. Option for 29 ship types listed in Llyods Register of Shipping [World Fleet Statistics- 2006] is provided in the system. 59 onboard materials covering IMO guidelines A 9629(23) and common bulk cargo residues are incorporated in the database of the system. The main web interface input screen of selected ship type “Bulk Carrier “ for the new report generation or to view reports which are created already in previous attempts, is given in fig. 5.13

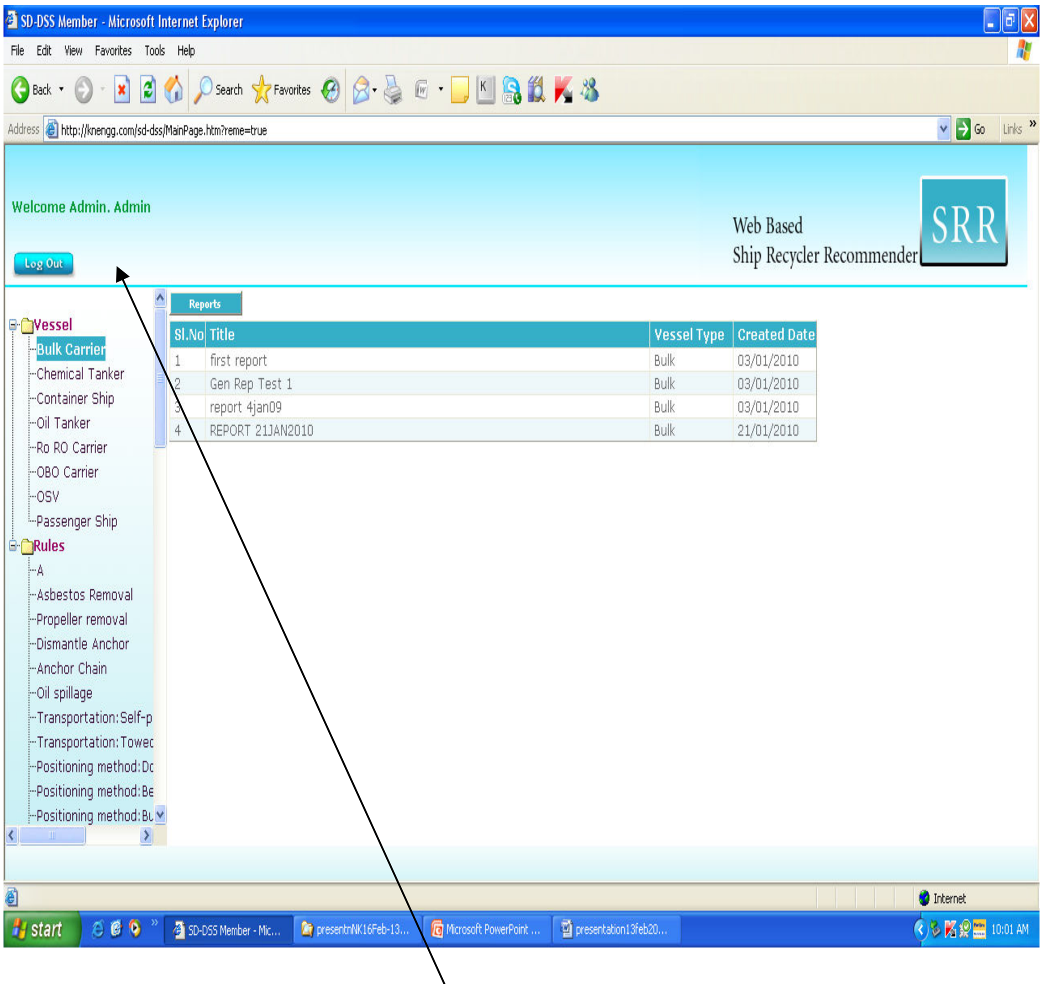

Fig. 5.13 Selection of Type of Vessel- Bulk Carrier for Generation of Reports

After selecting the ship type for which a report has to be generated, the input interface showing various options for input appears on the SRR input interface. Three inputs options are available in this and the options are,

- New Report Generation.
- List Existing Reports for this Type.
- Continue with Your Last Session.

Fig. 5.14 shows these options as it appear in the SRR screen. The user can select any one of the options and continue his report generation. If the user opts for new report generation, the QUESTIONNAIRE relevant to the selected ship type will appear. The screen dump of the QUESTIONNAIRE screen is given in fig 5.15. This is the user interface window for adding relevant input regarding the vessel to be recycled.

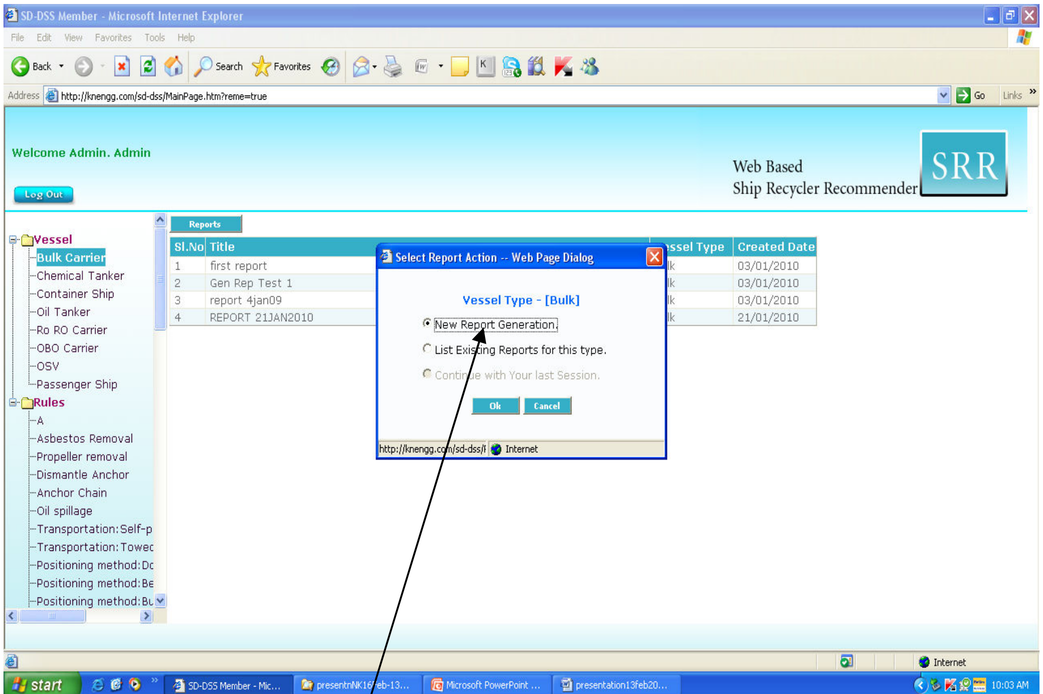

Fig. 5.14 Selection of 'New Report Generation'

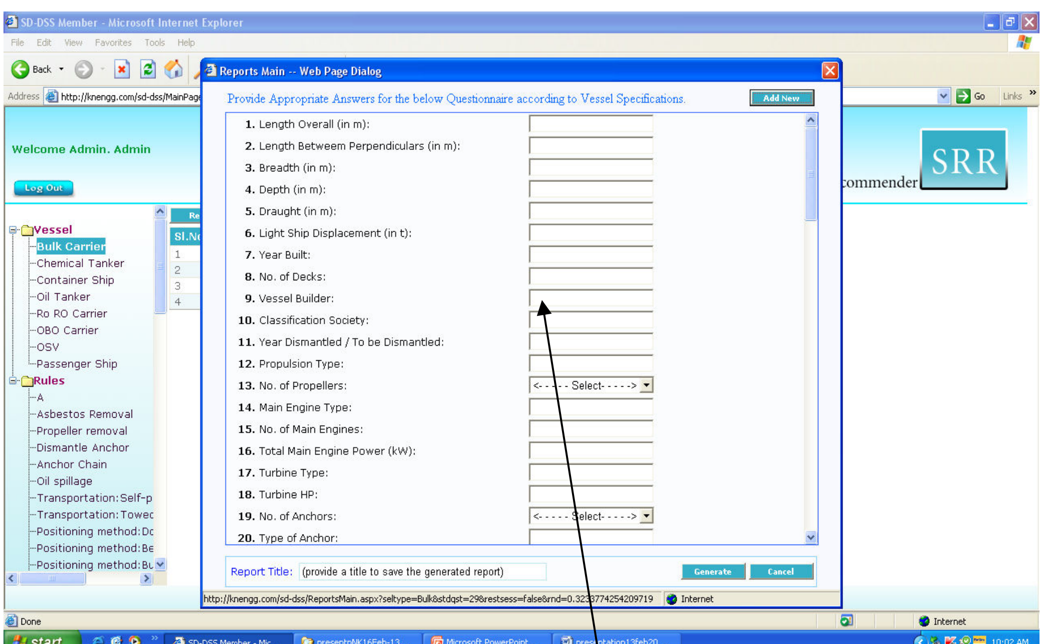

Fig. 5.15 Window Opens up for "INPUTS"

The input consists mainly of two types, viz, main particulars of the ship and the recycling related data. Fig 5.16 shows the inputting of main particulars of the vessel as the first set of input by the user. The next set of input are corresponding recycling data in the form of answers to the QUESTIONS. The ship recycling related inputs for the selected ship type are given in figures 5.17 to 5.19

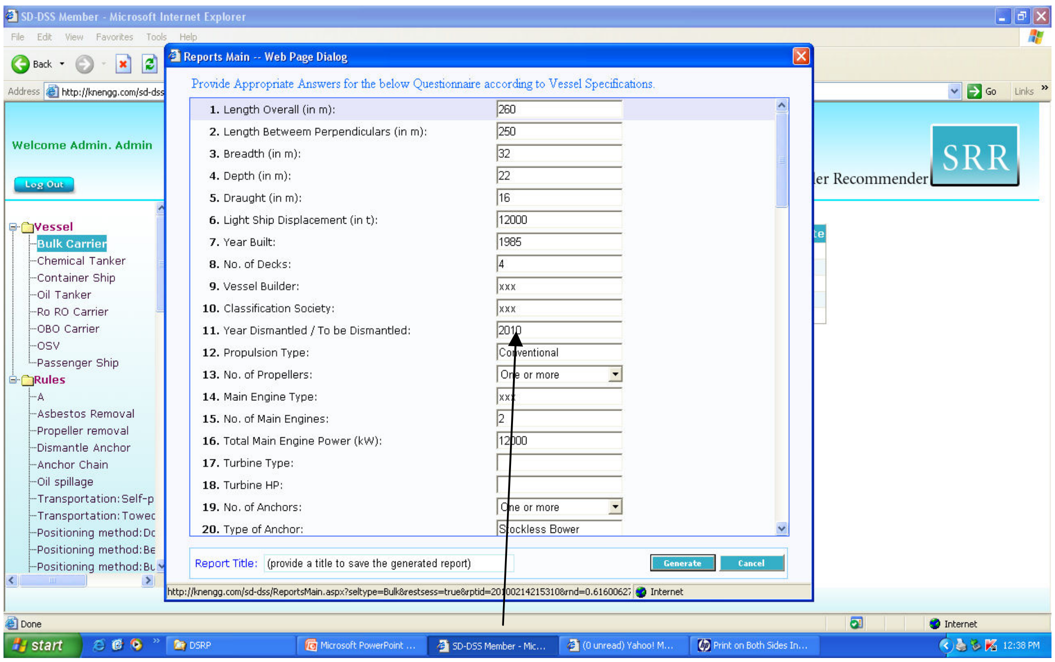

Fig. 5.16 Adding Vessel Main Particulars as Input

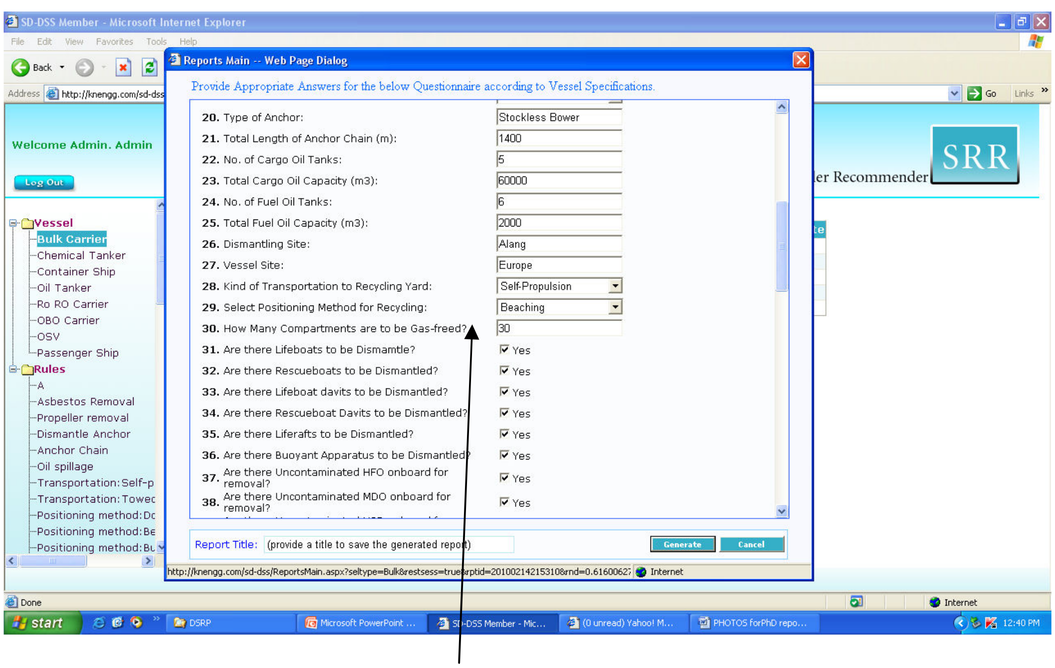

Fig. 5. 17 Window Showing Ship Recycling Data Input (Contd…)

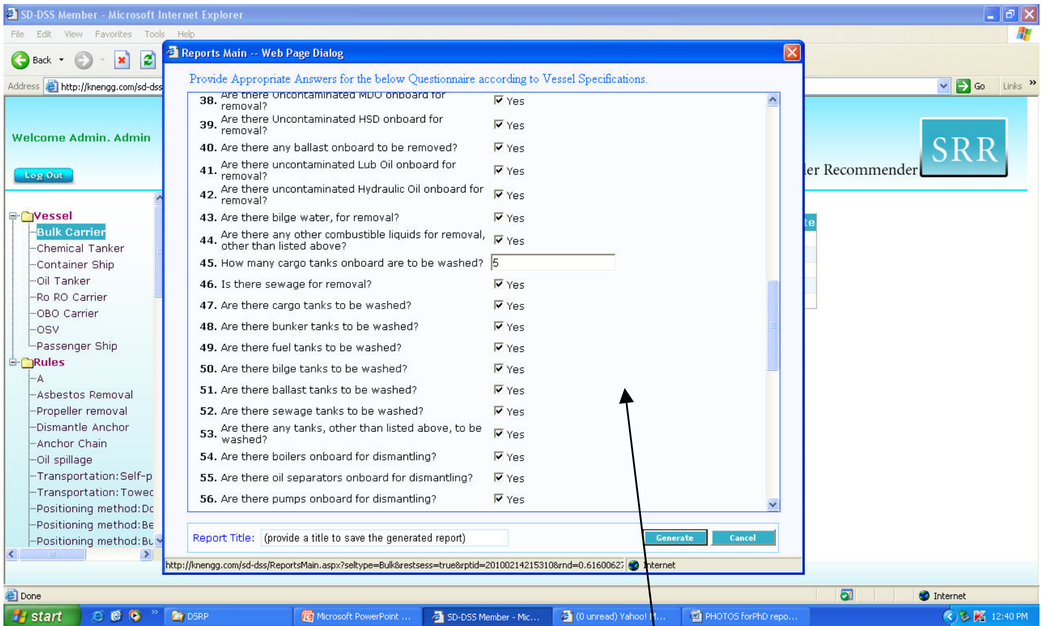

Fig 5.18 Window Showing Ship Recycling Data Input (Contd..)

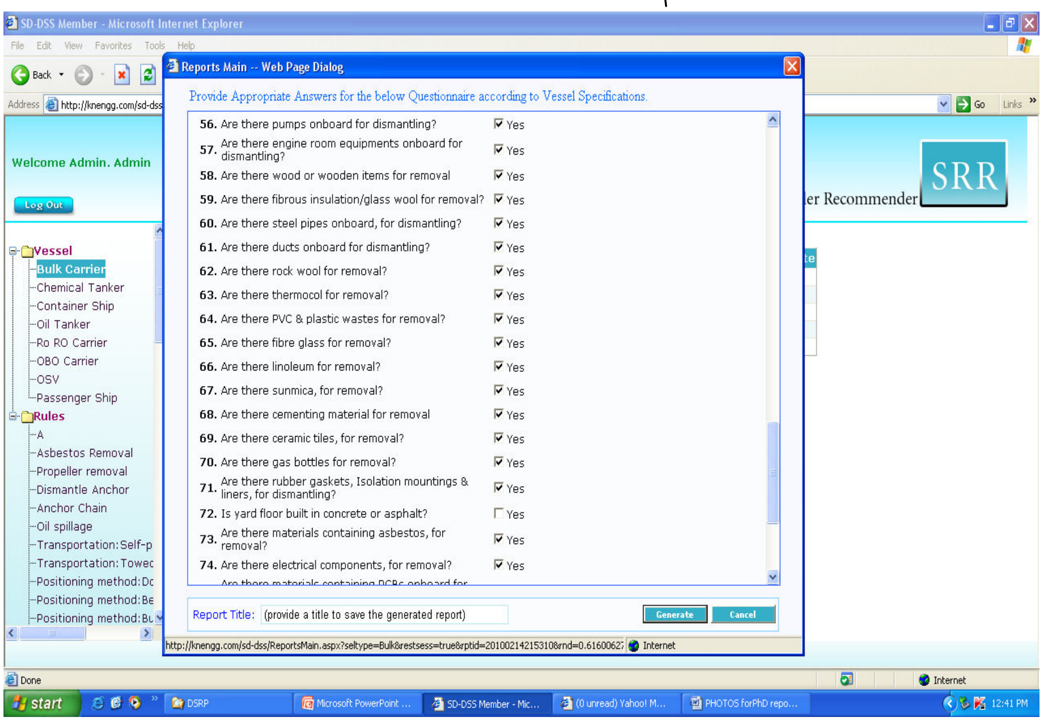

Fig. 5. 19 Window Showing Ship Recycling Data Input (Contd..)

The user can generate report after entering the input values. At the end of the input session click on to generate the ship recycling report. Figure 5.20 shows the screen for generating the report at the end of the input session. The sample report generation presented in this study has 82 QUESTIONS connected to recycling of Bulk Carrier. The generated reports contain description of *Best Practices* and information on handling of onboard materials to be followed during ship dismantling operatons along with the particulars of the ship entered by the user. A sample SRR ship recycling report is given in Appendix 3.

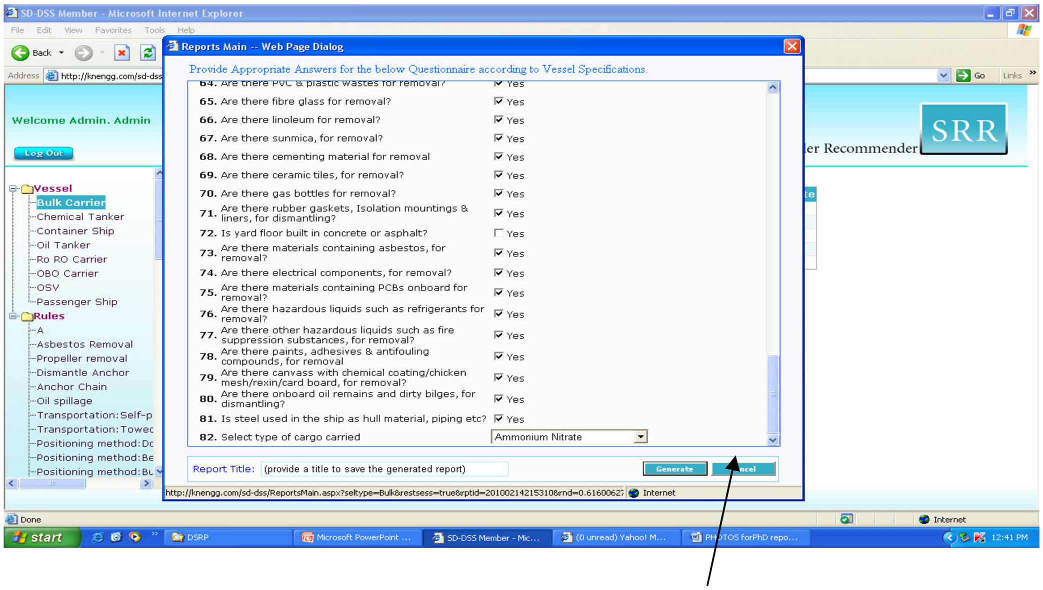

Fig.5.20 Window at the End of Input Session and Click to Generate Report

Acquire Repository Ship Recycling Reports

Fig. 5.21 shows the provision in SRR to get access into already generated reports if any, present in the SRR ship recycling report repository.

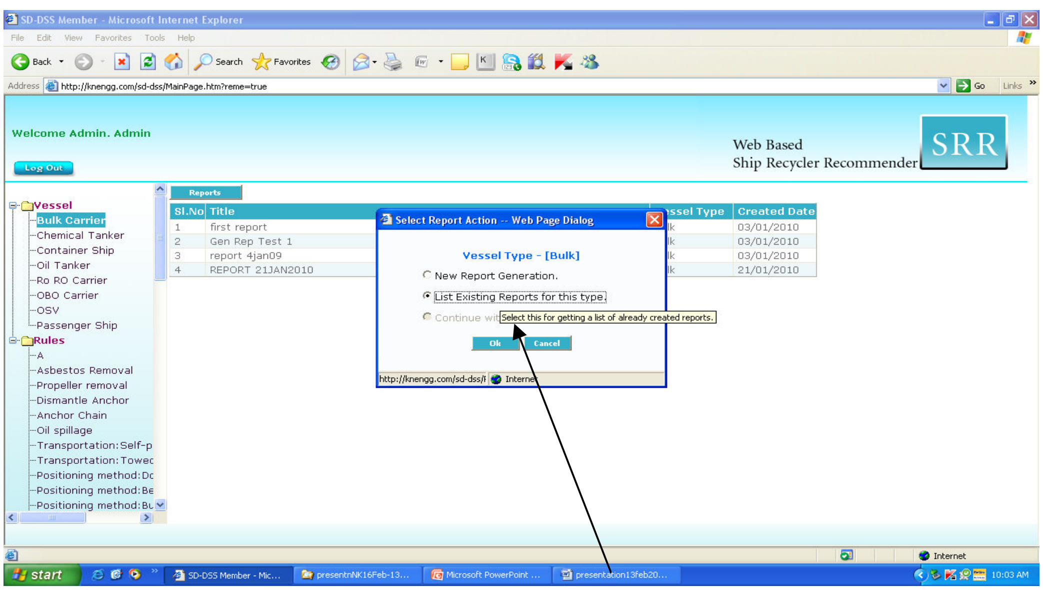

Fig 5.21 Click to Access the List of Already Generated Reports

Fig 5.22 shows the first page screen dump of sample ship recycling report generated using the input provided in SRR.

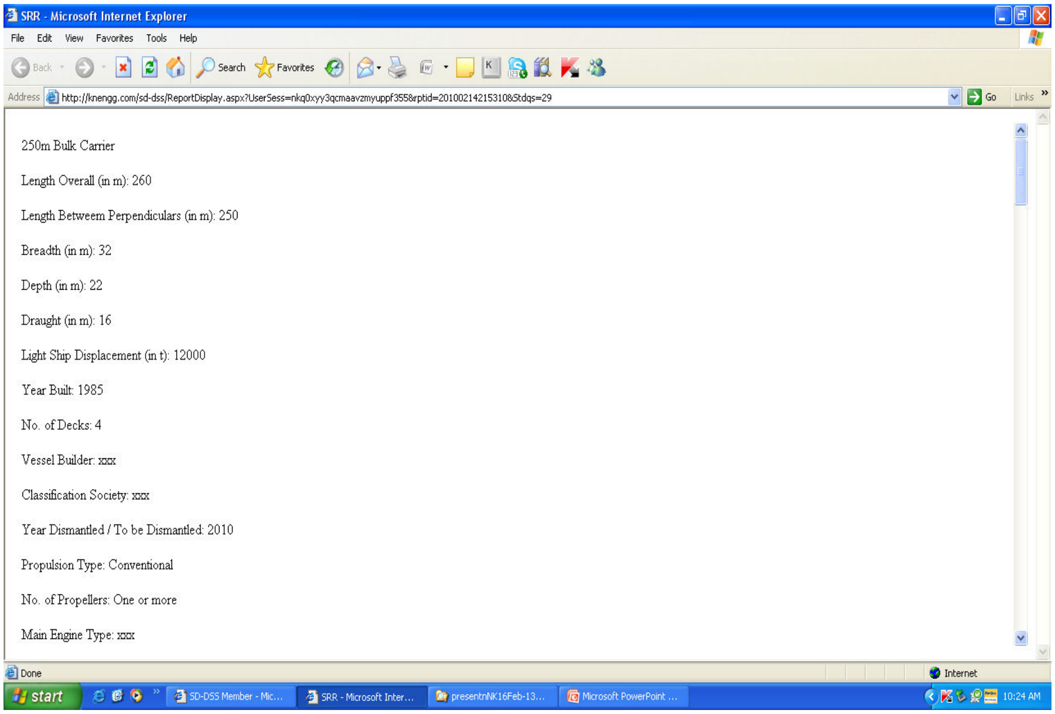

Fig. 5.22 First Page Screen Dump of SRR Generated Ship Recycling Report

Add New QUESTIONS

The interface mechanism is a set of QUESTIONS prepared and incorporated in the database of SRR. Knowledgebase of ship recycling processes and onboard materials may change from time to time in tune with the new technological developments in shipbuilding. New rules & regulations come into force frequently in the international maritime sector. These factors will influence the ship recycling processes also. In this context frequent updating of database and corresponding RULES in the SRR software becomes necessary. New QUESTIONS can be added, if required by a new development in ship recycling, in the software. This updating can only be carried out by the administrator. Addition of questions can be done by entering "new report" interface screen and activating 'add new' button. The same button can be used for editing and deleting the questions which become irrelevant in the wake of some new developments. The input data can be specified as numeric value, "Yes/NO" type or as a multiple selection. Fig. 5.23 gives details of adding a new question. New questions or edited questions should be saved for making it as a part of the programme. Similar input procedures as in the case of adding new questions are followed in edit/ delete existing questions. Editing a question is necessitated by changes in rules and regulations in international shipbuilding and ship recycling operations. Details regarding editing/adding/deleting of QUESTIONS in SRR is given in detail in Appendix 3.

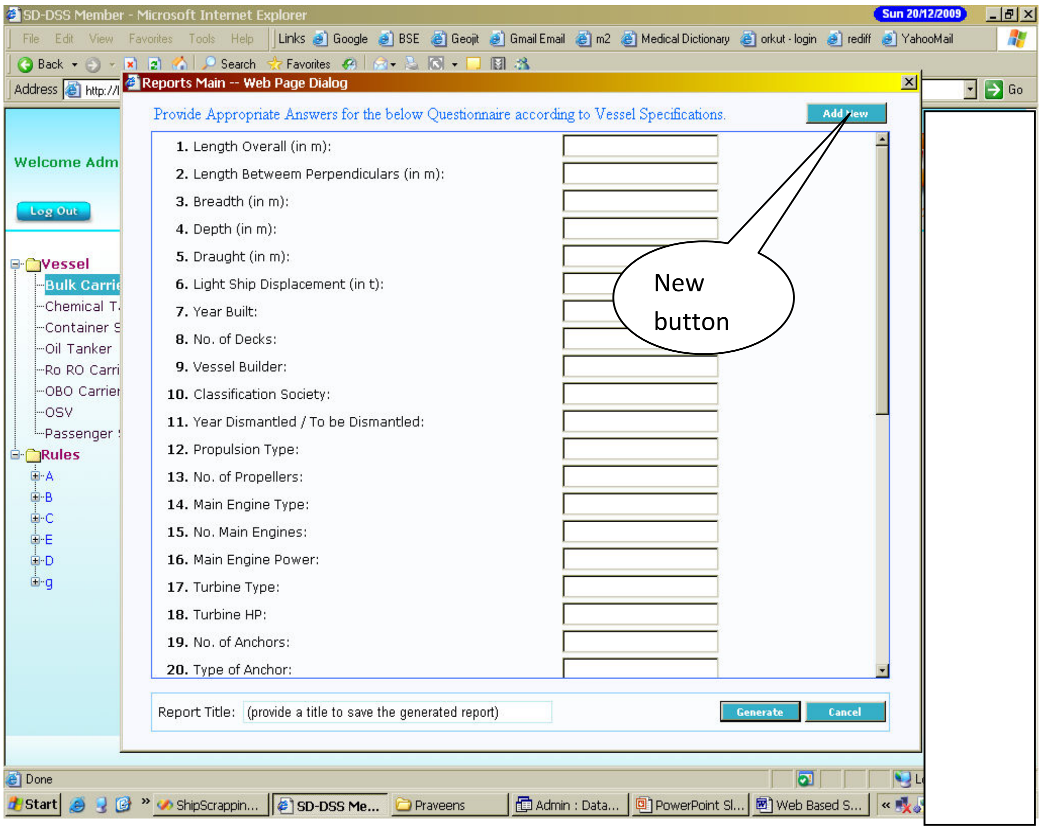

Fig. 5.23 Editing/Adding New QUESTIONS

Add New RULES and ATTACHMENTS

RULES constitute the main database of Ship Recycler Recommender. Fig 5.24 shows a sample RULE giving *Best Practices* to be followed in ‘Removal of Asbestos’ included in SRR database. RULES are a set of guidelines and recommendations which will be linked to the relevant QUESTIONS. RULES appear in the extreme left column, below the vessel selection drop down in the SRR main menu screen.

RULES can be added, edited or deleted as per the new developments in the ship recycling field. Relevant information associated with safe and clean ship recycling can be uploaded as ATTACHMENTS with the RULES. The ATTACHMENTS can be of various types including flow charts, spread sheets, document repositories and

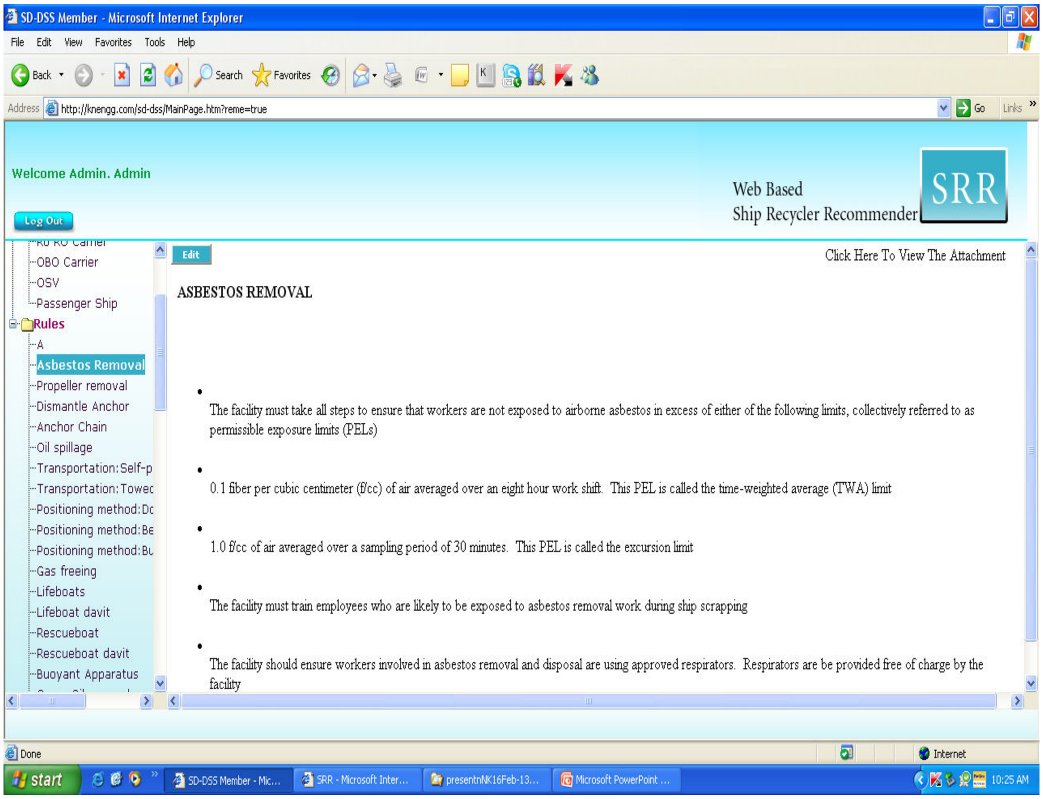

Fig. 5. 24 Screen Showing Content of a RULE in SRR

video formats etc.,. The set of RULES prepared in connection with generation of ship recycling report are provided in the left side of the screen below the slot given for ship types. The RULES are divided into two main types and sub RULES and all these will appear in the main menu box as a vertical tree structure. Fig. 5.25 shows selection of a RULE for adding/editing/deleting. The web interface input sheet depicting selection of the RULES for adding of new RULES by the administrator is given in fig 5.26

A dialogue box opens up as the selection is made for addition of a new RULE.The new RULE is entered into the SRR system by filling up the title and description related to the new RULE. The check box that appears in the SRR screen in this connection is given in fig 5.27 and the dialogue box for creating a new RULE is given in fig 5.28. Existing RULES can be edited by extracting the RULE from the main menu as in the case of adding a new RULE. Select edit option for modifying the selected RULE as given in fig. 5.25. Fig. 5. 29 shows the saving operation of the RULE that has been edited.

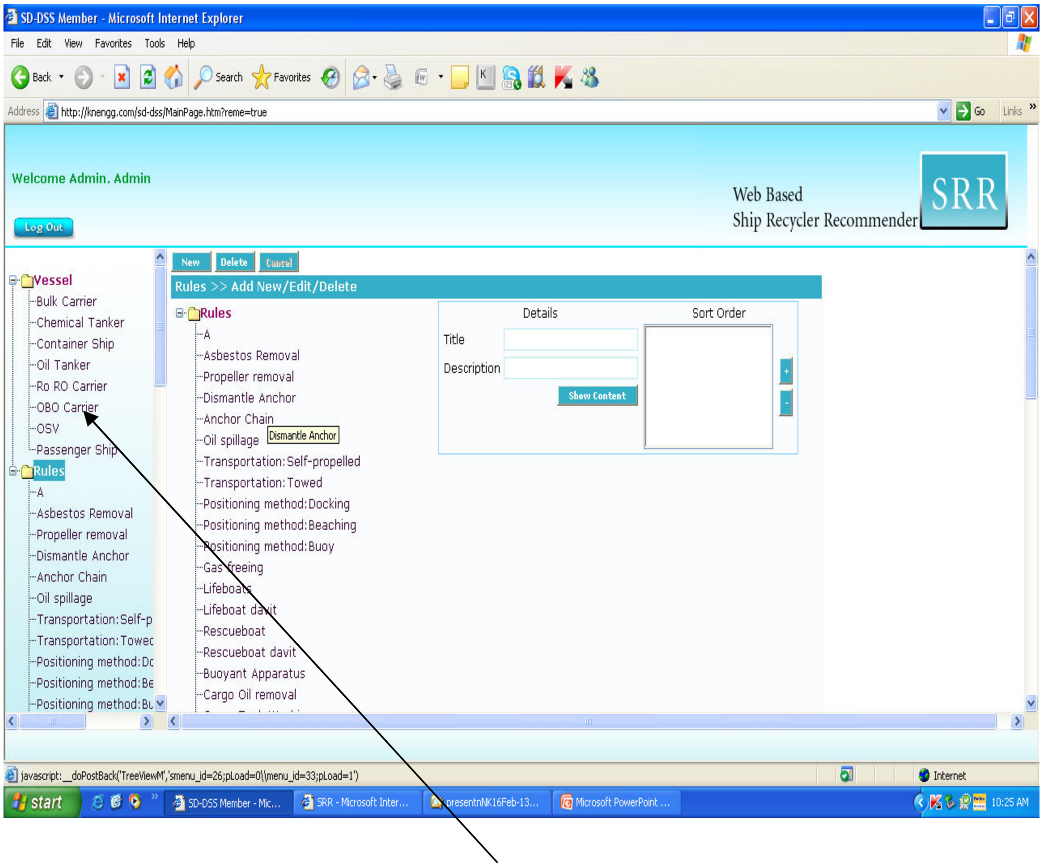

Fig. 5.25 SRR Screen Showing Selection RULES for Adding/Editing/Deleting

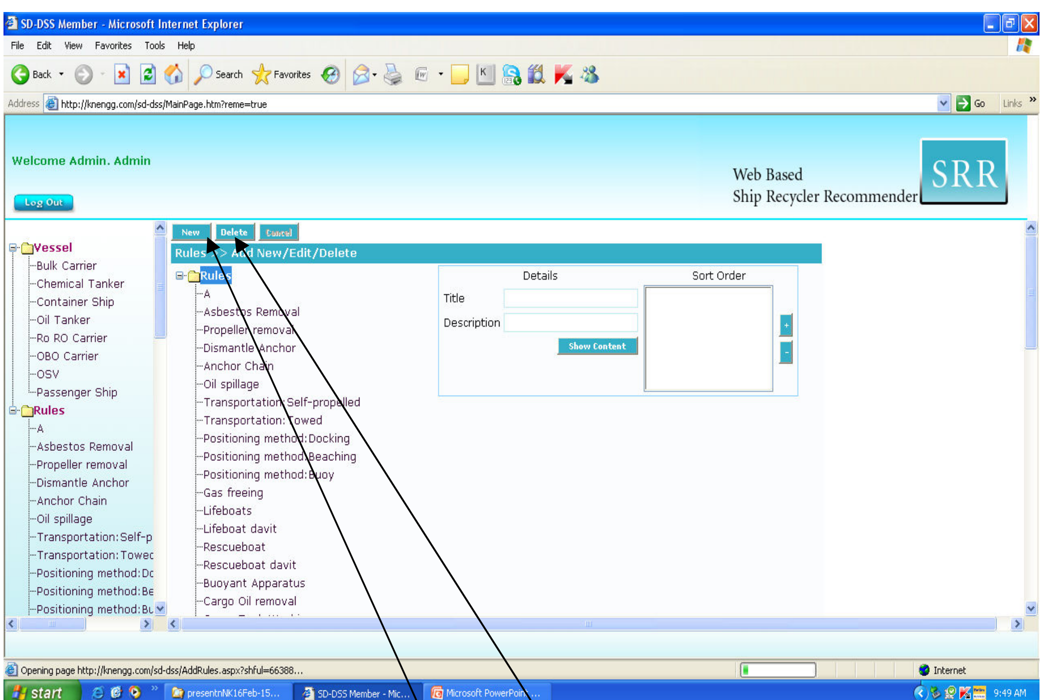

Fig.5. 26 SRR Screen Showing   Adding of RULES

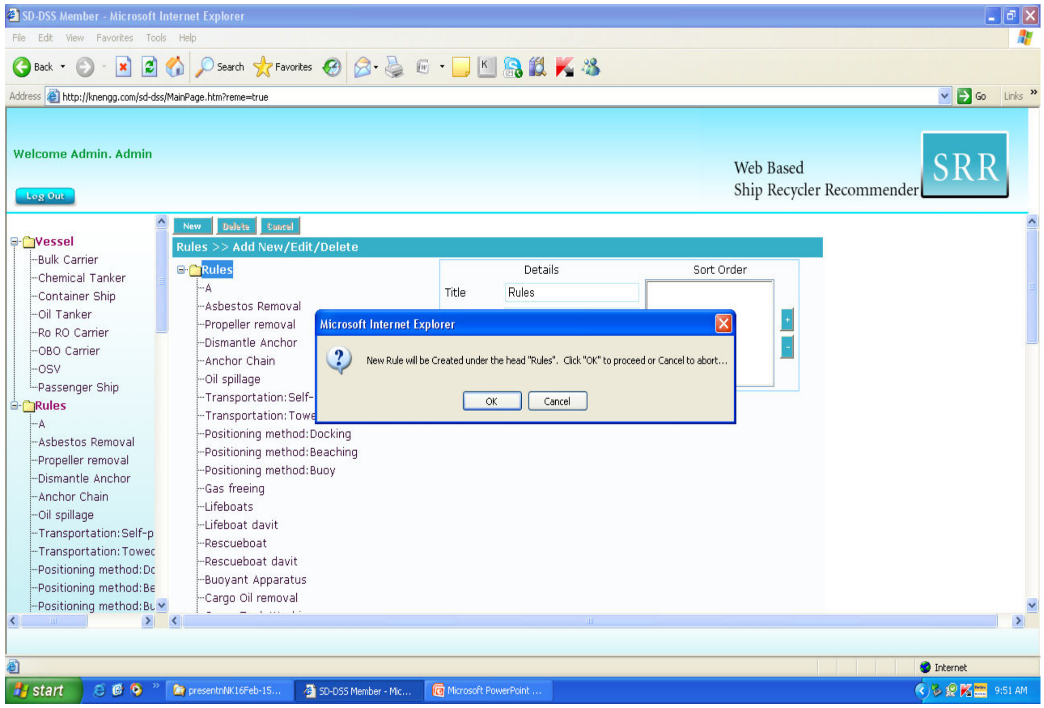

Fig. 5. 27 Screen Showing Check Box to Add New RULES in SRR

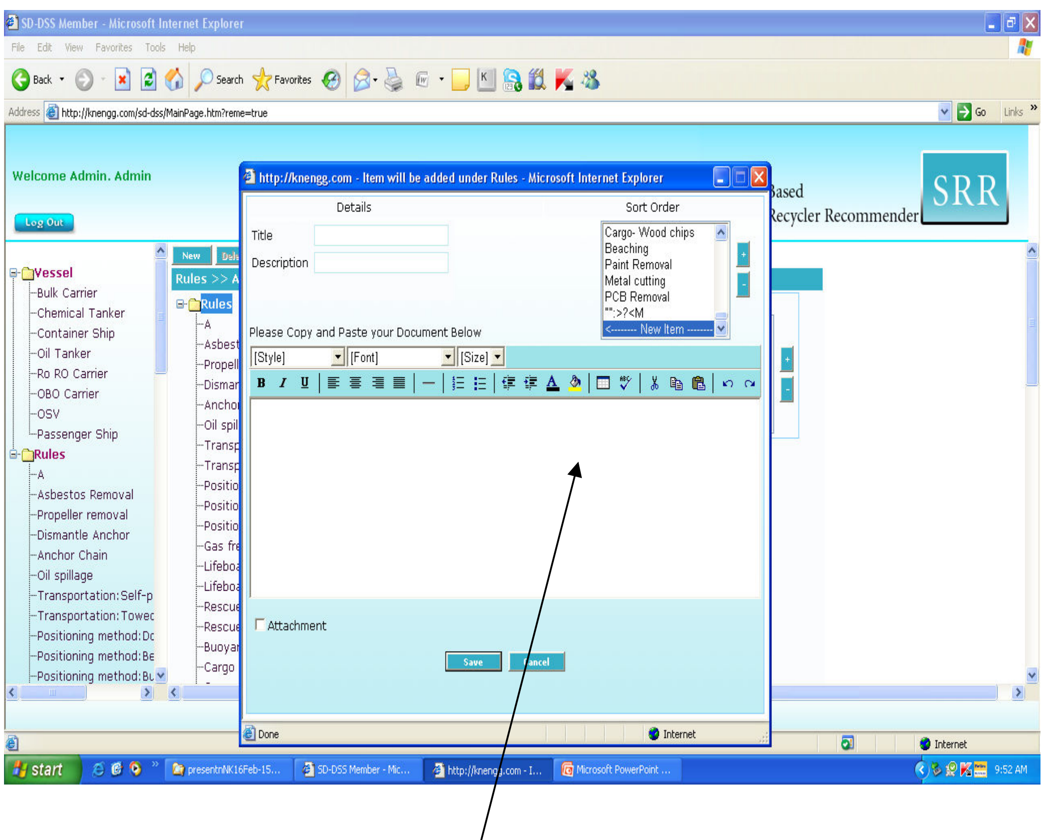

Fig. 5. 28 Screen Showing Dialogue Box for Adding New RULE in SRR

Upload ATTACHMENTS Associated With a RULE

Important guidelines and recommendations which can be treated as part of *Best Practices* of ship dismantling activity can be uploaded in the SRR. These documents can be in the form of spread sheets, schematic diagrams, flow charts and photographs. ATTACHMENTS can be uploaded by activating the "attach file" button in report generation input mode. Fig. 5.30 shows SRR screen for attachment uploading.

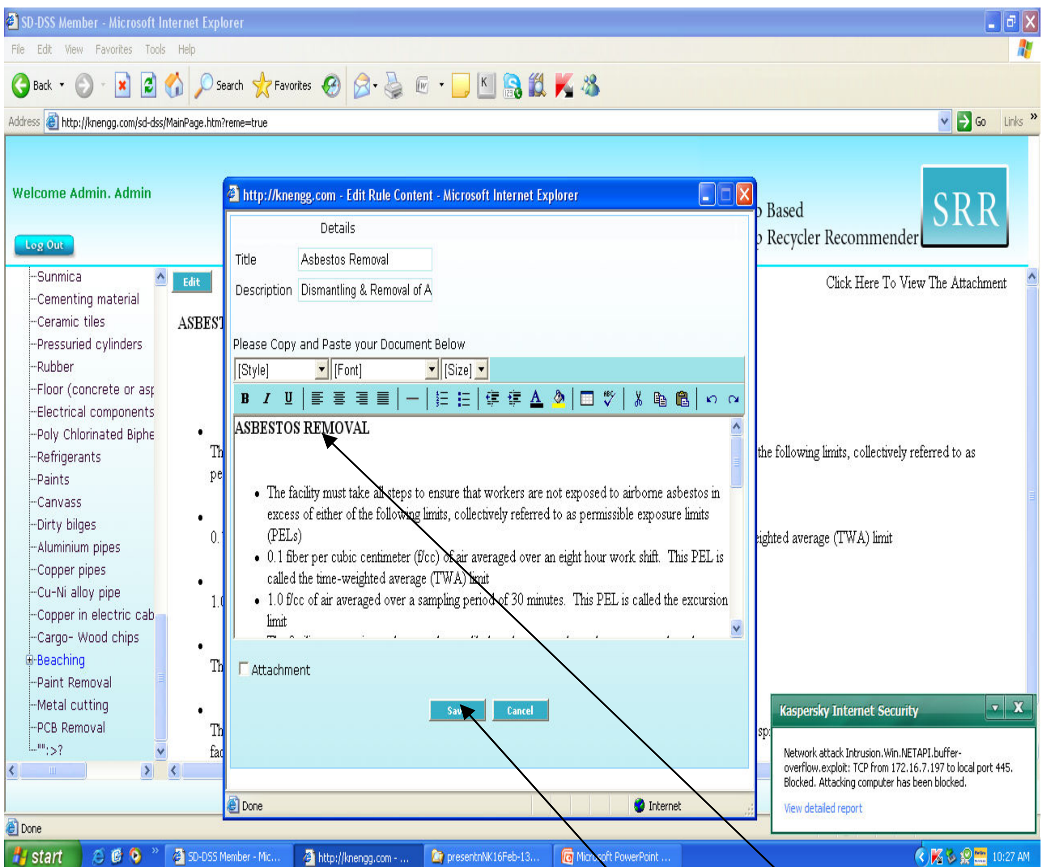

Fig. 5.29 Saving Operation of Edited/Deleted/Added RULES in SRR

Link QUESTIONS to RULES

All newly created and edited questions are to be linked to the RULE(S). This part also is done by the administrator. Linking can be made by clicking check box for linking the newly added or modified QUESTION. Links can be given to the parent node or to any child node which come under the parent node. Save all links before finishing the RULE - QUESTION linking session. Detailed description about the linking process is given in Appendix 3.

5.8.5 Description of the Input

To represent the sequential operations of the SRR software two schematic diagrams have been prepared and presented. Fig. 5. 31 show the functions of SRR that can be accomplished by a user and fig. 5.32 gives the details on editing of new QUESTIONS that can be performed by the administrator.

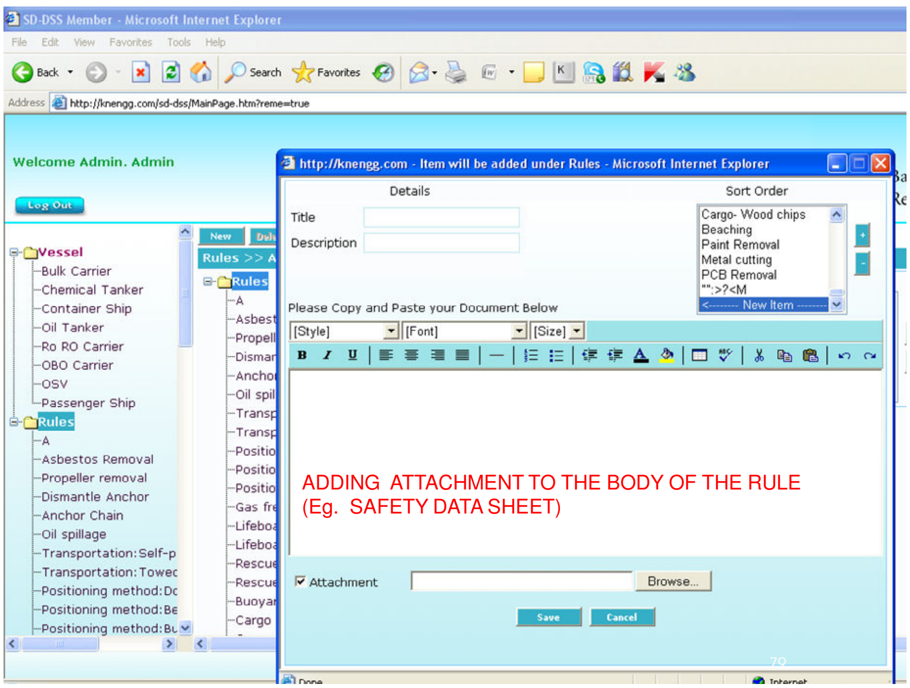

Fig 5.30 Uploading of Attachments

5.8.6 Description of the Output

The user output will contain recommended practices for recycling of that particular ship (for which input has been given). The recommended practices include the processes in table 5.3 and Extended Green Passport The major output (report generated) is given in Appendix 3.

5.9 SHIP RECYCLING WORK CONTENT ESTIMATION

5.9.1 Introduction

Work content estimation is an integral part of all industrial manufacturing activities. Ship recycling is no exception in this. The financial benefits that the ship recycler derive out of recycling a ship depends mainly on

1. Price for which obsolete ship is taken for dismantling

2. Expenses for beaching the ship and then dismantling the structure into components ready for reuse or recycling
3. Price of scrap steel, pre-owned items and other ship part which are sold out after dismantling.

The first and third items listed above are of fluctuating nature. Various factors such as global economic situation, world shipping market trends, freight rates, steel price, and scrap steel price influence the prices of obsolete ships and resale value of their parts. Whereas the second item, expenses for dismantling an obsolete vessel, remains mostly unaffected by the fluctuations outside. Expenses of ship recycling depends upon how efficiently and effectively various engineering activities involved in dismantling are carried out. Very little research has been conducted to measure the productivity in ship dismantling [Alkaner et. al [2], 2006]. The ship recycling content estimation method proposed in this thesis can be used as a tool to measure the productivity in ship recycling processes by adding suitable estimated values in man hours.

A very detailed schedule of cost estimation of entire ship recycling, based on individual activities is proposed as a part of this study. In order to achieve this, the activities involved in ship recycling have to be listed taking the subdivision to the lowest possible work content level. Detailed analysis of ship recycling activities have been identified

5.9.2 Description of the Spread Sheet for Estimation

The spread sheet for ship recycling is intended for estimation of work content for ocean going ships which are obsolete and destined for recycling yards using beaching method. The split up work content has been formulated in various stages, ie., offshore locations, in inter tidal zone and in the yard. In each of these stages possible works that can be efficiently accomplished are listed. These subdivisions of works have been noted either as outside (easy access) and as access required. These are presented as a list of ship recycling activities in table 5.3. This list has been taken as the basis of preparing the recycling work content. A spread sheet covering these subdivisions of recycling activities have been prepared for this purpose. Detailed ship recycling schedule for estimation is given Appendix 4.

These relevant man-hour estimates can be added to get a total man-hour estimate for the entire ship recycling activity of a particular ship.

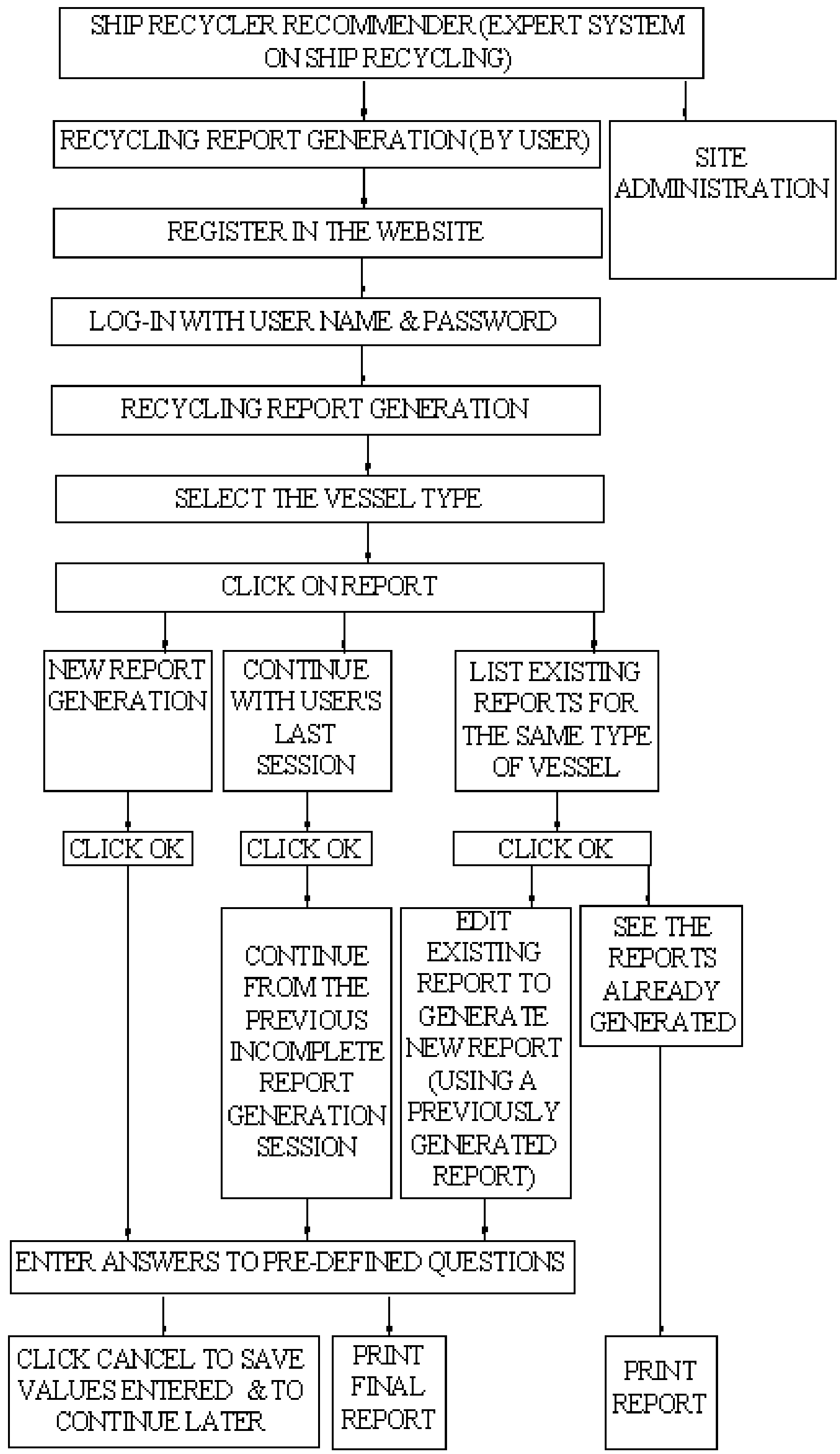

Fig 5.31 Schematic Diagram of Function of the User

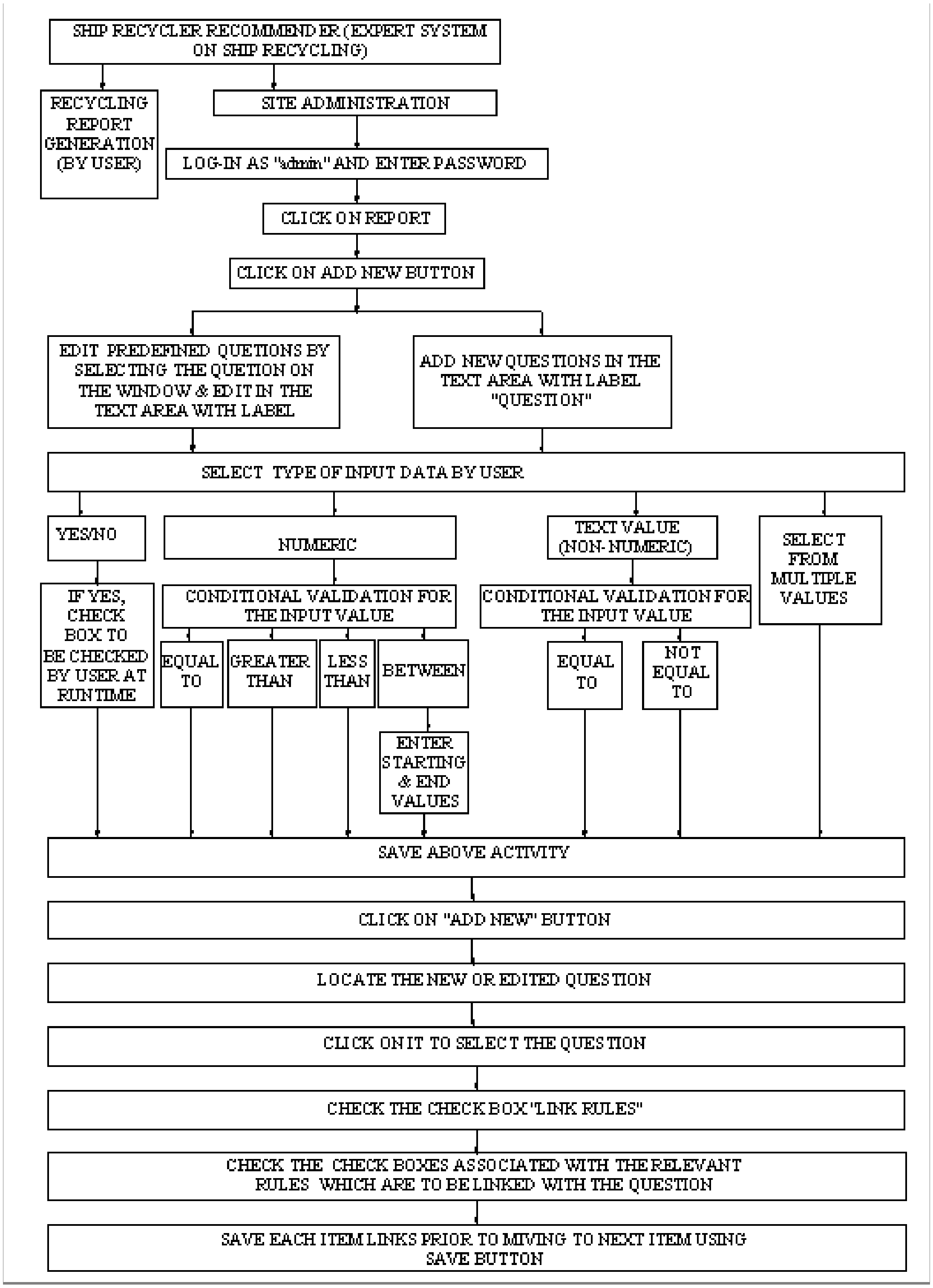

Fig 5.32 Schematic Diagram of Functions of the Administrator

5.10 COMMENTS

A pioneering effort has been made to develop a model of ship recycling adopting systems approach in the present study. Major elements participating in the activities of the ship recycling systems have been identified and their roles and duties in the system have been brought out in a convincing fashion. The sequential disassembly processes of all important beach based ship recycling activities have been prepared and presented as a engineering activity list and the same has been effectively applied in the formulation and development of the expert system for ship recycling in the form of Ship Recycler Recommender (SRR). The implementation of SRR has been successfully accomplished in web based and user friendly manner with multi-user support facilities. The expert system has been designed in such a way that the administrators of the system can make suitable modification and make it updated with the latest situation in the field. In order to make the process of work content estimation of ship recycling more systematic in terms of both economical and technical aspects a comprehensive work content estimation schedule has been made on the basis of the detailed engineering activity list of ship recycling processes.

CHAPTER 6

DESIGN FOR SHIP RECYCLING

6.1 INTRODUCTION

The three components viz., creation, sustenance and destruction in the life span of a man made system or material is much complex than any of the natural systems or materials. The design of such a system may be done very intelligently. The maintenance of the materials can be easy and cheap, whereas the destruction or disposal may be rather difficult. Manytimes, the man made products fail to deliver the complete natural life cycle. This issue has already sent serious signals to problems associated with environmental preservation and safety of life on the earth. In fact this marks the beginning of recycling oriented studies, and action plans are executed all over the world in different areas of science, engineering and technology for evolving effective recycling methodologies. A comprehensive examination of life cycle activities of a man made product is essential to derive the potential end of life use of obsolete products and their parts.

By looking at the man made chaos in product design and development, the process of recycling has to be redefined as an engineering project management tool used to plan and control the abandonment process of man made products strictly according to the underlying principles of sustainable development. The *design for recycling* philosophy is a tool as well as means to achieve this goal. Alkaner et. al [2] [2006] has proposed to apply design for dismantling philosophy covering some of the life cycle stages of ships. Cole [1998] has explained the relevance of life cycle analysis for environmental assessment of buildings. Though the operational conditions differ big residential and commercial complexes have similar features as ocean going vessels when compared with the available outfitting materials, engineering systems and equipment. *Design for recycling* concept presented by Cole can be improvised into a useful tool in recycling of engineering products, including obsolete ships since ship can be considered as a massive extension of a building.

Besides the conventional shipping operations, the marine activities have been enhanced by the offshore production and support structures subsequent to demand for offshore hydrocarbons. Massive nature and complex contents, of these components are likely to become a potential threat to sustainable development of global environment. Present study proposes a conceptual theme "*design for ship recycling*" to implement *design for recycling* in shipbuilding after a thorough analysis of extended life cycles of ship, knowledge base of naval architecture and product features of ship.

6.2 DESIGN FOR SHIP RECYCLING

6.2.1 Basics of Design for Recycling

Design for recycling is an engineering philosophy applied in all the life stages of an engineering product and it addresses the end of life stage in detail. *Design for recycling* philosophy is the only design philosophy which is implemented throughout the lifecycle of a product as observed by Rosemann et al. [1999] and the effectiveness of *design for recycling* is felt when the product is dismantled at the end of life stage. All other activities are carried out mainly to support the recycling. The design for deconstruction analysis proposed by Crowther [2000] for building construction has been suitably modified for shipbuilding by Dilok et al [2008]. The activities during end of life dismantling of ships have been considered and the design philosophy has been named as *design for dismantling*. The guidelines developed in *design for dismantling* focus on the recyclability options such as reuse, recycle, recovery of energy and land fill (of the dismantled products). Scope of integrating the demands of other major life cycle stages of ocean going ships have not been fully addressed by them. A wider design methodology featuring important demands of life cycle stages of ships based on naval architectural aspects has been envisaged in the present study.

6.2.2 Basics of Design for Ship Recycling

Sustainable development of international shipping sector is detrimental to the global sustainable development since the output from marine sector is massive and more complex. At the same time any positive move towards implementing a proper *design for recycling* will act as role model in the sustainable development of the sector. *Design for recycling* when applied to shipbuilding is termed as *design for ship recycling*. The following features of ocean going ships have been identified in the present study for the implementation of *design for ship recycling*.

a. Average life of ships

b. Physical product features
c. Life cycle stages and their characteristics
d. End of life and partial dismantling process
e. Management of obsolete parts and products
f. Rules and regulations on pollution, safety and health during ship dismantling

This philosophy has an important role to play from concept design of the ship to cutting of the last plate during dismantling. Applying *design for ship recycling* principles in shipbuilding will improve the status of the vessels and they will be made into a "clean carriage" of non hazardous materials and at the same time an industrial work centre with safe processes. Implementation of *design for ship recycling* ensures that the vessel will naturally remain eco-friendly causing no 'un-green' incident either in sea, dock or in beach. In brief, *design for ship recycling* is a merit certificate for 'Sustainable Development' of the maritime sector.

Design for ship recycling in shipbuilding is a wider concept incorporating comprehensive engineering methodology that focuses the major issues involved in various stages life cycle of a vessel including environmental pollution, occupational health, safety of personnel and ship parts, energy conservation, advanced engineering and ergonomics. Only a comprehensive engineering team work can facilitate effective and efficient *design for ship recycling*. It can be considered as a set of engineering guidelines to be followed during the entire lifecycle of a vessel in order to facilitate minimum negative impact on the major issues identified. A preliminary analysis on outcomes of application of *design for ship recycling* in shipbuilding has been done and the findings are presented in table 6.1

Besides these outcomes the following attributes may be associated with *design for ship recycling* activities,.

- If rule permits, recycled materials may be used for new shipbuilding projects
- Additional modifications during fitting may be minimised
- It is possible to keep track of identification and coding of replaced equipment /components

The product development in shipbuilding and the life cycle stages of ships are interpreted in the *design for ship recycling* philosophy and have been discussed in detail under subsequent subheadings.

6.2.3 Features of Ship as a Product

Traditionally product development procedure starts with initial design of a product and stops at completion of its manufacturing [Storch et.al 1995]. However in shipbuilding context, product development t is a continuous process which extends

Table.6.1 Major Outcomes of the proposed Design for Recycling on End-of-Life Activities

Elements Design for Recycling	Stages of Product development	Primary Outcome	Secondary outcome
• Development of knowledge base on components/equipment • Implementation of product standards such as modular design, unit assembly	Preliminary design Detailed design, purchase and construction	Easy reuse	*Design for recycling* document
• Efficient access, lighting and ventilation plan	Detailed design and construction		Efficient and safe handling of parts
• Reduction of total number of dissimilar equipment/components. • Minimize use of hazardous materials. • Design proper layout for machines / equipment/ components • Coding of components and equipment	Preliminary design and detailed design Detailed design	Easy dismantling process Smooth recycling pre processing Efficient and eco-friendly recycling	Mass purchase & efficient storage Support for after sales logistics No legal tangles Efficient administration Trouble free operations in other life cycle stages
• Develop recycling plan	Detailed design and construction	Easy dismantling by adjusting connection tolerances & working space. Identification of potential reusability of onboard materials and systems	Replacements and modification are made

well beyond the new shipbuilding activity. Ships when compared with other industrially designed and manufactured products are quite extraordinary in a sense that the four stages in life cycle of ships viz., design, production, operation and dismantling which are to be examined in detail to arrive at a comprehensive life cycle system. Each of these stages has more than one sub stage and these stages have an influence over the product development. The unique characteristics of product development of ships have been identified by Sivaprasad [1993] and are listed below:

a. One off kind product status
b. Active customer involvement
c. Multi functional product design attributes
d. Multi user product requirements
e. Extensive and sometimes contradicting rules and regulations
f. Proactive presence of classification and statutory agencies
g. Longer life cycle
h. Extensive repair and modification requirements

These characteristics together with the massive and complex nature of ships make them a vast engineering product.

6.2.4 Review of the Life Cycle Stages of Ships

Among the four life cycle stages mentioned earlier thrust is given on operation part, since it is the only life cycle stage with financial profit. Ship is over utilized as a transport mechanism and generally profit maximization is the motivation behind this.

Traditionally shipbuilding is a customer driven industry and the involvement of ship owner in design and development of the product design is more dominant compared to any other engineering products [Sivaprasad 1993]. In earlier periods, the naval architects and ship designers did not consider disposal of a ship as one of the life cycle stages as it did not figure in the owners requirements. Alkaner et al [2] [2006] have stressed the requirement of incorporating ship recycling as one of the important life cycle stages in shipbuilding and the model proposed by him can be represented as given in fig.6.1

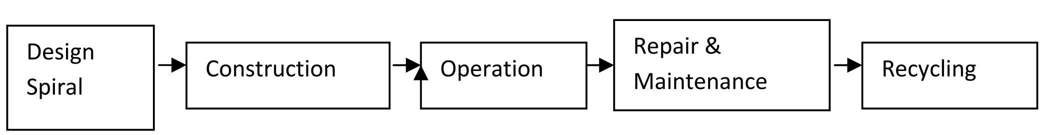

Fig 6.1 Modified Model of Life Cycle Stages of Ships Alkaner [2006]

The first two stages, ie., ship design spiral and construction appear only once in the entire life cycle of a ship. These two stages occur in a straight sequence in the beginning of the life cycle. During these stages ample scope exists for use of appropriate product and process standards, implementation of recommended guidelines on various design aspects and application of computer based technologies. This will help designers to manufacture a ship that will satisfy the owner's requirements. Any steps for recycling implemented in these two stages will have a positive impact on efficient and smooth end of life processes of ships. The next life cycle stage, ie.,. operation occur continuously throughout the life with relatively small breaks in between which is identified as the repair and maintenance stage. Though these two are the two stages are dominant, as on today, these have minimum influence on performance of end of life activities of obsolete vessels. Shipbuilding is characterized by the one-off kind product status and involvement of customers, classification societies and vendors in the product development process. This unique nature of product development in shipbuilding makes even the sister ships differ each other. The difference can be observed in product features such as lay-out of ships, materials and equipment fitted onboard. This special characteristic in product development offers a potential area for application of *design for ship recycling* concept, but with a new model of life cycle of ships.

6.2.5 Extended and Modified Life Cycle

Fig. 6.2 shows schematic diagram of an extended and detailed life cycle of ships based on the present study of *design for ship recycling*. The extended life cycle model presented here deviates from the existing model in two main aspects. The former is that the proposed model has few more important stages added. New life cycle stages such as Concept Design, Major Surveys, Conversion and Lay-up have been introduced in the proposed model. Minor life cycle stages which have been identified are initial surveys by various agencies like ship classification societies, statutory bodies and standardisation organisations. The later involves the segregation of these stages into primary and secondary. For example the *concept design* is a primary stage where as survey and inspection is a secondary stage. These stages are carried out simultaneously with the main stages and therefore they have been designated as secondary layer stages. However important *design for ship recycling* activities are taken up in these stages too. These life-cycle system components are arising from the 'systematic ship recycling engineering' concepts and are explained in the following sections.

6.2.6 *Concept Design*

Traditional concept design of ships generally evolves along with for a new ship type, not along with each of the new built ship, as in the case of containership evolved in 1960s, and the LNG in 1970s. This exercise involves a series of innovative design steps for introducing a new product and system concept. However what is projected here, as *Concept Design* is a practical stage in life cycle, which carries the seeds of recycling engineering along with it. Ship is a 'one-off kind' status product and even the sister ships vary at least marginally in their product specifications and operational features. This leads to extended scope for introducing variety concepts into individual product development and one of these concepts can be *design for ship recycling*. The recycling concept should be introduced in the *Concept Design* stage itself. The proposed Concept Design encompasses, the needs and demands of stages of ship life cycle right from detailed design to dismantling which has to include *design for dismantling, design for environment, design for safety, design for energy* [Alkaner et.al [2]]and *design for repair and survey* [Sivaprasad etal 2009]. These *design fors* which can be treated as individual design methodologies applied to the respective life cycle stages. These *design fors* have to be integrated to form a single design entity and the proposed *Concept Design* stage provides ample opportunity for that.

6.2.7 Survey and Inspection

During all stages of her life cycle, the ship as a product and as a system undergoes extensive surveying from both statutory bodies and classification societies. Though these surveys appear as a secondary layer in the proposed life cycle, these are continuous, exhaustive and comprehensive. Marine surveys can be considered as an effective quality auditing and reporting tool for various ship life cycle applications. These surveys can be used as an effective platform for the identification of onboard materials and their sorting, which finally leads to labelling of their current status.

Role of these secondary life cycle activities can be modified based on the above mentioned status allotted to survey and inspection so as to empower *design for ship recycling* activities. Capturing of history of repair activities, labelling quality and quantity of various engineering systems and components of the vessel such as hull, outfit and engineering, can be made a part of survey and inspection.

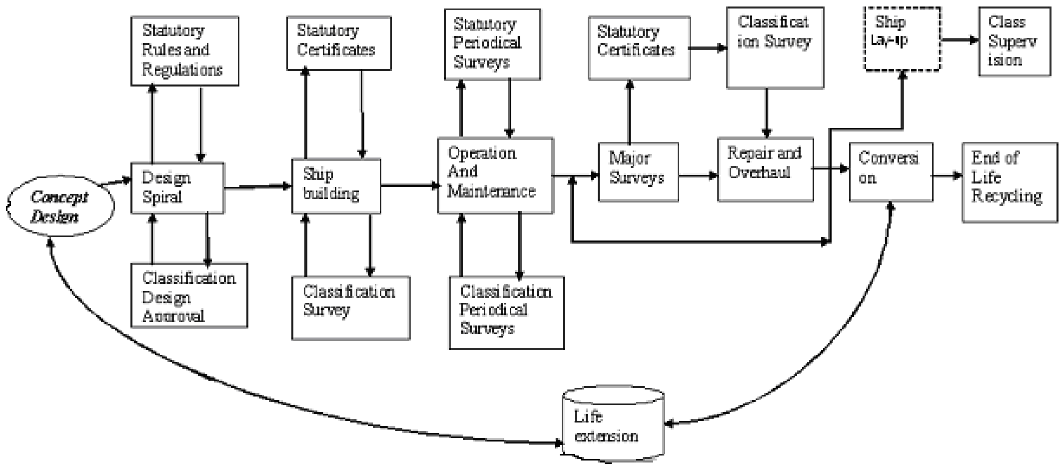

Fig.6.2 Schematic Diagram for Extended Life Cycle Stage System for Ships Based on Design for Ship Recycling Principle

6.2.8 Conversion

In the new era of global shipping, conversion option of ships, which involves massive functional and design modification, is likely to get more focus in the life cycle activities. This is considered as a 'recycling option under re-manufacture' by Alkaner et. al [2] [2006]. Conversion is the beginning of a new life cycle starting from another *Concept Design* and ending at ready for dismantling stage. For example when a tanker which was built based on the concept design of a 'tanker' is converted into an FPSO, its new life cycle will have to be based on the concept design of an FPSO and on expiry of its operation as an FPSO , it will have to be ready for recycling as per the regulations and procedures laid down for an FPSO. Massive replacement and refit of components and materials onboard while implementing latest amendments in rules and regulations can be treated as conversions. Global shipbuilding sector had witnessed this type of conversions during nineties when single skinned oil tankers were converted to double hull tankers as per the recommendations of the IMO. Similar type of conversion activities are expected to take place with the introduction of amendments in Safety of Life At Sea (SOLAS) 2010 rules in passenger vessels [Martinnen 2009]. Conversion activities include partial dismantling and massive replacements and refits, usually in a dry dock. Dry docks provide ideal platform for effective dismantling both in terms of safety and environmental aspects. Experience from partial dismantling activities carried out during the conversion stage can be used for the end of life activities of the same ship when it is listed as obsolete. The data collected from the conversion stage can be better utilised during the end of life recycling. For example, during conversion many components and materials have to be discarded and these items have to be settled or appropriated by the group involved in conversion. Proper documentation regarding the replaced component/material and their disposal plans have to be developed as the vessel will be under stringent survey and inspection by the authorities concerned. Such experience from conversion projects can be of great use to develop an effective ship recycling culture. So the significance of conversion has to be identified in recycling.

6.2.9 Lay Up

Ship owners may decide to lay-up their vessels during recession period which badly affect the maritime transport, and may prefer to layup to scrapping since the scrap price also goes down considerably during this period. Laying up of ships is often considered as the best option for a short term decline maritime shipping volume. Ships are temporarily withdrawn from the shipping trade and they are anchored in some calm sea zones. The laid up vessels will be almost idle expect routine check-ups for the critical machineries and systems. Improper survey and relaxed inspection procedure coupled with a lethargic operational discipline can add to many negative consequences. These include, malfunctioning of equipment which control operational waste and residues. The hull as such may be affected badly causing severe strength problems during the first voyage after the lay up is lifted. Classification societies should take a lead role in implementing the *design for ship recycling* recommendations as they get more time to inspect the condition of the laid up vessels. Ample opportunity is available during this period to go through the provisions of state of the art *design for ship recycling* rules and guidelines and for implementing them if these are not implemented onboard till then.

6.2.10 Design for Ship Recycling Knowledge Base for Naval Architects

Naval Architects attempting *design for ship recycling* should acquire extensive knowledge about various activities that may appear during various life cycle stages of a ship. The knowledge base should include complete and comprehensive understanding of the end-of life and partial dismantling processes for conversion. The other background information required include;

- New materials used and materials replaced during lifecycle stages of ships
- Recycling procedures and options for reuse/recycle of obsolete hull and onboard components
- Coding of reusable/recyclable parts of the obsolete vessel
- Possible ways of re-entry of parts of obsolete vessels in the marine markets.
- Recycling procedures and expertise available from similar industrial sectors.

6.3 IMPLEMENTATION OF DESIGN FOR SHIP RECYCLING

The involvement of experts and identification of expertise are very detrimental to successful implementation of *design for ship recycling*. The roles and responsibilities of participating engineering experts are to be fully identified and the expertise needed is to be assigned to various activities undertaken during the implementation. The development of *design for ship recycling* as a comprehensive and practical *design for* tool in shipbuilding has not yet occurred. However some isolated attempts have been made by IMO to improve the awareness regarding *design for recycling*, among the ship designers and shipbuilders. These concepts are discussed under the subsequent subheadings.

6.3.1 IMO Guidelines for Design for Recycling of Ships

IMO guidelines for ship recycling [IMO 2003] mention the importance of design of ships and ship's equipment to facilitate recycling and removal of hazardous materials onboard.

The major points included in the guidelines with regard to ship *design for recycling* are

a. Structural design for easy dismantling
b. Equipment product design facilitating easy and safe removal during dismantling.
c. Use of structural materials that support efficient recycling and disposal.
d. Maximization of recycled materials usage in shipbuilding
e. Minimizing the usage of non separable materials in hull and equipment.
f. Design measures to tackle removal of materials that are non separable from their specific individual substances.

Major issues addressed by IMO in its various global marine environmental protection conventions are compiled and analysed with respect to ship *design for recycling* has been given in table 6.2.

These guidelines by IMO are not generally focusing on core naval architectural aspects of ship *design for recycling*. Only exception to this is the emphasis given to preparation of list of onboard hazardous materials ie.,. Green Passport. According the IMO document A23/Res 962 section 5, the Green Passport should be prepared by ship designers and properly maintained by ship owners and operators. Green Passport has been considered as an essential part of ship recycling plan.

6.3.2 Roles and Responsibilities of Shipbuilding Engineers

A comprehensive approach to incorporate the concept of *design for ship recycling* should address the roles and responsibilities of all concerned involved in design, construction, operation, repair, survey, conversion lay-up and dismantling. Better understanding of life cycle models of ships is important in this context as effective life cycle management ensures efficient ship recycling.. Roles played by related engineering experts and the activities to be undertaken by them in various stages of development of *design for ship recycling* have been identified and shown in table 6.3.

Table.6.2 Analysis of IMO Guidelines on Design for Recycling in Ship Recycling

Sl. No	Ship Design Attributes	Major areas to be Addressed	Design Recommendation
1.	Ship design	Structural design	• Easy and safe removal of hull and outfit while dismantling • Use of recylced materials and parts
		Design of systems and equipment	• Standardisation of structural parts and equipment
		Material selection	• Use of recycled materials in new ships • Minimize usage of materials difficult to separate into individual elements.
		Ship recycling knowledge base	• Preparation of Green Passport • Design and development of Recycling Plan.

Table.6.2 contd..

Sl. No	Ship Design Attributes	Major areas to be Addressed	Design Recommendation
2.	Design of outfitting items and layout	Equipment design Selection of equipment Ship recycling documentation	• Easy removal and safe access • Use of recycled materials as parts and components • Maximization of usage of reconditioned and recycled equipment • Ship recycling plan with detailed equipment removal and dismantling description
3.	On board hazardous substances system design	Material selection Waste management system Ship recycling knowledge Base	• Minimization usage of hazardous and potential pollutants materials • Selection of production system design which minimizes routine and end of life waste generation • Design and development of waste treatment and efficient waste disposal system. • Preparation of Green Passport. • Equipment product specification documentation to support Green passport implementation. • Use of sustainable development indices indicating the green point of equipment, components, hull parts

Table 6.3 Roles and Responsibilities of Shipbuilding Engineers in Ship Design for Recycling

Sl.No	Life Cycle Stage	Trade of Shipbuilding Engineers	Activity for Implementation of Design for Ship Recycling
1	Prelim Ship Design	• Naval Architect • Marine Engineers • Production Engineers • Chemical Engineers • Mechanical Engineers • Electrical Engineers	• Development of rules on recycling /dismantling • Conceptual development of *design for ship recycling*. • Selection of environmentally materials • Futuristic study of potential issues related to materials • Preparation of recycling plan for life cycle stages
2	Detailed Design	• Owners Representative • Surveyor Representative • Naval Architect • Marine Engineers • Production Engineers • Chemical Engineers • Mechanical Engineers • Electrical Engineers	• Preparation of Green Passport • Allotment of index for vessels based on environment friendliness and safety aspects • Development of accesses plan for dismantling and repair
3	Ship Production	• Shipbuilding Engineers • Subcontractors • Classification Society / Statutory Body Surveyors • Naval Architect	• Implementation of *design for ship recycling* guidelines • Recycling assessment survey at various stages (for finalization of Green Passport) • Creation of recycling knowledge base • Finalisation recycling plan to be followed during, Operation, Survey, Conversion, Lay-Up and Dismantling

Table 6.3 Contd…

Sl.No	Life Cycle Stage	Trade of Shipbuilding Engineers	Activity for Implementation of Design for Ship Recycling
4	Operation and Survey	• Marine engineers • Electrical Engineers • Executive Officers • Ports Engineers • Classification-Society and Statutory Surveyors • Naval Architect	• Evaluating potential of materials on intermediate approval • Correction in the Index • Modification of Green Passport • Operational features regarding waste generation, storing and disposal
5	Repair	• Classification Society Surveyor • Statutory Surveyor • Ship Repair Engineer • Marine Engineer • Naval Architect	• Consolidation of in between survey findings • Recommendations based on new developments in rules and regulations (usage of materials) • Status of equipments (on quality, condition of working)
6	Conversion	• Classification Society Surveyor • Statutory Surveyor • Ship Repair Engineer • Marine Engineer • Naval Architect	• Implementation of provisions under new rules on use of materials, environment issues • New concepts implementation with respect to *design for ship recycling* • Re- check on all similar issues as in the case of concept and detailed naval architectural design

Table 6.3 Contd..

Sl.No	Life Cycle Stage	Trade of Shipbuilding Engineers	Activity for Implementation of Design for Ship Recycling
7	Lay up	• Statutory Surveyor/ • Marine Engineer • Classification Surveyor	• Condition monitoring of onboard dormant system
8	Dismantling	• Ship Dismantler • Ship recycling Broker • Ship Surveyor • Maritime Administration Surveyor • Pollution Scientist, • Safety Engineer • Naval Architect • Production Engineer • Logistics Manager	• Formulation of best practices of ship recycling

6.4 STEPS INVOLVED IN DESIGN FOR SHIP RECYCLING

Following are the steps involved in implementing *design for ship recycling*. The steps are listed for various life cycle stages

Preliminary Design

a) Incorporation of rules /procedures on recycling/dismantling based on ship types, deadweight item carried and onboard materials. If rules/procedures are not available, formulate them for the vessel being designed.

b) Give provisions for amendments/replacements for materials based on futuristic study

c) Generate a schematic flowchart of the recycling activities (beach based) similar to that provided in fig. 2.2

Detailed Design

a) Conduct recyclability analysis of the onboard systems, equipment, parts and materials.

b) Assign an index based on environmental and safety features of the ship and the recyclability analysis.

Production, Operation, Repair, Conversion and Lay Up

a) Conduct survey and ensure implementation of *design for ship recycling* guidelines prepared for the preceding stages of the life cycle.

b) Based on the survey evaluate the index, Green Passport and other relevant plans and offer corrections or modifications

Dismantling and Recycling

a) Formulate ship recycling plan as recommended by various statutory bodies, ship classification societies and other agencies.

b) Prepare Best Practices of dismantling using an expert system and their implementation

6.5 RECYCLABILITY ANALYSIS

6.5.1 Introduction

Recyclability is the stage/situation of a product or a component to make itself available for reuse and is a new technological term proposed in the ship recycling. Previously there was no method used to express the status of a product or component which makes it available for reuse, recycle or landfill. Scientists, engineers and technologists have been trying to find various solutions to tackle the ever increasing threat from accumulating unusable and waste products and components from the marine industry. If the designers and naval architects start looking into the concept of recyclability of obsolete ships and her components that will add to their overall ship design capacity. Recyclability analysis will help the designer to identify the components/equipment which are more likely to be refurbished and then reused at the end of their life. Ships and offshore structures are massive structural units which contain considerable amount of environmentally hazardous material. Such structures produce huge quantity of hazardous waste and other non reusable materials. Recyclability analysis of ships hull and other onboard items will be helpful in sorting out major issues caused by such structures while in operation, partial dismantling and during end-of-life dismantling. The recyclability analysis of such products is a continuous process carried out throughout the life cycle of the product. Recyclability analysis acts as good tool during selection of components/equipment in the initial stages of design. Functional and economical criteria are being considered along with this analysis.

Recyclability analysis starts with identification of eligibility of materials for various systems and equipment present onboard. In this step a detailed study of the environmental and occupational safety status of each and every material present onboard is made. If possible the failure status may be predicted using available techniques. Rules and regulations regarding the use and recycling of the materials may be thoroughly referred for assessing the status. The onboard materials are categorized on the basis of direct reusability, possible recycling status, non-conventional energy generation capacity and land filling nature of the components [Dilok et al 2008].

6.5.2 Processes in Recyclability Analysis

The activities and processes involved in ship recyclability analysis are identified and listed as the following:

i. Identifying and assessing environmental, health and safety impact of onboard components of materials.
ii. Categorization of materials as Reusable, Recyclable, Energy Recoverable and Land filling
iii. Development of rules for categorization
iv. Development of replacement plans for items which need frequent replacement during ship's operational life.
v. Assessment of reusability potential of the components/materials based on their reuse potential (like after 2 years /5years), availability of the potential users, detailed material safety data records and environmental and safety index.
vi. Preparation of recycling /reuse plan for components/materials based on the merit of method of recycling for the particular material. In case of absence of the existing regulations on recycling /reuse, propose available research areas. Identify potential end users or recyclers (category wise/country dependant).
vii. In case of necessity, opt for intermediate assessment for modifying the replacement plan. (going back to step iv)
vii. Assessment of recycled products with non-conventional energy potential.
viii. Preparation for plan for generation of non-conventional energy.
ix. Assessment of recycled products meant only for dumping based on potential problem of land filling, land filling procedures , rules and regulations in force (country wise),

x. Generation of new proposals regarding land filling, and preparation of dumping plan.

After the categorization is done based on the four major features of the components, the information generated should be compiled and edited. For the direct reuse, the components are assessed for their reuse capacity after a period of continuous onboard usage. Potential buyers are identified and a list is generated for further use. An index based on environmental friendliness and safety aspects can be assigned to the components at this stage itself. For recyclable components, best practices for recycling can be generated and documented. These documents will be helpful for facilitating clean and safe recycling of the components during partial or end of life recycling stage. Potential recycling agents are to be identified and located in this category. All these documentation activities, regarding recyclability status, should constitute a recycling plan for each individual recyclable component. Intermediate assessment and upgrading of the plan should be an essential part of recyclability analysis. Similar procedures are done for dealing with onboard materials which can be used for generally non-conventional energy after they are removed from the ship. No onboard materials should be left untouched in the recyclability analysis. All materials which can be used only for land filling are to be identified in a rigorous manner. Components in this category form the biggest threat to the sustainable development. The problem associated with land filling of these materials should be specially noted and documented effectively. Rules & regulations in this regard are to be carefully examined before arriving at a feasible land filling plan.

6.5.3 Preliminary Recyclability Analysis of Hull Steel

An attempt has been made in the present study to do recyclability analysis of one recycled product from ship dismantling, ie.,. steel plates and other steel products. Very detailed and specific recyclability analysis depends on the exact specification of the dismantled product. The analysis will also depend on the prevailing rules and regulations of the where the dismantled product is reused/recycled. Bearing in mind these two main points, very detailed recyclability analysis is not attempted here.

Generally marine quality steel is considered superior compared to those employed in land based engineering. Such quality steel recovered from dismantled ships can be used in structural, marine and industrial applications. Besides, it can be employed in railways, domestic application and automobiles. Recycled steel has to be subjected to proper inspection and assessment by competent authorities before allotment for reuse.

Dismantling of ship yields various types of steel products which differ in terms of physical and chemical properties, thickness, shape, functional properties etc.,. The steel products retrieved from ship dismantling are those recovered from hull steel, from plates, stiffeners and castings and forgings. Among these, plates may be of Plating, Sheeting, Corrugated Plates and Chequered Plates. Stiffeners can be from Bulb Sections, Angles, Pipe/Pillar, Flat Bars, and T Sections. Similarly Castings and Forgings include Chain, Mooring Bit, Anchors, Honey Comb, Shafts and Hydraulic Pistons. These products may be grouped into various steel quality types like different grades of Mild Steel, High Tensile Steel and Stainless Steel

These dismantled products can be employed either as direct reuse, usage of the recycled products after recycling or reprocessing (application of some of the products after completing re-melting). A preliminary recyclability analysis showing the use of recycled steel products have been given in table 6.4. Hull steel plates are initially placed either in recyclable or in reusable category in the analysis. Various options under these two categories of recyclability options are listed in the table. The exact option of recyclability can be determined after assessing the condition of the dismantled part at site. Potential users of the dismantled hull steel products can be identified after the condition assessment. From the past experience recyclability option of some of the hull steel parts can be identified in the initial stages of life cycle itself. Periodic classification surveys can also give some useful information regarding the updating of the recyclability analysis of hull steel products.

Major areas of application of the dismantled steel products are civil construction, railways, marine applications such as ship & boatbuilding and other marine structures, industrial works which includes construction of plated structures and ordinary applications in domestic works. Proper assessment should be made before deciding the application areas. Very strict guidelines as codes of practice are to be implemented for the recyclability analysis which will enable the proper selection of possible application areas and the structural parts for which recycled products can be used.

Table 6.4 Preliminary Recyclability Analysis of Steel Plates

Application	Recycling operation	Use	Remarks on usage
Civil construction	Hot re-rolling to thin sheets	Shuttering of the support	Only Mild Steel
Civil construction	Hydraulic cutting	As reinforcement in Reinforced Concrete.	Condition assessment survey
Civil construction	Hydraulic cutting	windows grills/gates	Condition assessment survey
Shipbuildin g	Hot re-rolling and fabrication	As non-strength partition in barges and inland vessels.	Condition assessment survey. Only Mild Steel
Marine	Hot re-rolled and fabricated	Inland buoys, buoyancy drums	Condition assessment survey. Only Mild Steel
Railways	Hot rolled and cut using hydraulic scissors	Fencing	
Industrial	Hot rolled to thin sheets and corrugated	Container living mobile habitats	
Civil Engineering	Hot rolled to thin sheets	Name boards, display arches	
Marine	Direct cutting /shaping	In-house barges, floating jetties in shipyards, ports etc	Direct Reuse with in-house quality survey
Industrial	Fabrication	Scrap bins	Direct reuse (Only Mild Steel)
Civil Engineering	Fabrication	Manhole Cover	Direct reuse(Only Mild Steel)
Railways	Rerolling and fabrication	Junction boxes	Only Mild Steel
Domestic	Re-melting and rolling	Open area truss work	Inspection by standardization agencies
Industrial/m arine	Fabrication	Vehicle ramps and false flooring in inland vessels	Direct reuse

Steel Sheet is usually found in super structure. Except the outermost bulkheads in superstructure all sheet metals will be protected using deck covering or panelling or ceiling. Due to this, plates from these locations will usually be of better quality. These sheets can be re-used directly after proper survey by a competent authority. Corrugated plates will have to be properly shaped before it is cut and made into pieces. Some of the uses of dismantled steel sheets based on preliminary recyclability analysis are given in table 6.5.

Table 6 .5 Preliminary Recyclability Analysis of Steel Sheets

Area of use	Recycling operation	Use	Remarks on Usage
Civil Engineering	Hot rolling to further thin sheets	Shuttering of the support	Only Mild Steel
Industrial	Hot re-rolling to further thin sheets	Container living mobile habitats	
Ship building	Direct	Superstructure partition in inland barges and boats	Direct reuse Classification Society assessment
Railways	Direct	Railway station and crossing fencing.	Direct reuse
Civil Engineering	Direct	Name boards, arches	Direct reuse
Civil Engineering	Re-rolling fabrication	Chequered plating floor	
Automobile	Fabrication	Chequered plating floor	
Marine (Corrugated plates)	Fabrication	Superstructure accommodation units in inland vessels Ramps in boat jetties and inland ports	Direct reuse Classification Society assessment

Details of preliminary recyclability analysis of stiffeners are given in table 6.6 and that of casting and forgings are given in table 6.7

Table 6.6 Preliminary Recyclability Analysis of Hull Stiffeners

Dismantled product	Application area	Recycling operation	Use	Remarks on Usage
Flat bars	Civil Engineering, Railways, Boat building	Fabrication	Various uses	Direct reuse
Bulb profiles	Boat building	Fabrication	As stiffeners in inland vessels	Direct reuse Only Mild Steel profiles
Angle sections	Boat building, Industrial, Civil engineering, Domestic and Railways	Size modification	Stiffeners, truss members and fencing	Direct reuse
Pillar pipe sections	Industrial, Domestic and Civil construction	Size modification and fabrication	Staging, truss work, posts, support	Direct reuse Only Mild Steel pipe sections
T section		Size modification, cutting	Same as that of plates	Only Mild Steel where welding fabrication is involved.

Table 6.7 Preliminary Recyclability Analysis of Castings and Forgings

Dismantled product	Application area	Recycling operation	Use	Remarks
Chains	Ship dismantling	Size modification	Winch handling operations	Direct Reuse Inspection and testing by Classification Society
Cast & forged pieces	Marine	Remelting	Anchors fair leads, hooks	Classification Society assessment
Shafts	Marine	Size modification	Re-rolling rollers	Direct reuse Classification Society assessment
Shafts	Industrial	Size modification	Cold forming rollers	Direct reuse

There are small amounts of special quality steels which are recovered during ship dismantling like Bimetallic strips (Aluminium-steel), Corton Steel (high temperature application) and Nickel- chromium steel.. These steel items can be reused in specialized industry applications.

6.5.4 Comments

Recyclability analysis requires massive database handling and decision are made from number of choices available. Support from computer based expert system/decision support system is essential for efficient recyclability analysis of recycled products form obsolete ships. This can be cited as one of the validations of the relevance of the knowledge based expert system as a part of the present study.

6.6 GREEN SAFETY INDEX FOR SHIPS

6.6.1 Introduction

Ship recycling is a major issue like global warming or ozone depletion yet to be addressed along with sustainable development. *Design for ship recycling* activities should give more importance to reducing the hazardous materials used onboard, minimizing the operationally generated waste, controlling the emissions and the marine pollution due to corrosion products.

Aged ships are one of the main sources of marine pollution and the threat come from various onboard materials and systems such as pollutant cargo residues, heat insulation materials like a asbestos, PCB, TBT etc.,.. Ship owners are now more aware of the potential threat from unscientific ship recycling and honest efforts are made by international maritime regulatory authorities to bring ecological awareness among the stake holders in the global shipping sector. Definite necessity is felt for classification of ocean going vessels based on four major features such as “green” product characteristics, energy efficient systems onboard, application of emerging engineering concepts and complement friendly onboard working environment [Sivaprasad et al 2008]. A representative index for all the ships, taking into consideration all the above mentioned features, is proposed in the present study. The proposed index assigned to the ships is named as Green - Safety Index.

Green Safety Index for ships follows the Green Passport concept introduced by IMO. Green Passport essentially deals with listing of various categories of materials present onboard and on the severity each material as a pollutant. IMO has not put forward any categorisation of vessels based on presence of hazardous and other non eco-friendly materials onboard. The criteria and assessment of Green Safety Index for ships can be considered as the foundation of any rules and regulations to be framed in the future. Green Ship theme proposed by Brown [2010] is a conceptual development in this field. The Green Safety Index for ships has been defined based on the 4E's, viz, Environment, Energy and Engineering and Ergonomics.

The implementation of *design for ship recycling*, especially the recyclability analysis, helps the designer to know more about potential problems caused by various materials used onboard and due to the operationally generated waste. Other major concern in this area is pollution due to gas emissions from various onboard machinery systems. Reduction in the total pollution as well as safe handling of hazardous material will help supporting the ecological cause of sustainable development of international shipping sector. The Green Safety Index assessment involves collecting and compiling important information on onboard materials, equipment and systems. For assigning the Green Safety Index these information are processed by giving due weightage.

Green Safety Index is similar to assigning a class notation by ship classification societies. However the assessment is based not purely on the provisions of the statutory regulations but based on the provision of additional features onboard to enhance the overall quality and performance which eventually support the cause of sustainable development. Some of the assessment values adopted for the indexing will have the potential of providing a scientific base for formulating ship recycling and other related rules and regulations in the future.

6.6.2 Necessity for Assigning Green Safety Index

The stakeholders in ship recycling play active role in making the ship recycling activities into safe and environmental friendly engineering process. The ship owners are to be more aware of the potential threat from unscientific ship recycling in the way as it is practiced in some ship recycling yards. In order to make the owners feel the relevance of ship life cycle operations management oriented sustainable development the vessels owned by them should be assessed for various characteristics of their vessel and a ‘ representative value’ such as Green Safety Index be assigned to them.

It has become almost mandatory to classify all products available in the market according to its environmental impact. Governments are introducing mandatory environmental standards for various types of industrial and domestic products. ‘ECOMARK’ [1991] standard introduced by Government of India is one among these mandatory product classifications. ECOMARK is applied mainly to house hold products and commodities as potential health and environmental threats from some of the domestic products such as food and cosmetic items are reported. However ships and other marine structures so far have not been classified in this regard

A definite need for the extension of ECOMARK to ship recycling processes has been felt and it has been proposed in this study for the government initiation in this regard. Considerable environmental impact is expected from massive industrial products, such as ships and other marine structures and the same is likely to grow in the coming years. The impact of these types of highly complex products may appear in the form air pollution due to NOx emissions from onboard machineries and systems, land pollution due to dismantling of the vessel in beaches, ecological imbalances due to ballast water operations, blow-up off oil well heads, oil spills due to vessel capsizing, collisions and failure of the hull girder. Apart from this the threats related large scale depletion of fossil fuels owing to use of inefficient power generation and other onboard systems is an area of concern. On the other hand occupational health and safety of construction workers, engineers, ship surveyors and crew members engaged in various life cycle stages owing to carcinogenic and toxic material exposure create another type of problems which hinders sustainable development prospects aims. Working in unsafe onboard locations and potential fire hazards are to be viewed as a part of the wide spread threat.

Sustainable development of international shipping sector is detrimental even to the global sustainable development as the contribution from the shipping sector towards this is quite considerable. At the same time any positive move towards assigning a Green Safety Index for ships can be treated as a humble effort in the maritime sector. Any engineering activity to facilitate improved sustainable development in the marine sector will have more impact on certain global geographic locations like South Asia where ship dismantling is carried out en-masse. Similar action plans related to sustainable development of maritime sector are being discussed in various high level international summits. The focus of all these conventions is regaining the 'green base' of mother earth. The marine sector should aim to achieve the same and incorporate the fundamental "green and safe" priorities onboard vessels and other marine structure. As a part of this it is proposed to introduce an index based on sustainable development or Green Safety Index to all vessels operating globally. The underlying factors of 'Green Safety Index' are the 4Es mentioned previously, ie., Environment, Energy, Engineering and Ergonomics.

6.6.3 Advantages of Assigning Green Safety Index

More stringent international maritime regulations are likely to be in force in the forth coming years. The basic frame work of these regulations will be mainly aimed at maintenance of sustainable development of global maritime sector. Green and safe attributes of the ocean going vessels would be the two major themes that might be reflected more in these regulations. Rules and regulations pertaining to green and safe characteristics of ships and ocean structures can be anticipated to be implemented in various life cycle stages. The attributes include,

- Environmental friendliness
- Energy conservation systems
- Engineering applications to facilitate efficient life cycle management of ships.
- Ergonomics based onboard working environment

In this context the proposed Green Safety Index assignment becomes more relevant. Some of the advantages of having a Green Safety Index fixed to the vessels are discussed below;

I. Green passport concept introduced by IMO serves a partial assessment of presence of hazardous and other non-ecofriendly materials present onboard. This database regarding all materials present onboard can be further used for carrying out recyclability analysis and developing best practices for ship recycling processes.

II. The proposed 'Green Safety Index' evaluation of ships and other structures can be of good use as a preliminary trial of the procedures for a very comprehensive formulation of rules and regulations in ship dismantling.

III. The proposed Green Safety Index assessment involves collecting and compiling important information on onboard materials, equipment and systems. These information can be further added into the existing product model and a modified product model for efficient ship recycling can be achieved.

6.6.4 Calculation of Green Safety Index

Green safety index is notation allotted during the design stages. This is done as per the presence of identified elements under 4Es mentioned earlier. Some of the significant categories the elements include, materials listed under the Green Passport, onboard power generation and distribution systems, naval architectural and ship design features, safety equipment and systems installed onboard and the standard of working environment provided to various personnel working onboard during different life cycle stages of the ship.

Table 6.8 shows the proposed Green Safety Index (GSI) assessment plan for ocean going ships. The Green -Safety Index is assigned in first two stages of lifecycle, i.e., *concept design* and detailed design. The development part is done in the next three stages production, operation and survey. In these stages the assigned Green Safety Index is

Table 6.8 Green Safety Index (GSI) Assessment Plan

Life Cycle Stage	Design	Construction and Survey	Periodic Survey	Repair and Conversion	Dismantling
GSI Assessment Activity	Preliminary Assessment	Allotment	Maintenance	Re-assignment	Outcome as benefits

modified using measured values and continuous recording done on the status of components/materials/standards. During the important survey the records are modified maintained and made ready for re-assessment if required. In the major repair and conversion stages already fixed Green Safety Index is modified to improve the rating incorporating state of art materials, technological procedures and engineering standards.

A sample Green Safety Index calculation format applicable for ocean going tankers is given in table 6.9. Green Safety Index can be calculated after adding up the relevant individual indices as listed in table 6.9. For example if a vessel has the Clean Ship Class assigned by Dets Norske Veriats, (or similar class by any other ship classification society) the vessel will acquire four index points. In some other case if the assessment element is present certain points will accrue to the tally of index points and if the same element is not present negative points will be added to the total tally. The index point is assigned as per the gravity of the assessed element (or the ship's attribute) with regards to the green and safety concerns. Following this if a tanker having no double skin fitted will get a high negative ('negative ten' in the example) index points as double skin is mandatory in ocean going tankers. Whereas presence of hull condition monitoring is less serious compared to the double skin and absence of that feature onboard will fetch no negative index points in the GSI assessment. After analysing the presence of all the elements given in the format the final index can be calculated. The total index point accrued by adding up all the relevant individual points will be the basis for assigning Green Safety Index. The Green Safety Index assessment format given here is applicable only for ocean going tankers. Similar type of index calculations can be prepared for other type ships considering the salient features of the ship type coming under the 4Es.

6.6.5 Green Safety Index Notations

It is proposed in this study to assign the notation for the Green Safety Index is given as a combination of a symbol and a alphabet indicating the position or grade of the vessel. Highest range total index point is given by X1 and X2 and vessel accruing total index between X1 and X2 will be assigned highest index denoted by;

GSI **Green** **(Total Index Point between X1 – X2)**

a lower index points between X2 and X3 and the corresponding Green Safety Index notation is denoted by;

GSI **Yellow** **(Total Index Point between X2 - X3)**

and the vessels getting lower most total index points, ie.,. between X3 and X4 will be assigned a notation;

GSI **Grey** **(Total Index Point between X3 – X4)**

The limits of the total index points (X1- X2, X2- X3, X3-X4) may be stipulated by the statutory bodies.

6.6.6 Maintenance of Green Safety Index

Once Green Safety Index is assigned during the design stages based on the features listed against the elements of the assessment corresponding notation can be assigned to the vessel, she starts receiving the benefits of being in a sustainable development class.

Table 6.9 Assessment of Green Safety Index of Tankers

Green- Safety features of ships	**Assessment Elements**	**Index Points**	
		If the Element is present	If the Element is not present
Design	Clean Design (DNV)	**4**	**0**
	Double Hull for a Tanker	**2**	**-5**
	No Ballast Tanker (Class NK)	**3**	**0**
Environment	Toxic materials (Ex.,PCB)	**-5**	**5**
	Carcinogens (Ex., Asbestos)	**-10**	**5**
	Pollutants (Ex., Used Oil)	**-5**	**5**
	Recyclable materials	**8**	**0**
Safety focus	Anti-rolling tanks - Stability	**2**	**0**
	Fire resistant materials	**5**	**-3**
	Collision prevention systems	**2**	**0**
Energy conservation	Super efficient propellers	**2**	**0**
	Renewable energy sources(Solar/Wind)	**5**	**0**
	Energy conservation plan (Onboard energy audit)	**2**	**0**
Technology	Hull and equipment condition monitoring systems	**5**	**0**
	FMEA based structural design	**5**	**-2**
	TBT based paints	**-8**	**5**
Ergonomics	ISM/ISO based onboard manning	**5**	**-2**
	Safe working locations onboard	**5**	**-2**
	Maintenance management	**6**	**-5**
	Health & safety Plan	**5**	**-5**

In production stage first cross checking should be done and records are to be prepared on arrangements. Any deviation addition, modification of components and materials and their related features under 4Es should be noted and recorded. These records will enable the design team to reassign the Green Safety Index. During operation and surveying the above-mentioned activity can be carried out. Regular updating of replacements, repairs, modifications, additions, and enhancements of parts, components and system should be noted down. A separate logbook has to be prepared by the ship management to accomplish the task of updating and maintaining the Green Safety Index. At any point the Green Safety Index should act as an indicator of the sustainable development.

Major repairs and conversions are considered as beginning of an extended life cycle. In fact conversion can be treated as a redesign and there by beginning of a new life cycle. The potential non-recyclable components and materials and environmentally contraband materials can be replaced by new recyclable friendly and permitted equivalents. Here the Green Safety Index gets a phase lift as the performance pertaining to some of sustainable development features get a positive up-gradation.

6.7 SCOPE OF DESIGN FOR SHIP RECYCLING

The scope of *design for ship recycling* in this context has been defined as various aspects that should come under the purview of *design for ship recycling* philosophy which will improve the efficiency of recycling of ships.

6.7.1 Design Philosophy

Happenings at the end of life of the vessels are not taken into serious consideration during initial stages of design and in the follow up activities in the life cycle by the designers. The major task before them used to be the preparation of the best design for easier construction and efficient operation. Designers are still working around design for production and its contemporary *design fors*. Marine pollution related issues have created awareness among designers towards design for environment. Similar awareness has to be developed in recycling oriented design attributes as well. *Design for ship recycling* is the best way to address the environment and safety problems related to ship recycling. Implementation of *design for ship recycling* philosophy is essential for achieving sustainable development of international maritime sector.

6.7.2 Product Design and Development

Design for ship recycling envisages product design and development with easy parts and components assembly procedures. It gives more focus on integrated assembly of various identical parts. Simple product structure will always enable easy disassembly activities which in turn makes end of life dismantling of onboard equipment and parts less cumbersome. Dilok et al. [2008] has discussed the characteristics of the product structure and concept of design for dismantling of ships. The present study extends the scope of this concept by incorporating five objectives of *design for ship recycling*, viz, environmental orientation and safety during operations, energy consciousness, use of state of art technology and ergonomics in all onboard operations including final and partial dismantling.

6.7.3 Common Industrial Standards

Quality requirements of various industrial products for marine application are more stringent. Onboard systems are complex owing to the high standard of safety requirements and accessibility problems due to onboard space constraints. These characteristics of marine quality parts make recycling of equipment and components different from the common recycling processes adopted in civil construction. *Design for ship recycling* emphasizes common industrial product standards. Recycling activities and reusability of dismantled products with common standards can be easily compared. This will make recycling of ships less complex and more acceptable.

6.7.4 Product Standardisation

Product standardisation ensures improved quality and productivity in design and manufacturing in shipbuilding and this concept has been developed to support simplifying ship design procedures, minimizing different types of inventories in ship production, compatibility of component replacements in ship repair and ensuring implementation of essential international rules and recommendations by agencies such as IMO and IACS. The present study proposes extension of the concept of product standardization incorporating the requirements of ship recycling activities too. This can be better achieved by introducing the *concept design* as a part of life cycles of all vessels as described in section 6.2.3.

6.7.5 Process Standardisation of Ship Recycling and Proposing Best Practices

Standardisation of ship recycling process is as important as the product standardisation. For ship recycling to be more effective, both product and process standardisations should go in tandem. Process standardisation focuses on development of best practises for ship recycling operations. Ship recycling yard organisation, infrastructure support and lay out management of recycling yards constitute one part of the process standardisation. This part has been included in International Standardisation Organisation (ISO) standards [ISO/DIS 30000:2008]. This process standard covers all yard oriented issues in ship recycling. Best practices for ship recycling activities, right from towing of the obsolete vessels to dismantling of the last component, constitute the second phase of the process standards. Process standards for the later part have been developed and presented in the expert system software, Ship recycler Recommender (SRR) in the present study. Ship General Arrangement (GA) design attributes such as accessibility, water/weather/fire tightness, availability of light, ventilation and features of materials and components act as fundamental frame work for the development of the best practices.

6.7.6 Environmentally Contraband Materials

Presence of environmentally contraband materials in hull structure, outfit items and machineries are considered as the most serious issue by the agencies involved in uplifting the status of ship recycling industry. Dets Norske Veritas has developed an onboard material inventory recording database, Green Passport addressing this special ship recycling issue. The present study has widened the scope of this inventory recording mechanism by proposing Extended Green Passport. Various characteristics of common onboard materials and cargo residues with respect to ship recycling activities have been prepared and included in this onboard material safety data record. Extended Green Passport reports are already incorporated as a part of SRR and presented in 5.

6.8 APPLICATIONS OF DESIGN FOR SHIP RECYCLING

IMO guidelines on ship recycling envisage a proper *design for ship recycling* which will minimize marine pollution and reduce accidents causing loss of life and damage of property during dismantling. Some of the important applications of *design for ship recycling* are given under the subsequent subheadings.

6.8.1 Structural Design of Hull and Lifting Devices

Structural failures of the ship result in marine pollution especially in the case of tankers. Failure Mode Effect Analysis (FMEA) is a good tool to check the potential models of failure within a system. FMEA can be applied effectively in ensuring adequate residual strength while collision, grounding and other severe damage causing incidents occur FMEA principles have already been applied to structural design approval procedures by the classification societies. And this can be extended to *design for ship recycling* area as well. Lifting and handling of hull parts are considered as critical shipwrights operations in shipbuilding and these operations can be classified as very risky in ship dismantling context. FMEA for shipwright activities during ship dismantling will provide a better background data for safe and risk free disassembly processes. Lifting pad eyes are fitted normally during ship construction in engine rooms and other areas where heavy machineries are installed. Rungs are fitted in tanks and holds for easy access and safe operations during repair, survey and conversion. However during dismantling phase and conversion phase, if any, more number of properly designed and located lifting supports are required for handling the dismantled structural parts, onboard equipment, and for transferring them outboard through an opening cut temporarily on side shell or deck plating. *Design for ship recycling* methodology envisages inclusion of design and layout of these dimensionally trivial items in the detailed structural design stage itself. As a part of the recycling plan separate drawings incorporating the structural requirements for ship dismantling should be prepared. The same may be validated during the ready for recycling stage by the competent authority.

6.8.2 Design of Access Systems

Safe and easy access to different butts and seams of various compartments is one of the crucial prerequisites of safe and sound dismantling. During the functional design stage the designers develop the access based on the necessities during the sailing operations. One of the main draw backs of the present ship design procedure is that the onboard access needs during other important life cycle stage procedures are not addressed in it. Major access requirements for other life cycle activities, especially the one during ship dismantling will have to be built during the course of the design spiral. Locations of soft spots for openings in side shell and main deck are to be assigned taking into account the other requirements. Other application areas connected to the onboard access include selection and positioning of rungs on tanks and hold boundaries such as side shell, bulkheads and web frames. These rungs also have to be designed and positioned considering an anticipated structural condition during the dismantling stage. Fixed and rigid type of access systems located on relatively unexposed and rigid hull parts will ensure more safety and efficiency during the actual dismantling process. These rungs and ladders are to be positioned and fitted after a comprehensive analysis cutting and handling operations of hull parts during end-of-life dismantling. Benefits, of having a far reaching access system, are wide spread in the entire life cycle stages of the vessels.

6.8.3 Equipment Manuals

All equipment used onboard have got descriptive product manuals for the reference purpose for crew members and ship repair engineers. However these manuals do not contain any relevant information regarding dismantling and recycling aspects. The equipment manuals are to be prepared with useful information regarding recyclable parts, their orientation and handling of hazardous material content etc.,. Tips regarding pre-owned use are likely to be useful important data in fixing the market value of such products. Active participation of equipment manufacturers is solicited in this *design for ship recycling* activity. Suppliers of all products, equipment and materials have to comply with this proposal.

6.8.4 Knowledge Base on Recycling

Usually at end of life (even at various stages of ship lifecycle), the attending engineers and other authorities are faced with a serious problem of lack of data for undertaking tasks. This can happen in major repair, refit and conversion. Regarding the end of life recycling the situation becomes worst, with hardly any traces of information. *Design for ship recycling* philosophy primarily focuses the theme of sustainable development in maritime industrial sector and addresses the implementation steps by suggesting effective use of comprehensive knowledgebase of ship recycling. The implementation methodology involves generation, compilation, classification, coding and retrieval of the knowledgebase Sivaprasad et al [2010]. Retrieval of the knowledgebase is very critical as it is required during partial or end of life dismantling which happens many years after commissioning of the vessel. In this context it is recommended that a comprehensive knowledge base focusing recycling phase of all ships should be prepared, updated and maintained onboard and also in some other strategic location like a specially designated IACS nodal centres or a centre for ship recycling of IMO. It is worthwhile to note that IMO has successfully intervened in this critical area and Green Passport has been made mandatory now. The proposed ship recycling knowledgebase repository development efforts as a part of *design for ship recycling* should cover areas other than the present requirements stipulated by IMO.

6.8.5 Effective Scantlings Onboard

Reduced thickness of various structural parts will minimize the structural weight and improves the pay load capacity. This also contributes to easier fabrication, assembly, dismantling and recycling. More effective and comprehensive structural analysis during design using Finite Element Method can reduce structural scantlings of various members. Use of high strength materials can add to this effect. Table 6.10 gives application of various materials used ship construction along with their recyclability value.

6.8.6 General Arrangement of Ships

During conventional ship design process general arrangements are made after finalizing the lines plan of the ship. Lines plan is generated mainly based on stability and powering requirements of the vessel. Structural design is done without considering the specific requirements of general arrangement. This approach results in limitations of space and access requirements in general arrangement. *Design for ship recycling* approach is just reverse of this, ie, finding out the layout requirements first and then finalizing other design options. Though this cannot be achieved fully, some trade-off is possible between these design attributes. Layout related issues that are to be considered in *design for ship recycling* are, access for maintenance and dismantling and accommodation space design

These spaces located in extreme forward and aft regions of ship’s hull will have access and ventilation problems due to the curved hull shape, limited head room and narrow walking space. These problems can be solved following *design for ship recycling* steps while developing general arrangement of ship as a part of the detail design.

Table.6.10.Application Areas and Recyclability of Materials

Material	**Physical Prop**	**Application area**	**Durability**	**Recyclability/ Disposability**
Aluminium	High strength/Weight ratio	Light duty	Highly durable	Excellent
GRP	High strength/Weight ratio	Light duty	Highly durable	Poor
High tensile steel	Average strength/Weight ratio	Heavy duty	average	Good
Marine Plywood	Below average	Light duty	Below average	Good

Layout of engine room, pump room, forecastle, deck, other store rooms in the forward part are to be made taking into consideration the dismantling requirements. These spaces are usually located in the narrow regions of hull and access and space requirements likely to cause inconvenience and these problems can be solved using *design for ship recycling* approach in initial stages of ship design.

6.8.7 Equipment and Outfit Items

Strict implementation of international standards will certainly improve the recyclability of ships and her components. New rules and regulations proposed by IACS should consider implementing standardization and modularity of equipment, components, hull materials etc.,.

6.9 Comments

Two major application of *design for ship recycling* have been dealt in detail in this chapter viz. recyclability analysis of ships and her components and allotment of Green Safety Index. Other applications of *design for ship recycling* in various lifecycle stages of ships are identified and presented in Section 6.7. These applications will serve as a set of best practices in ship recycling field.

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 SUMMARY

The present study deals with the development of Knowledge Based Expert System and the conceptual developments in ship recycling. The research efforts initiated with the review of the available literature and visit to recycling yards of Alang, Gujarat, India The lack of engineering concepts in ship dismantling activities at Alang was noticeable. Similar situations in the yards at Bangladesh have been reported in the literature. From this the definite need to have a knowledge based decision support system for identifying the best sequence of process in recycling and the necessity to develop conceptual design processing in recycling have been felt.

The expert system software, Ship Recycler Recommender have been developed for beach ship recycling activities and, is functional. The software is capable of giving *best practices* recommendations for recycling of Bulk Carriers and its use can be extended for any other ship types. A conceptual base for application of *design for ship recycling* taking into consideration the naval architectural aspects has been formulated Two applications of *design for ship recycling* viz, recyclability of ships and her products and allotment of Green Safety Index for ships have been presented as a part of implementation of the philosophy in actual practice.

7.2 CONCLUSIONS AND NOTICABLE CONTRIBUTIONS

- The state of art of ship recycling has been documented. The benefits and drawbacks are discussed and commented. Major elements of beach based ship recycling system have been identified and their interaction routes and lines have been described.

- The processes and practices in beach based ship recycling have been identified and steps in the processes have been developed based on systematic planning.

- The ship recycling industry heavily depends on the number and type of ships that will be ready for recycling. A preliminary attempt has been made to assess the various demand forecasting methods and their suitability for ship breaking demand forecast. The general input for any of the demand forecasting method are identified and presented. Comparing the suitability of the various methods for demand forecasting it has been concluded that the causal method is suitable for this purpose.

- Identification of information base of various branches of knowledge related to ship recycling has been carried out for the development of an expert system. Based on this, a general advice type expert system, *Ship Recycler Recommender* has been developed and is operational.

- The concept of the Green Passport has been modified to an Extended Green Passport and this will serve as a comprehensive base for the allotment of Green Safety Index.

- The novel concept of *Design for ship recycling* approach in shipbuilding has been proposed with proper emphasis on the naval architectural concepts of ship recycling.

7.3 RECOMMENDATIONS

Present study essentially has been based on the analysis of state of art of ship recycling at the yards as well the rules and regulations on this matter. The knowledgebase that has been mobilized using this research studies has resulted in giving the following recommendations to ship recycling industry. Of course there are a few among the *best practices* that have been identified in the study

a) Usage of Approved Cutting Plan

It is estimated that 5% of LDT is lost if the present day dismantling methods are used. The cutting and handling of the removed part are done in a haphazard way and that adds to the losses. Considering the price of steel from recycled ships, 5% loss is on the higher side. If a properly designed and well planned disassembly system is used, the loss can be reduced. One of the proposals in this regard is the use of approved **cutting plan**. Similar to unit assembly plan in ship building, a part removal plan based on the cutting of plates and sections is to be developed. This has to be made available in the form of drawings and documents. This plan has to be approved by an internal quality control personnel (production engineer) before the actual dismantling is carried out. The plan should focus various attributes of effective ship recycling such as safety, environment, engineering and economics. In-house standards on disassembly should be made mandatory for all ship recycling yards. In brief the

CUTTING PLAN has to be made a mandatory part of the recycling plan proposed by IMO.

b) Application of Safe Cutting Operations and Marshalling

Though relatively cost effective, flame cutting has inherent disadvantages. Potential problems with respect to fire and explosion and free fall of dismantled units can be avoided using **notch-discontinuity dismantling method**. This method also avoids contact of contaminated hull parts and materials with the permeable beach sand due to free fall. Designated areas with proper covering on beach can be set for marshalling the dismantled units and subsequent dismantling. Notch discontinuity dismantling methods has been recommended for primary cutting in lieu of flame cutting.

c) Product Model of Obsolete Ships

The product model of a ship among for recycling is its data model in "as –is" condition at the time of ready for recycling. This computer based production model has to be prepared from an extensive survey on hazardous materials and their disposition, weaker structural parts, tanks and other inaccessible locations, cutting plan information, making use of cutting edge information technology. The processes and materials have to be identified based on this product model. It is recommended to generate the product model and to use it as a pre-processor for input generations to the expert system like the one developed in the present study.

d) Knowledge Base Generation

Fundamentally ship recycling is a simpler task than ship building. However, the later is supported by various product information-base and the former is done in a haphazard way. Various changes and modifications might have been carried out in a ship throughout her life cycle. It is recommended to have the knowledge base consisting of history of the ship from keel laying to decommissioning and incorporating all changes and modification. This knowledge base has to be made available while the recycling and dismantling operations are carried out.

e) Implementation of Design for Ship Recycling

Design of each stage in the life cycle of a ship has to be arrived at keeping room for recycling of it at the end. This concept is precisely presented in the study as *design for ship recycling*. This will go hand in hand with knowledge base creation and generation of product model. This helps in easy evaluation of sustainability index (Green index) of the vessel and indirectly contributes to global sustainable development. It is recommended that ship designers and naval architects may follow the concept of *design for ship recycling*.

f) Implementation of Extended Green Passport [EGP]

Green Passport was a proposal from DNV and later implemented by IMO (IMO 962, 2004), which carried essential information regarding presence of hazardous components onboard a ship. Modifying this concept to a comprehensive base, an extended Green Passport has been proposed in the present study. The EGP includes various characteristics of all probable hazardous material present onboard and these characteristics have been provided in SRR software. It is recommended to go for EGP for recycling.

g) Recycling Information in Equipment Manuals

All equipment used onboard should have manuals clearly indicating the recycling information of the product. This can be added as a part of Extended Green Passport which will certainly make recycling and reuse more efficient and smooth. Pre-owned market can readily depend on this recycling content information for the further use of equipment. The other components such as deck covering, insulation, paints etc also should have readymade recycling manuals clearly indicating their life, recyclability, recycling methods, hazards, safe practices etc. This can also set a role model for other industries regarding recycling of equipment and materials installed for various applications. It is recommended to specify an equipment manual indicating recycling information so as to help preparing EGP based on that.

7.4 SCOPE OF FUTURE WORK

a) Development of ship recycling demand forecast software for various ship types
b) Development of layout of ship recycling yards based on disassembly concept and re engineering of shipbuilding activities.

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APPENDIX 1

DETAILS OF DISMANTLING OPERATIONS AT ALANG SHIP RECYCLING YARD, GUJRATH MARITIME BOARD, GUJARAT, INDIA

A 1.1 INTRODUCTION

The main ship recycling activities undertaken at Alang are beaching permission, preparation for dismantling, cutting, transporting and marshalling of the dismantled parts. These activities and some mandatory provisions are described in the following subheadings

A 1 2 BEACHING PERMISSION

Application for beaching permission along with relevant records and documents; should be submitted 2 days prior to the date beaching. However, Physical Delivery Certificate can be submitted before beaching.

Gujrath Maritime Board will accept the application for beaching on Saturday/ Sunday and holidays as an exceptional case only in the case of high tide time beaching falling on these days.

The beaching of Reefer Vessels, Fish Processing Vessels and Oil Tankers will be given only on an assurance from ship dismantlers that the full safety conditions will be observed to avoid any fire accidents. Beaching permissions will be given subject to removal of all the debris in the sea.

Only one vessel will be allowed to beach at a time in a plot. Second vessel will be allowed to beach if the total width of both the ship/vessel is equal to 5 meters less than the width of the plot. In smaller plots the second vessel can be beached behind the first vessel, if first vessel is 60 % dismantled.

Before giving beaching permission for Oil Tanker, LPG Carrier, Chemical Tanker, Gas Free Certificate has to be obtained from the Gujrath State Explosive Department

In the case of own powered vessels, Gas Free Certificate for fuel tank as well a slop/sludge tank is also necessary.

A 1.3 PREPARATIONS FOR DISMANTLING

Emptying of Oil Fuel Tanks

Man Entry Certificates and Hot Work Certificate have to be submitted from the explosive department, for Chemical Tankers, LPG Carriers, Oil Tankers. All kinds of petroleum oils/including fuel tank of the vessel/ship should be emptied and evacuated before starting of cutting operations.

Permission from Recycling Yard/ Port Authorities

No cutting should be started without taking written permission from the local port authority. Lightening of the ships shall be allowed in the case if the ship is beached away from the shore and port office will give the permission for the same.

Removal of Insulation and Covering Materials

In case of Reefer Vessels and Fish Processing Vessels, all insulations should be removed before starting main cutting. But permission will be given to remove the insulations and maximum precautions be taken for preventing fire and flames.

A 1.4 PREREQUISITES AND SAFETY MEASURES UNDERTAKEN DURING CUTTING OPERATIONS

A 1.4.1 Safety Measures for Eliminating Fire Risk

All thermal and mechanical cutting operation of engine room and fuel tanks are to be commenced after all oil is pumped and the hull surface is cleaned thoroughly cleaned with river sand . Wet gunny bags should be spread on the floor or the tanks before cutting. Minimum number of LPG and gas cylinders required for cutting should be stocked on the deck or cutting area. If oxygen contents or gas contents are more than prescribed limits, the tank should be ventilated fully with the help of blowers before starting the cutting operations. In case of fuel pipelines, gas cutting should not be done. Fuel pipelines shall be dismantled by cold work and proper water flushing should be done. Any cutting done after 6 pm should be quenched by pouring water.

A 1.4.2 Equipment and Manning

Cutting operations should be carried out under the supervision of technically qualified hands certified by the Gujrath Maritime Board Inspection Authority. Gas meter and oxygen meter should be in possession of the supervisor.

A 1.5 TRANSPORTATION

Cutting is done on the ship from the end facing the beach to the end facing the ocean. Large blocks are cut and allowed to fall down freely. Further removal is from flat lying block using gas cutting. The cutting operations continue till manual labourers or a small crane can handle a dismantled product to nearby location. The handling is done manually as well as using crude mechanical lifting procedures. No weight lifting calculation or lifting analysis is done prior to lifting. As weight is removed from the ship, the vessel is towed further inland by teams of men using winches and cutting and transportation progresses.

A 1.6 MARSHALLING

Dismantled metal is sorted by material type: steel, aluminum, copper, etc. Steel plates are often sold to re-rolling mills. Various machinery items are sorted and kept separately in a covered region. There is no identification or coding given to these items.

A 1.7 RECYCLING

An overview of recycling activities are listed below;

a) Products Sent for Recycling

75% of the metal recovered is ferrous, 8% is non-ferrous and 12% is pipes and cables. About 5% of the metal is lost during the cutting operation. Numerous small retailers have established businesses around the ship breaking sites. The small retailers specialize in handling specific items, such as, bathroom fixtures, furniture, pipes, plates, generators or engines. Typically, the items removed from the ship are bought by the retailers the same day. About 90% of the material obtained in ship dismantling is steel which is sold to rolling steel mills. There are about 250 steel rolling mills in area around Alang using steel scrap procured from the yard.

Onboard CO_2 fire extinguisher cylinders are discharged at the ship before undertaking gas cutting of the ship. After discharging, empty cylinders are brought to the plot and cut so that these are not recycled. Cut pieces of the cylinders are sold to rolling steel mills.

b) Recycling Supervision

- Each plot should have a well-qualified supervisor, graduate in chemistry or industrial safety. The supervisor will be totally in-charge of cutting operations.
- Senior supervisor will look after other administrative and other safety measures.
- Minimum proper training will be provided to labourers in cutting operations in their mother tongue.
- The above plots are thoroughly surveyed with a sensitive radiation survey meter to detect the presence of any radiation source

c) Ship Dismantling Plot: Layout and Practices

- LPG and Oxygen Cylinder should be stored in separate safe areas.
- The cylinders should be stored in a separate safe area.
- No petroleum products of combustible material should be stored in vicinity of the LPG storage area. No cutting should take place in the vicinity.
- No carbon dioxide cylinders should be used for storing oxygen.
- The disposal of carbon dioxide cylinders from the ships will be monitored by GMB in the interest of Safety for use of these cylinders outside ship breaking yard.
- Underground sump with sufficient capacity will be installed for storing water in the plot, along with a fire hydrant point and water pump on sharing basis between two plots.
- Minimum fire fighting equipments extinguisher, fighting suit (aluminum fire foil), liquid foam care, mask foam sprayer, oxygen mask, fire reel with hose complete attachments has to be compulsorily maintained in the yard.
- Sufficient space may always be kept for safe passage of fire fighting units at any given point of time
- All the equipments on plot like crane, winch, chain, generator set, rope etc., will be maintained as per Factory Act. Periodical check will be done by the Supervisor of the plot.
- All workers should be provided with helmet and boot. Gas cutters and labourers should be provided with welding goggles.

APPENDIX 2

SHIP RECYCLER RECOMMEDER - USER MANUAL

A 2.1 DESCRIPTION OF INPUT

Provisions are made in the program such that the input details can be provided by the user as well as the administrator. Input related to the user will be for the creation of the report where as that related to administrator will be the provisions to improve or alter the user interface. The schematic of these two input phases are shown in fig 5.31 and 5.32

A 2.2 DESCRIPTION OF OUTPUT

The user output will contain 'Best Practices' for recycling of that particular ship (for which input has been given). The "Best Practices" have been prepared for the ship recycling processes which has already been described in 5.7.2.

A 2.3 DESCRIPTION OF THE USER MANUAL

The User Manual provides step by step information regarding use of SRR details regarding generation by the User group and description on the edit/delete/add functions by the Administrator group are provided in various subheadings

A 2.4 GENERATING REPORTS BY PROVIDING DETAILS OF THE SHIP TO BE DISMANTLED.

In order to generate reports for ship dismantling, one has to register in the site and log in with the user name and password.

Click on the button 'Reports' after selecting any one of the 'Vessel Type' from the left tree menu. The user will then be prompted with three Options as follows;

- New report generation.
- List existing reports for a type ship
- Continue with the last session of report generation.

Selecting the first one and clicking "OK" will provide an interface to generate a new report from scratch by providing answers to a set of predefined QUESTIONS. The values entered by the user will be saved and can continue with it next time, if he is opting "Cancel" during the session for the same vessel type.

Selecting the second option allows the user to see the reports already generated and also allows him to generate new reports by using any one of the previously generated report details as template. This option will be available only if there are reports generated earlier for the type of vessel selected from the left tree menu.

The third option will be enabled only if the user is having an incomplete report generation session. Selecting this will reload the values previously entered by the user during his last session.

A 2.5 SITE ADMINISTRATION

Site administration is allowed only to the user 'admin'.Only the site Administrator of the site can make changes to the existing QUESTIONS in the default questionnaire or add new QUESTIONS to it with this login. Fig. A2.1 shows the shows interface screen for this provision.

Log in to the site as 'admin' with the password. Click on 'Reports' button and the interface provided will have an additional button "Add New" at the right upper corner. Click on this button to add a new question or edit the existing QUESTIONS in the default QUESTINNAIRE.

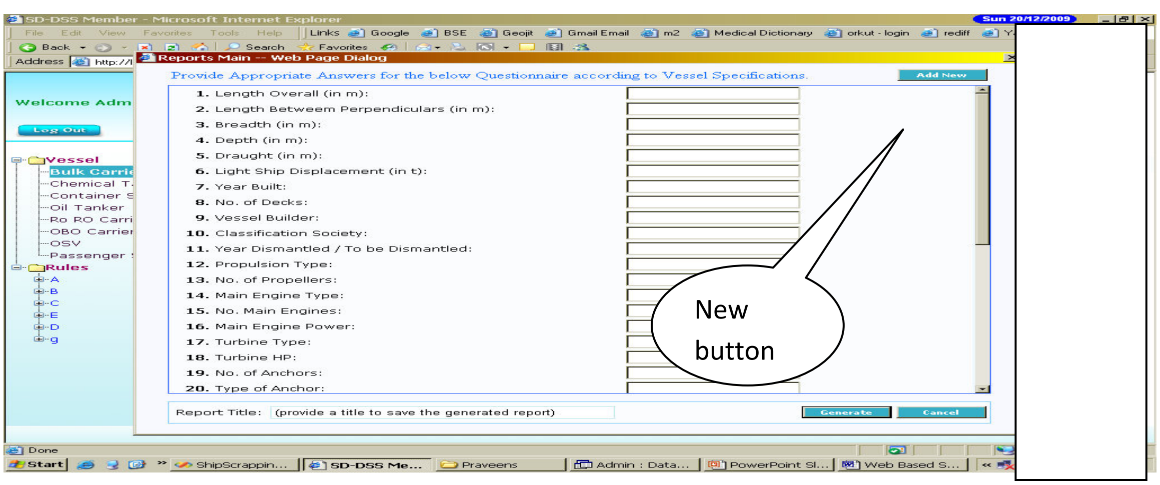

Fig. A2.1 Adding New QUESTIONS by the Administrator

By clicking this button, the interface will be shifted as below with provision to enter details for the new QUESTION. The text area with label "QUESTION" is for entering the body part of the QUESTION. The drop down labeled "Input Data Type:" is used to define the type of input the user is supposed to enter, for example - numeric values, Yes/No or multiple-choice selection during runtime. Fig. A2.2 shows the procedure for selection of input type of new QUESTIONS added.

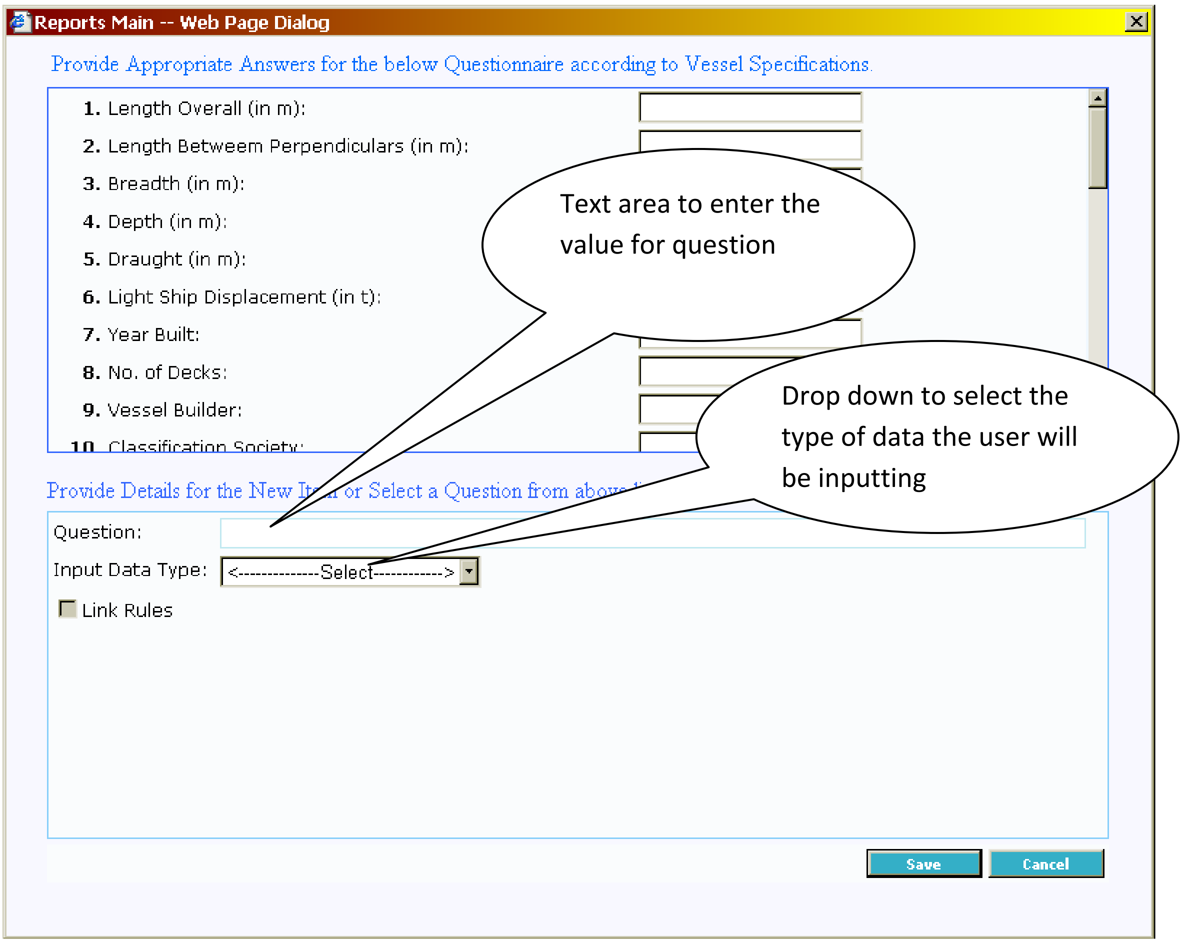

Fig. A2.2 Selection of Input Type of New QUESTION Added

Click on this drop down to select the required data type as below.

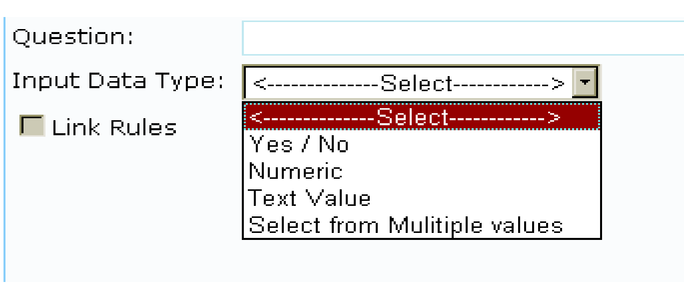

Fig A2.3 Drop Down Window for Input Type of Newly Added QUESTION

Options are

- **a.** **Yes/No**
- **b.** **Numeric**
- **c.** **Text Values**
- **d.** **Select from Multiple Values**

a. **Yes/No**: - This option is used when the answer to the QUESTION is “Yes”. By selecting this, at runtime, the user will be prompted with a QUESTION with a check box to be checked if the answer to the question is “Yes” as below.

Fig A 2.4 Format of Yes/No Type of Value Input in New QUESTION Addition

b. **Numeric**: - This option is used to restrict the user to input only numeric values ie. Numbers only. By selecting this, at runtime, the user can enter only numbers in the value field. This option, if selected, will provide with four additional sub options as shown below to refine the value entered by giving additional conditional criteria.

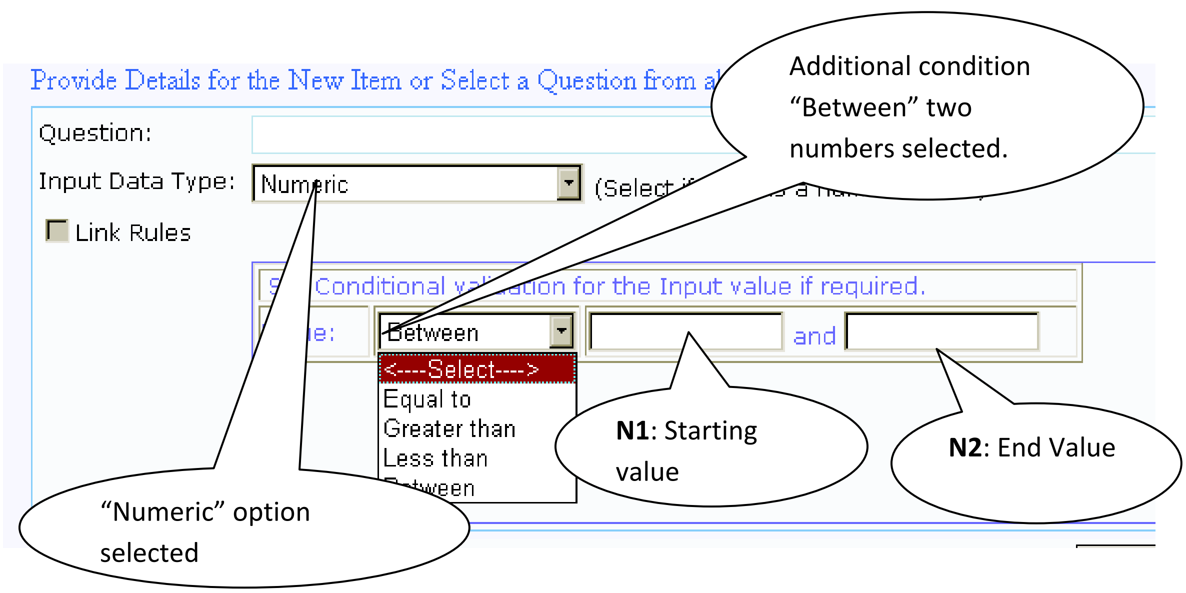

Fig A2.5 Format of Numeric Input Value in New QUESTION Addition

Select “Equal to” in the sub options drop down if the rule linked to this QUESTION to be included while generating the report only when the user inputs a specific numeric value. Specify the number in the first text area **N1**. Select “Greater Than” if the linked RULES to be included in the report only if the user inputs a value greater than a specified number. Give this minimum value in the text area **N1**.

Select “Less Than, to restrict the linked RULES from including the generated report if the value entered by the user is greater than a specific number. Provide this maximum value in the **N1** text area.

“Between” is selected if the linked RULE to be displayed only if the value entered by the user is in between two specified values. Provide the lower limit in **N1** and upper limit in **N2** text areas.

c. **Text Value: -** Selecting this allows the user to enter nonnumeric text values. This option also provides two sub options, which can be used to restrict user input as below.

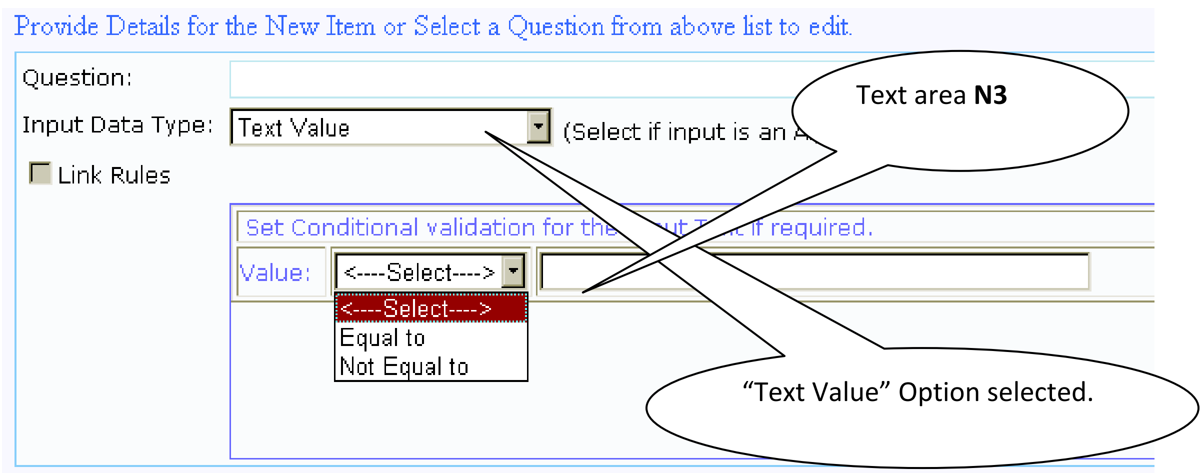

Fig A2.6 Format of Text Value Input Value in New QUESTION Addition

Select “Equal to” in the sub options if you want the linked RULES to this question to be included in the report only if the user enters a specific text at runtime.

Select “Not Equal to” for including linked RULES in report if the user is entering some other value other than a specific value.

In both these sub options, the conditional value is to be entered in text area **N3**.

d. **Select From Multiple values**: - This is selected when we need to give the user option to select from multiple choice items at runtime.

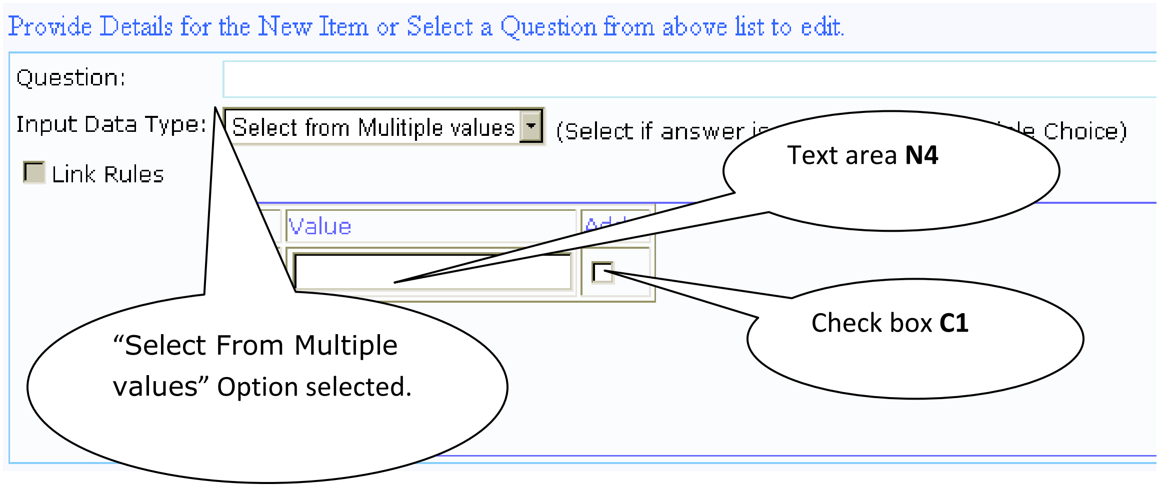

Fig A2.7 Format of Multiple Input Value in New QUESTION Addition

Enter the multiple choice item elements in the text area **N4**. After entering the first value and checking the check box **C1** will provide the next text area **N5** as below for the next item.

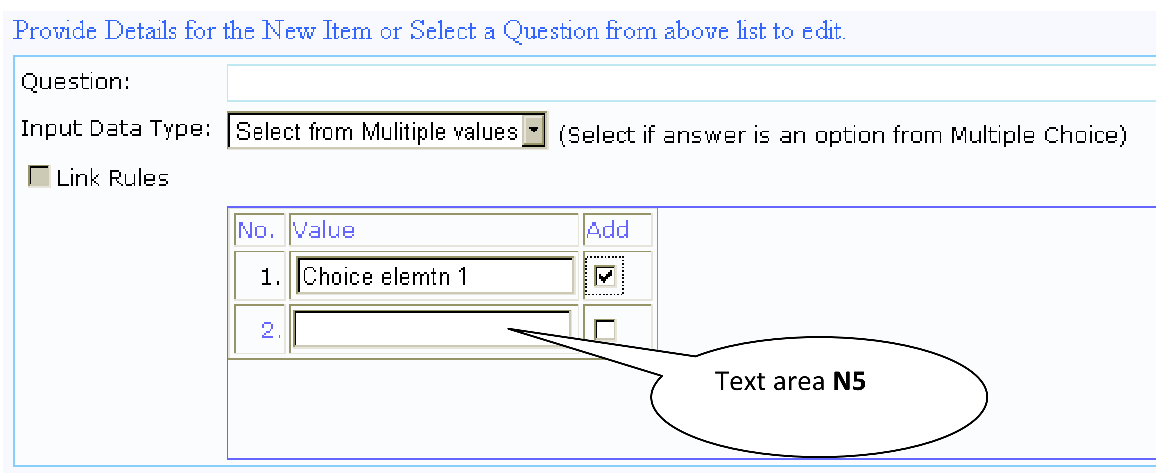

Fig A2.8 Format of 2nd Numeric Input Value in New QUESTION Addition

This process can be repeated to enter multiple elements. While editing the existing QUESTIONS, you can add new items to the choice elements by unchecking and checking the last item's check box.

Save the newly defined QUESTION by clicking the "Save" button at the right bottom corner.

A 2.6 Linking of RULES to QUESTIONS

The RULES can be linked only to the existing QUESTIONS. After creating a new QUESTION as described above and after saving it, click "Add New" button again and locate the new QUESTION with scroll bar and select it by clicking on it to select it. Then it will be highlighted and the details will be displayed in the respective controls in the bottom panel as shown fig. A 2.9

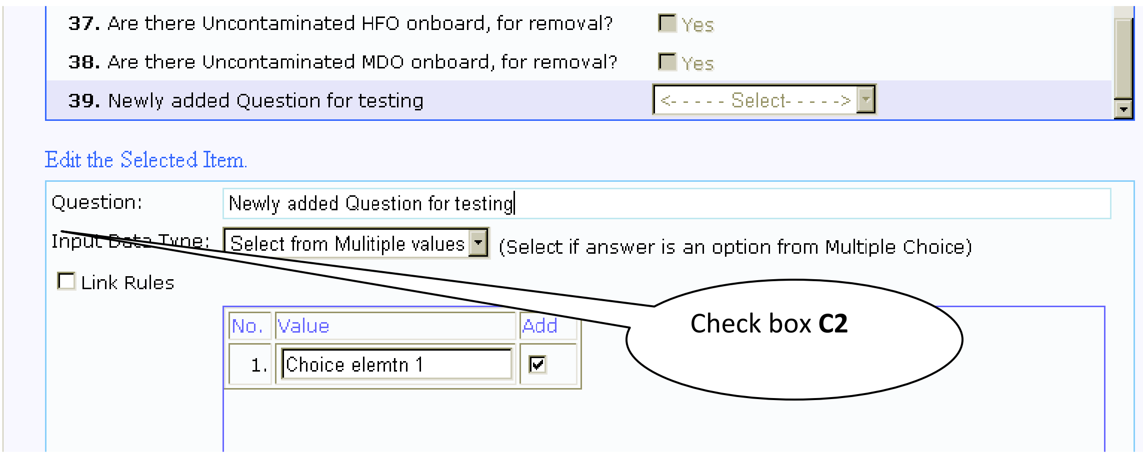

Fig A2.9 Select Links to RULES for a New QUESTION

Then checking the check box **C2** will provide an interface showing all the rules with independent check boxes as shown below.

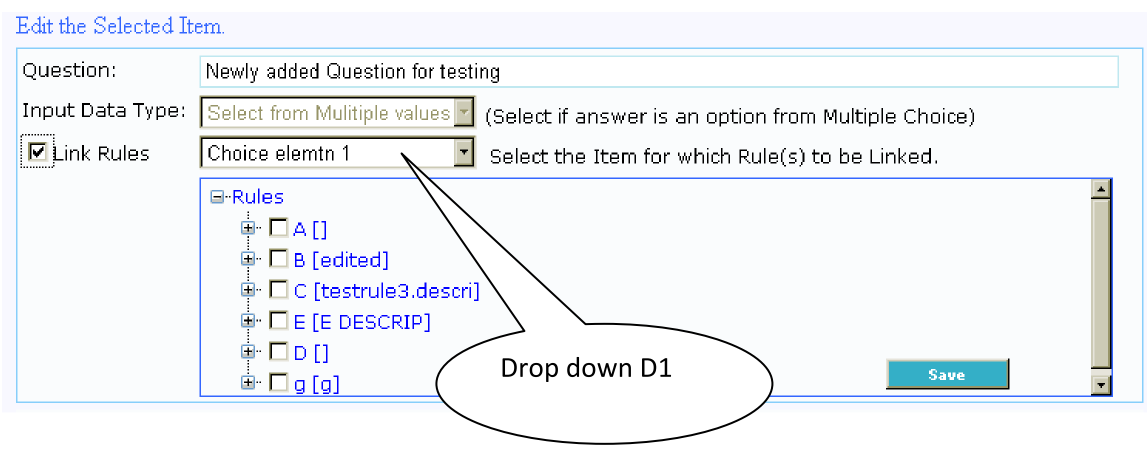

Fig A2.10 Linking RULES to Multiple Choices of a New QUESTION

Select the RULES to be linked with the QUESTION by checking the check box associated with each rule. You can expand each node by clicking the "+" sign and select RULES under different nodes. Only the checked RULES will be linked with the question excluding the unchecked parent or child nodes. For "Select From Multiple Values", you can link RULES to each of the choice item by selecting each of the choice item from the drop down **D1**. Please remember to save each item links prior to moving to next item with the "Save" button.

Linking of RULES is allowed for the saved items only and will not be allowed while editing is active for any of the other values.

APPENDIX-3

PART OF SHIP RECYCLING REPORT GENERATED USING SHIP RECYCLER RECOMMENDER (SRR)

250m Bulk Carrier

Length Overall (in m): 260

Length Between Perpendiculars (in m): 250

Breadth (in m): 32

Depth (in m): 22

Draught (in m): 16

Light Ship Displacement (in t): 12000

Year Built: 1985

No. of Decks: 4

Vessel Builder: Cochin Shipbuilders

Classification Society: Lloyds Register of Shipping

Year Dismantled / To be Dismantled: 2010

Propulsion Type: Conventional

No. of Propellers: One or more

Main Engine Type: SULZER

No. of Main Engines: 2
Total Main Engine Power (kW): 12000

Turbine Type: N/A

Turbine N/A:

No. of Anchors: One or more

Type of Anchor: Stockless Bower

Total Length of Anchor Chain (m): 1400

No. of Cargo Oil Tanks: 5

Total Cargo Oil Capacity (m3): 60000

No. of Fuel Oil Tanks: 6

Total Fuel Oil Capacity (m3): 2000

Dismantling Site: Alang

Vessel Site: Europe

Kind of Transportation to Recycling Yard: Self-Propulsion

Select Positioning Method for Recycling: Beaching

ASBESTOS REMOVAL

The facility must take all steps to ensure that workers are not exposed to airborne asbestos in excess of either of the following limits, collectively referred to as permissible exposure limits (PELs)

0.1 fibers per cubic centimeter (f/cc) of air averaged over an eight hour work shift. This PEL is called the time-weighted average (TWA) limit

1.0 f/cc of air averaged over a sampling period of 30 minutes. This PEL is called the excursion limit

The facility must train employees who are likely to be exposed to asbestos removal work during ship scrapping

The facility should ensure workers involved in asbestos removal and disposal are using approved respirators. Respirators are be provided free of charge by the facility

Protective clothing, such as coveralls, head coverings, gloves and foot covering, during asbestos removal work must be used.

Wherever the possibility of eye irritation exists, face shields, vented goggles, or other protective equipment must be provided and used.

When removing Asbestos Containing Material (ACM) the facility is required to control visible emissions of asbestos to the outside air

The primary method used to control asbestos emissions is to â€œadequately wetâ€� ACM with a liquid or wetting agent prior to, during and after removal activities.

To adequately wet ACM means to sufficiently mix or penetrate the material with liquid to prevent the release of asbestos particulates. If visible emissions are seen coming from ACM , then that material has not been adequately wetted.

The absence of visible emissions does not necessarily mean that the ACM is adequately wet

Wetting agents may be applied with garden sprayers or hoses

The facility must place warning labels on all bags, containers, or wrapping materials containing Asbestos

These labels must be printed in letters of sufficient size and contrast so that they are easily visible and readable.

The facility must label those bags of Asbestos Containing Waste Material destined to be transported offsite with the name of the facility (ie. The waste generator) and the location of the facility.

For Ship Recycling Material Data Sheet please see attachment.

Click here to View Attachment

Propeller is to be removed Anchor is to be removed Anchor chain is to be released from the anchor and dismantled from bitter end connection on ship.

OIL SPILLAGE

Some of the most important activities during ship breaking are:

Unloading fuel oil from ship
Unloading engine oil from ship

Pumping out of bilge water
Pumping out of oily water after rain
During the beaching operation
Cutting hull for removal of engine
Cutting of double bottom hull
Removal of oil sludge from the bottom of the hull
Loading in oil tankers
Oil separation from oily waste water

Some techniques to counter spillages:

- Mechanical containment or recovery is the primary line of defense against oil spills, Containment and recovery equipment includes booms, barriers and skimmers, as well as natural and synthetic absorbent materials
- Mechanical containment is used to capture and store the spilled oil until it can be disposed of properly
- Chemical and biological methods can be used along with mechanical means for containing and cleaning up oil spills
- Dispersants and gelling agents are useful in helping to keep oil from reaching shorelines and other sensitive habitats
- Biological agents have the potential to assist recovery in sensitive areas such as shorelines, marshes, and wetlands
- Natural processes such as evaporation , oxidation , and biodegradation can start the cleanup process, but are generally too slow to provide adequate environmental recovery
- More physical methods, such as wiping with absorbent materials, pressure washing , and raking and bulldozing, can be used to assist the natural processes
- Scare oil tactics are used to protect birds and animals by keeping them away from oil spill areas. Devices such as propane scare-cans , floating dummies and helium-filled balloons are often used, particularly to keep away birds.

There are a number of methods available for controlling oil spills and recovering oil at the same time minimizing their impacts on human health and the environment

The key to taking suitable action when a spill occurs is careful selection and proper use of equipment and materials according to the type of oil and the conditions at the spill site.

Causes of oil spillage:
Leakage of hose pipes
Over flow of tanker
Human error Leakages during beaching and cutting operation
Operational failure

APPENDIX-3

Table A.3.1 EXTENDED GREEN PASSPORT (PART OF SRR -SHIP RECYCLING REPORT)

EXTENDED GREEN PASSPORT		***ASBESTOS***
General Description		Any of a group of impure magnesium silicate minerals that occur as slender, strong, flexible fibers. Colors range from white to gray, green, brown. Resistant to fire and most solvents. Breathing of asbestos dust causes asbestosis and lung cancer. Used as a heat resistant material, in cement, furnace bricks, and in brake
Section 1:		**Chemical Product Identiication**
Product Name	:	Asbestos
Common synonyms	:	Chrysotile, amosite, crocidolite, actinolite, anthophyllite
Chemical Name	:	Not Applicable
Chemical Formula	:	Not Applicable
Formula		Asbestos consist of mixed oxides of aluminium, iron, magnesium and silicon
Molecular Formula	:	[Mg6(Si4O10)(OH)8], chrysotile
Alternate names for this chemical, including trade names, synonyms, and foreign names		4T04,7N05,7R-F9,7RF10, ACTINOLITE, ACTINOLITE ASBESTOS, AMOSITE (CUMMINGTONITE-GRUNERITE), ANTHOPHYLLITE, ANTHOPHYLLITE ASBESTOS,ASBESTOS (FRIABLE), ASBESTOS FIBER, AT 7-1, BK 6-20, BP 3-50, BP 5-65, CALIDRIA HPP, CALIDRIA R-G 244, CAREY 4T, CHLOROBESTOS 25, CHRYSOTILE, CROCIDOLITE (RIEBECKITE) ,FAPM 410-120 ,FERODO C3C ,FIBERS, MINERAL, ASBESTOS ,HPO (MINERAL) ,K 6-20 ,LITAFLEX ,M 3-60 ,M 4-5 ,M 5-60 ,M 6-40 ,MOUNTAIN CORK ,MOUNTAIN LEATHER ,MOUNTAIN WOOD ,MTM ,P 5-50 ,PRZH 2-30 ,SEPIOLEX 3 ,SEPIOLEX 5 ,SM 1 (MINERAL) ,SM 2 (MINERAL) ,T 135 ,TREMOLITE ,TREMOLITE ASBESTOS ,
Section 2:		**Composition & Information on Ingradients**
Composition:	:	
Section 3:		**Hazards Identification**
Potential Acute Health Effects:	:	Very hazardous in case of ingestion, of inhalation. Hazardous in case of skin contact (irritant, permeator), of eye contact (irritant).
Potential Chronic Health Effects:	:	Non-irritant for skin. CARCINOGENIC EFFECTS: Classified A1 (Confirmed for human.) by ACGIH, 1 (Proven for human.) by IARC, 1 (Known.) by NTP, + (PROVEN) by OSHA [Asbestos]. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to lungs, upper respiratory tract. ``
Principal hazards		*** Asbestos is a known human carcinogen when inhaled. The different varieties pose different levels of hazard, but all are harmful. *** Asbestos acts as a severe eye irritant.
Health Hazard		Exposure Routes: inhalation, ingestion, skin and/or eye contact
Symptoms		Asbestosis (chronic exposure): dyspnea (breathing difficulty), interstitial fibrosis, restricted pulmonary function, finger clubbing; irritation eyes; [potential occupational carcinogen]
Target Organs		respiratory system, eyes (NIOSH, 2003)
Section 4:		**First Aid Measures**
Eye Contact	:	Check for and remove any contact lenses. Do not use an eye ointment. Seek medical attention.
Eye		If this chemical contacts the eyes, immediately wash the eyes with large amounts of water, occasionally lifting the lower and upper lids. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.
Skin Contact	:	After contact with skin, wash immediately with plenty of water. Gently and thoroughly wash the contaminated skin with running water and non-abrasive soap. Be particularly careful to clean folds, crevices, creases and groin. Cover the irritated skin with an emollient. If irritation persists, seek medical attention.

TABLE A.3.1 CONTD..

Serious Skin Contact :	Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek medical attention.
Inhalation :	Allow the victim to rest in a well ventilated area. Seek immediate medical attention.
Serious Inhalation :	Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention.
Breathing	If a person breathes large amounts of this chemical, move the exposed person to fresh air at once. Other measures are usually unnecessary. (NIOSH, 2003)
Ingestion :	Do not induce vomiting. Loosen tight clothing such as a collar, tie, belt or waistband. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek immediate medical attention.
Serious Ingestion	Not available.
Emergency	Eye contact: Immediately flush the eye with water. If irritation persists, call for medical help. Skin contact: Wash off with soap and water. If inhaled: Call for medical help.
Section 5:	**Fire & Explosion Data**
Fire Hazards in Presence of Various Substances	Not applicable.
Explosion Hazards in Presence of Various Substances	Risks of explosion of the product in presence of mechanical impact: Not available. Risks of explosion of the product in presence of static discharge: Not available.
Fire Fighting Media and Instructions	Not applicable
Fire Fighting	Extinguish fire using agent suitable for type of surrounding fire. (Material itself does not burn or burns with difficulty.) Keep run-off water out of sewers and water sources.
Special Remarks on Fire Hazards	~~Not available~~
Special Remarks on Explosion Hazards	Not available
Fire Hazard	Some may burn but none ignite readily. Containers may explode when heated. Some may be transported hot.
Section 6:	**Accidental Release Measures**
Small Spill	Use appropriate tools to put the spilled solid in a convenient waste disposal container
Large Spill	Use a shovel to put the material into a convenient waste disposal container. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.
Non-fire response	Keep material out of water sources and sewers. Land spill: Cover solids with a plastic sheet to prevent dissolving in rain or fire fighting water. Dike surface flow using soil, sand bags, foamed polyurethane, or foamed concrete. Water spill: Use natural barriers or oil spill control booms to limit spill travel. (AAR, 2003)
Section 7	**Handling and Storage**
Precautions	Keep locked up Do not breathe dust. Wear suitable protective clothing In case of insufficient ventilation, wear suitable respiratory equipment If you feel unwell, seek medical attention and show the label when possible. Avoid contact with skin and eyes
Storage	Carcinogenic, teratogenic or mutagenic materials should be stored in a separate locked safety storage cabinet or room.
Safe handling	There is nowadays almost never a need for asbestos in the laboratory; good alternatives exist for all the applications to which asbestos used to be put. If it is present at all, asbestos will probably be in the form of asbestos cement, used perhaps as an oven lining. It is essential that asbestos is not cut, drilled or machined, since these actions release fibres into the air which are then readily inhaled.

TABLE A.3.1 CONTD..

Section 8	**Exposure Controls/Personal Protection**
Engineering Controls	Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.
Personal Protection	Splash goggles. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.
Personal Protection in Case of a Large Spill	Splash goggles. Full suit. Dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.
Protective equipment	Protective equipment should not be necessary, since you should not be in contact with asbestos!
Protective Clothing	Skin: Wear appropriate personal protective clothing to prevent skin contact. Eyes: Wear appropriate eye protection to prevent eye contact. Wash skin: The worker should wash daily at the end of each work shift. Remove: No recommendation is made specifying the need for removing clothing that becomes wet or contaminated. Change: Workers whose clothing may have become contaminated should change into uncontaminated clothing before leaving the work premise. (NIOSH, 2003)
Section 9	**Physical and Chemical Properties**
Physical state and appearance	Solid.
pH (1% soln/water)	Not applicable.
Boiling Point	Decomposes (NIOSH, 2003)
Melting Point	Melting Point: 1112.0 ° F (Decomposes) (NIOSH, 2003)
Specific Gravity	Weighted average: 2.62 (Water = 1), varies, depending upon form
Vapor Pressure	Not applicable.
Vapor Pressure	0.0 mm Hg (approx) (NIOSH, 2003)
Water/Oil Dist. Coeff.	The product is insoluble in water and oil.
Dispersion Properties	Is not dispersed in cold water, hot water.
Solubility	Insoluble in cold water, hot water, methanol, diethyl ether, n-octanol.
Form	fibrous solid which may be white, grey, brown or blueish
Stability	Stable
Molecular Weight	Varies (NIOSH, 2003)
AEGL	data unavailable
ERPG	data unavailable
TEEL-1	0.075 mg/m3
TEEL-2	0.5 mg/m3
TEEL-3	2.5 mg/m3 (SCAPA, 2008)
IDLH	A potential human carcinogen. (NIOSH, 2003)
Section 10	**Stability and Reactivity Data**
Stability	The product is stable.
Corrosivity: Non-corrosive in presence of glass.	Non-corrosive in presence of glass.
Polymerization	No.
Reactivity Profile	ASBESTOS minerals are generally unreactive.
Section 11	**Toxicological Information**
Routes of Entry	Dermal contact. Eye contact. Inhalation. Ingestion.
Toxicity to Animals	Not available

TABLE A.3.1 CONTD..

Chronic Effects on Humans	CARCINOGENIC EFFECTS: Classified A1 (Confirmed for human.) by ACGIH, 1 (Proven for human.) by IARC, 1 (Known.) by NTP, + (PROVEN) by OSHA [Asbestos]. The substance is toxic to lungs, upper respiratory tract.
Other Toxic Effects on Humans	Very hazardous in case of ingestion, of inhalation. Hazardous in case of skin contact (irritant, permeator).
Section 12	**Ecological Information**
BOD5 and COD	Not available
Products of Biodegradation	Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation	The products of degradation are as toxic as the original product.
Section 13	**Disposal Considerations**
Disposal	Removal of asbestos must be handled by specialist contractors. If you discover asbestos in the laboratory, leave it undisturbed and contact a suitable waste disposal company qualified to deal with asbestos.
Section 14	**Transport Information**
DOT Classification Identification:	CLASS 9: Miscellaneous hazardous material. Asbestos (Asbestos) : NA2212 PG: III
Section 15	**Other Regulatory Information**
Other Regulations	OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).
Other Classifications	WHMIS (Canada): CLASS D-2A: Material causing other toxic effects (VERY TOXIC).
DSCL (EEC)	R36/38- Irritating to eyes and skin. R45- May cause cancer.
HMIS (U.S.A.):	Health Hazard: 2 Fire Hazard: 0 Reactivity: 0 Personal Protection: E
National Fire Protection Association (U.S.A.):	Health: 2 Flammability: 0 Reactivity: 0 Specific hazard:
Protective Equipment:	Gloves. Lab coat. Dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate. Splash goggles.
UN/NA Number	2212
CAS Number	1332-21-4
CHRIS Code	none
CAA RMP	Not a regulated chemical.
CERCLA	Regulated chemical with a Reportable Quantity of 1 pounds.
EHS (EPCRA 302)	Not a regulated chemical.
TRI (EPCRA 313)	Regulated chemical.
RCRA	Chemical Code: none

APPENDIX-4

Table A4.1. Schedule of Estimation of Ship Recycling Activities

Table A4.1 Schedule of Work Content Estimation of ship Recycling Activities

No.	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
B.1.1	Decommissioning & sale of ship			
B.1.2	Transportation Ship to the shipyard and keep afloat in shallow water	Towage preparation: Manhours for a bulk carrier or any other vessel		
		Tugs: Rate per tug (for different bollard pull)		
		Towage survey: Approval Fee of authority conducting towage survey		
		Sailing a ship by own propulsion: Rate per nautical mile of voyage		
B.1.3	Gas Free the compartments/ spaces for entry purpose	Open a compartment: Manhours to unbolt and open a manhole cover		
		Ventilation: Manhours to provide ventilation per tank		
		Safe entry: Fee of certifying agency per compartment or tank		
B.1.4	Conduct an inventory survey			
B.1.4.1	Identify, quantify and locate the types of hazardous materials such as fuels, oils, asbestos, PCBs & hazardous wastes onboard			
B.1.4.2	Prepare inventory list of hazardous wastes and other wastes.			
B.1.4.3	Conduct preliminary sampling of media, starting in the compartment that will be cut first			
B.1.5	Dismantle small motors	Disconnect electrical connection from motor: Manhours per motor		
		Lifting or transferring motor to shore (Rate per kW of motor)		

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd.				
B.1.6	Dismantle pumps	Removal of pump: Manhours to unbolt and remove pump+motor from its foundation (for different capacity ranges or motor kilowatts)		
		Diconnect pipe lines from pump: Manhours per pump		
		Diconnect electrical connection to pump motor: Manhours per kW of motor		
		Disconnect motor from pump: Manhours per pump		
B.1.7	Dismantle navigation equipment	Disconnect electrical connection from navigational equipment & remove from foundation, if any: Manhours per navigational equipment		
B.1.8	Dismantle (LSA) Life saving appliances			
B.1.8.1	Dismantle Lifeboats	Unbolt & remove lifeboat from foundation: Manhours per lifeboat		
		Lift lifeboat ashore: Manhours per tonnes or m3 of lifting		
B.1.8.2	Dismantle Lifeboat davits	Unbolt & remove lifeboat from foundation: Manhours per lifeboat		
		Lift lifeboat ashore: Manhours per tonnes or m3 of lifting		
B.1.8.3	Dismantle Rescue boats	Same as lifeboat		
B.1.8.4	Dismantle Rescue boat davits	Same as lifeboat davit		
B.1.8.5	Dismantle Life rafts	Unbolt & remove lifeboat from foundation: Manhours per liferaft (for different capacities)		
		Lift lifeboat ashore: Manhours per tonnes or m3 of lifting		
B.1.8.6	Dismantle other buoyant apparatus, if any			
B.1.8.7	Dismantle Lifebuoys	Unbolt & remove life buoys from ship: Manhours per lifeboat		

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.1.8.8	Dismantle Life jackets			
B.1.8.9	Dismantle LSAs other than those listed above			
B.1.9	Dismantle Furniture	Remove furniture: Manhours per bunk/chairs/table/settee/sofa etc		
B.1.10	Dismantle electrical cabling			
B.1.10.1	Dismantle end connections of cables	Disconnect cables from end connections: Manhours per connection		
		Disconnect cables from cable trays: Manhours per meter of tray or cable		
B.1.10.2	Dismantle insulation on cables, if any	Remove insulation and covering for insulation: Manhours per meter of tray or cable		
		Cut and remove cable trays: Manhours per meter of cable tray		
B.1.11	Remove uncontaminated oil-products			
B.1.11.1	Remove uncontaminated Heavy Fuel Oil	Pumping out HFO: Manhours per m3		
		Rate to pump 1m3 or 1 tonne of HFO from ship to shore		
B.1.11.2	Remove uncontaminated Marine Diesel Oil	Pumping out MDO: Manhours per m3		
		Rate to pump 1m3 or 1 tonne of MDO from ship to shore		
B.1.11.3	Remove uncontaminated High Speed Diesel	Pumping out HFO: Manhours per m3		
		Rate to pump 1m3 or 1 tonne of HSD from ship to shore		

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.1.11.4	Remove uncontaminated Lub Oil	Pumping out HFO: Manhours per m3		
		Rate to pump 1m3 or 1 tonne of HSD from ship to shore		
B.1.11.5	Remove uncontaminated Hydraulic Oil	Pumping out Hydraulic Oil: Manhours per m3		
		Rate to pump 1m3 or 1 tonne of Hydraulic Oil from ship to shore		
B.1.12	Remove onboard consumables	Manhours to transfer cold provisions from ship to shore		
		Manhours to transfer dry provisions from sip to shore		
B.1.13	Remove saleable (loose) equipments such as electronic equipment			
B.1.14	Washing of cargo tanks	Cargo Tank washing: Manhours per m3 of cargo tank(HFO) tank		
		Cargo Hold (bulk cargo) washing: Manhours per m3 of cargo hold		
B.2.1a	Beach the vessel by its own propulsion power at high tide	Beaching: Manhours per tonne displacement or LDT of ship		
B.2.1b	Tow the vessel to recycling yard			

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.2.2	Secure the vessel	Manhours for mooring of vessel in beach: Manhours per tonne displacement of vessel		
B.2.2.1	Provide safe access to all areas, compartments, tanks etc ensuring breathable a	Open up manholes of compartments: Manhours per manhole		
		Supply forced ventilation to each compartment: Manhours for supplying ventilation		
		Rate for ventilating per tank (considering expenses towards compressors etc)		
		Rate for giving lighting per tank (considering expenses towards generator rent, fuel for generator engines, lights with spark arrestors for oil tanks etc)		
B.2.3	Remove remaining fuel, if any left out after removal in stage B.1, from fuel oil tan	Wipe up and clean fuel oil tanks: Manhours per m3 of tank		
		Chemical cleaning of fuel oil tanks: Manhours per m3 of tank		
B.2.4	Remove Lub Oil, if any left out after removal in stage B.1, from Lub oil tanks.	Same as fuel oil		
B.2.5	Remove oil sludge & used/waste oil (& spent lubricants)	Same as fuel oil		
B.2.6	Remove oil sludge at bottom of fuel oil tanks, cargo hold of tankers and bilge	Same as fuel oil		
B.2.7	Remove combustible liquids and materials other than those listed above	Same as fuel oil		

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.2.8	Removal & treatment of bilge water	Pumping out bilge water: Manhours per m3		
		Rate to pump 1m3 or 1 tonne of bilge water from ship to shore		
		Rate for separating oil from water		
		Rate for disposal of dirty oil		
		Rate for storage of bilge water		
		Rate for disposal of dirty bilge water		
B.2.9	Removal & treatment of ballast water	Pumping out bilge water: Manhours per m3		
		Rate to pump 1m3 or 1 tonne of bilge water from ship to shore		
		Rate for storage of bilge water		
		Rate for disposal of dirty bilge water		
B.2.10	Washing of tanks, if not done in stage B.1.14			
B.2.10.1	Washing of cargo tanks			
B.2.10.2	Washing of bunker tanks			
B.2.10.3	Washing of fuel tanks			
B.2.10.4	Washing of bilge & ballast compartments			
B.2.10.5	Washing of sewage tanks			
B.2.10.6	Washing of tanks other than those listed above			
B.2.11	Proper containment & treatment of waste water & any used solvent from cleaning station			

TABLE - A.4.1 CONTD..

No.	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.2.12	Remove fire hazards other than listed above	Remove insulation (rock wool or mineral wool): Manhours per m2 of insulation		
B.2.13	Arrange safe conditions for hot work			
B.2.13.1	Cleaning/ venting	Cleaning for hotwork: Manhours per m2 of cleaning area or per m3 of compartment		
B.2.13.2	Removal of toxic or highly flammable paints from areas to be marked	Paint removal: Manhours per m of paint (narrow)		
B.2.13.3	Removal of toxic or highly flammable paints from areas to be cut	Paint removal: Manhours per m of paint (narrow)		
B.2.14	Certification for hot work permit	Rate by certifying agency for hotwork		
B.2.15	Recheck of tanks before start of cutting operation			
B.2.16	Dismantle stern aft of the propeller			
B.2.16.1	Divide stern into 2 parts along Centre line	Cutting: Manhours for cutting per meter length or per m2 area		
B.2.16.2	Drop down the stern into the sea	Fabricate and fit pad eyes: Manhour per pad eye (different SWLs)		
		Manhours to lower down or lift steel structural blocks: Rate per tonne weight		
B.2.16.3	Pull stern to shore at high tide using winches			
B.2.17	Removal of propeller			

TABLE - A.4.1 CONTD..

No.	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.2.18	Cut & dismantle side shell plate, except outer hull plates at the bottom to avoid wa	Rate per m3 or m2 of staging (both for hanging staging and tower staging)		
		Marking for cutting: Manhours per block or assembly		
		Cutting: Manhours for cutting per meter length or per m2 area		
		Lifting of steel panels/blocks: Manhours per tonnes of structure or per m2 of plate panels		
B.2.18.1	To gain access to engine room & adjacent areas	Rate per m3 or m2 of staging (both for hanging staging and tower staging)		
B.2.19	Dump the plates on the floor/mud and transfer to shore using winch			
B.2.20	Dismantle bulkhead structure			
B.2.21	Dismantle bow (collision bulkhead to forward) free from the rest of the hull			
B.2.21.1	Cut & dismantle the bow (collision bulkhead to forward) free from the rest of the hull (to gain access to components of value)			
B.2.21.2	Transfer bow ashore using winch			
B.2.22	Remove equipments/items, using skilled workers from the relevant trade of downstream industry			

TABLE - A.4.1 CONTD..

Code	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.2.22.1	Boilers	Disconnect pipe connections to boiler: Manhours per boiler (based on boiler capacity)		
		Unbolt from foundations: Manhours per boiler depending on boiler capacity)		
		Remove insulation on exhaust lines: Manhours per m2 of insulation or per meter length of exhasut pipe		
		Remove exhasut lines		
		Remove economizer and other related items: Manhours per boiler(based on boiler capacity)		
B.2.22.2	Separators			
B.2.22.3	Pumps			
B.2.22.4	Engine room equipments	Dosconnect and remove from foundation of Engine room equipments: Manhours per each type of equipment		
B.2.23	Transfer of items to shore			
B.2.23.1	Lifting through deck	Manhours for lifting per tonnes of item		
		Lifting using crane: per tonne		
B.2.23.1.1	Transfer items from their location onboard to top deck using deck lift.			
B.2.23.1.2	Transfer items ashore using winches			
B.2.23.2	Taking out through hull openings			
B.2.23.2.1	Dump or lower down items through hull openings.			
B.2.23.2.2	Make the items afloat using air filled oil barrels or by boats on high tide ashore.			

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.2.24	Break down of larger components of equipment, engines/generators & send for remelting			
B.2.24.1	Engine components	Dismantle engine driven pumps: Manhours per pump (based on motor kW or pump capacity)		
		Dismantle pipe connections: manhours per engine or per connection		
		Dismantle electrical connections: Manhours per connection or per engine (depending on engine kW)		
		Dismantle couplings to shaft: manhour per coupling		
		Dismantle flexible connections: manhour per connection		
B.2.24.2	Generator components			
B.2.25	Remove Anchor			
B.2.25.1	Lower down anchor using windlass, if there is power available from ship. Otherwise carry out the removal in the following steps	Rate for external electrical supply for winch motor		
B.2.25.2	Change weight of anchor to a crane	Hooking anchor to crane: Manhours per anchor		
B.2.25.3	Remove D shackle of chain from anchor shackle	Remove anchor shackle: Manhours per anchor		
B.2.25.4	Lower down anchor through hawse pipe	Lower down: Manhours per anchor for lowering		

TABLE - A.4.1 CONTD..

No.	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 Contd..				
B.2.26	Remove Chains	Remove anchor chain: Manhours per meter of anchor chain		
B.2.26.1	Release bitter end of chain	Release bitter end: Manhours per bitter end connection		
B.2.27	Remove Furniture			
B.2.28	Dismantle glass	Glass removal from windows: Manhours per m2 of glass		
B.2.29	Dismantle wood			
B.2.30	Dismantle fibrous insulation/ glass wool			
B.2.31	Dismantle pipes	Dismantle pipes: Manhours per meter of bolted flanged mild steel pipes		
		Dismantle pipes: Manhours per meter of welded mild steel pipes		
		Dismantle pipes: Manhours per meter of bolted flanged pipes of other material (Copper, Cu-Ni, stainless steel etc)		
		Dismantle pipes: Manhours per meter of welded pipes of other material (Copper, Cu-Ni, stainless steel etc)		
B.2.32	Dismantle ducts	Dismantle ducts: Manhours per m length of ducts (based on m2 of cross section area)		
B.2.33	Remove rock wool			
B.2.34	Remove thermocol	Removal: Manhours per square meter of removal		
B.2.35	Remove PVC & plastic wastes	Removal: Manhours per square meter of removal		
B.2.36	Remove fiber glass	Removal: Manhours per square meter of removal		
B.2.37	Remove linoleum	Removal: Manhours per square meter of removal		
B.2.38	Remove sunmica	Removal: Manhours per square meter of removal		

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 contd..				
B.2.39	Remove cementing material	Removal: Manhours per square meter of removal		
B.2.40	Remove ceramic tiles	Removal: Manhours per square meter of removal		
B.2.41	Dismantle construction with AC sheets	Removal: Manhours per square meter of removal		
B.2.42	Remove rags and sacks	Removal: Manhours per square meter area of removal		
B.2.43	Remove broken ceramic ware, glassware, paper, wood, all sorts of junk	Removal: Manhours per square meter of removal		
B.2.44	Human excrement	Manhours per m3 of sewage removal		
B.2.45	Remove concrete slabs used as waste	Removal: Manhours per square meter of removal		
B.2.46	Remove Gas Bottles			
B.2.47	Remove fire detectors	Removal: Manhours per fire detector		
B.2.48	Remove Waste Electrical and Electronic Equipment (WEEE)	Removal: Manhours per equipment (based on type of equipment)		
B.2.49	Remove Fluorescent lights	Removal: Manhours per light		
B.2.50	Dismantle Small Equipments	Dismantle: Manhours per equipment		
B.2.51	Remove rubber gaskets & isolation mountings. Remove waste rubber sheets, gaskets & liners	Remove gasket: Manhours per gasket		
B.2.52	Washing with water at 80˚ C for oil, sludge & insulation removal	Washing with water: Manhours per square meter of surface		
		Rate per square meter of washing (considering expense for fresh water, pump etc)		

TABLE - A.4.1 CONTD..

No.	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 contd..				
B.2.53	Remove accumulated water (this is through out the ship scrapping process)	Removal of accumulated water: Manhours per m3 of accumulated water		
B.2.54	Treatment of oil contaminated sand, generated due to clearing of oily surfaces bef	Manhours for collection of oily sand		
		Manhours for chemical wash, if required		
		Rate for chemical washing per m2 of area		
B.2.55	Treatment of contaminated sand with paint	Manhours for collection of sand contaminated with paint		
		Manhours for chemical wash, if required		
		Rate for chemical washing per m2 of area		
B.2.56	Remove materials containing asbestos	Manhours per m2 of asbestos area		
		Rate for removal of asbestos (including expenses for associated equipments, safety devices etc required for removal)		
B.2.57	Removal of electrical components			
B.2.57.1	Removal of cables (left out after removal in offshore quay side)			
B.2.57.2	Removal of batteries	Removal of battery: Manhours per battery		

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 contd..				
B.2.58	Removal of materials containing PCBs	Manhours per quantity or weight of PCB		
		Rate for removal of PCB (including expenses for associated equipments, safety devices etc required for removal) per quantity or weight of PCB		
B.2.59	Removal of other hazardous liquids such as refrigerants	Removal of refrigerant: Manhours per litre		
		Removal of refrigerant: Rate per litre (for pumps etc)		
B.2.60	Removal of other hazardous liquids such as fire suppression substances			
B.2.61	Remove paints (surface preparation for cutting)			
B.2.61.1	Mechanical removal / using hand hammer			
B.2.62	Treatment of Paint chips			
B.2.63	Removal of contaminated paint chips.			
B.2.64	Remove canvass with chemical coating/chicken mesh / rexin / card board			
B.2.65	Collect onboard oil remains and dirty bilges into oil-drums and transfer to liquid waste area of the yard.			
B.2.66	Cut super structure (horizontally) in large pieces & allow free fall to shallow water			

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 contd..				
B.2.67	Cut upper decks (horizontally) in large pieces & allow free fall to shallow water			
B.2.68	Cut Main deck (horizontally) in large pieces & allow free fall to shallow water			
B.2.69	Cut lower decks (horizontally) in large pieces & allow free fall to shallow water			
B.2.70	Move structural blocks using winch to the Panel yard.			
B.2.71	Dismantle the ship from the end facing the beach to the end facing the ocean (using cutting torches & saws).			
B.2.72	Pull bottom portion of hull ashore using winch with extreme care			
B.2.73	Lift structures by crane to land			
B.2.74	Further disassemble & sort structures by metal type.			
B.2.75	(Final stage of the ship cutting process) Cut large sections into smaller pieces (using torch cutting &mechanical or saw cutting).			
B.2.76	Handle, transport and dispose hazardous wastes, produced during cutting process, according to regulations & local environmental laws and ordinances.			
B.2.77	Remove scales generated during gas cutting of steel from shore as well as onboard			
B.3.1	Dismantle machinery at hold level			
B.3.2	Transfer structure blocks from Panel Yard to Cutting Yard			
B.3.3	Removal of stiffeners, brackets and other projections from plate by torch cutting			
B.3.4	Cutting of plate, to size, for grading and sale			
B.3.5	Transport different pieces/materials from beach to temporary storage sites			
B.3.6	Sort materials in different piles in the scraping yard			

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 contd..				
B.3.7	Unify materials into the same "standard" sizes, cut if necessary, in the scrapping yard			
B.3.8	Store "standardised materials" in separate piles (eg.plates of different thickness, pipes of different diameter etc)			
B.3.9	Disassemble all equipment components (eg. valves, flanges & gaskets) from the pipelines in the scrapping yard			
B.3.10	Disposal of hazardous materials			
B.4.1	Sort scrap metals gap by metal type, composition and grade for selling to			
B.4.1.1	Steel			
B.4.1.2	Aluminium			
B.4.1.3	Copper			
B.4.1.4	Cu-Ni Alloys			
B.4.2	Separate metals which are mixed with other materials (Eg: Copper in electrical cable) using shredders & separators			
B.4.2.1	Shredders produce fluff, a mixture of metal and other materials that			
B.4.2.2	Magnetic separators, air floatation separator columns, or shaker tables			
B.4.3	Load the items on truck for transfer to market using crane or fork lift.			
B.4.4	Transport/export of materials and substances			
B.4.5	Transportation of sorted materials to nearby markets or reprocessing facilities.			
B.4.6	Sell things, which need no reprocessing, directly			
B.4.6.1	Pumps, Valves, Motors, Machines			
B.4.6.2	Navigational equipments			
B.4.6.3	Life-saving equipments (rafts, life buoys, life-vests, survival suits etc)			
B.4.6.4	Personal protecive equipments (helmets, workboots, gloves, goggles,			
B.4.6.5	Chemicals & paints			
B.4.6.6	Steel components (Anchors, Chains, grills, ventilation components,			
B.4.6.7	Sanitary equipment (toilets, sinks, bathtubs and so on)			

TABLE - A.4.1 CONTD..

	List of activities in ship recycling	Details of the activities for which estimation is done	Tariff Rate/mh	Manhours
Table A4.1 contd..				
B.4.6.8	Furniture			
B.4.6.9	Electrical cabling (intact) and batteries			
B.4.6.10	Insulation materials			
B.4.6.11	Oil products (for manufacturing industries)			
B.4.7	Sell things, which need reprocessing, as scrap			
B.4.7.1	Ferrous scrap metal (steel to re-rolling mills)			
B.4.7.2	Non ferrous scrap			
B.4.7.3	Minerals			
B.4.7.4	Plastic			
B.4.7.5	Liquids & Chemicals (included under different heading)			
B.4.8	Re-manufacturing/ re-processing			
B.4.8.1	Steel re-manufacturing			
B.4.8.1.1	Undamaged plating (by cutting, grinding & hotwork), Anchors, chains,			
B.4.8.1.2	Reprocess steel to make reinforcing rods for use in construction industry			
B.4.8.1.3	Reprocess steel to make corner castings and hinges for containers			
B.4.8.2	Oil re-manufacturing			
B.4.8.2.1	Used (dirty) oils (lubricating oils) are re-processed and offered for sale			
B.4.8.2.2	Use hydrocarbons onboard as reclaimed oil products to be used as fuel in			
B.4.8.3	Mineral re-processing			
B.4.8.3.1	Insulation material (asbestos) is in some facilities reprocessed by manual crushing and sold to manufacturing industries			
B.4.8.4	Copper reclaim			
B.4.8.4.1	Damaged cabling or non-saleable cabling is stripped for insulation either by mechanical stripping (sometimes also carried out at the scrapping site).			
B.4.9	Send materials/components that could be reused to the revised items.			
B.4.9.1	Use ship's generators ashore			
B.4.9.2	Use ship's batteries ashore			
B.4.9.3	Use ship's light fittings ashore			

Curriculum Vitae

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LIST OF PAPERS

SUBMITTED ON THE BASIS OF THIS THESIS

I REFREED JOURNALS

1. **Sivaprasad, K** Ship recycling activities in India –An overview, *Journal of Ship Technology,* Vol.2 No.21, 91-99
2. **Sivaprasad, K and C G Nandakumar.** Expert System for Ship Recycling, *Expert System with Applications* (Communicated)
3. **Sivaprasad, K and C G Nandakumar.** Deign for Ship Recycling, *Ship and Offshore Structures* (Communicated)
4. **Sivaprasad, K and C G Nandakumar** Role of Naval Architects in Ship recycling, Journal of Ship Technology, (Communicated)

II PRESENTATION IN CONFERENCES

1. **Sivaprasad, K, C G Nandakumar**, Recyclability analysis of obsolete ships and products, Proceedings of 3rd International conference on dismantling of obsolete vessels, Glasgow, September 2010.
2. **Sivaprasad K, Dileep Krishnan K,** and **C G Nandakumar,** Sustainable Development Index- Proceedings of 2nd International conference on ship dismantling, Glasgow, September 2008.

III EDITED BOOKS

1. **Sivaprasad, K and C G Nandakumar,** Recycling of Decommissioned Naval Fleet, Cmde. Garg Memorial Lecture Series, 2010, (Communicated)