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Technological and Economic Advancement of Tug Boats

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Abstract : *Tug boats are one of the most important components of the maritime industry. With the increase in effective usage of tug boats and timely delivery of cargo effective saving of finance in maritime industry can be achieved. Today, our Indian ports are challenged with better ship handling facilities and increased number of ship movement day by day in order to meet ever increasing demand of trade. This work analyses on how the operation and design of a tug can be done more effectively on the basis of technological and economical factors. The presence of tug boats in different form for different operation brings the importance of technological factor into existence. The main example is Escort tug boats, which is different in form and performance lead to a great step in maritime industry. The economical factor leads to the financial performance of the tug boats and its various operations. Main aspect of this paper to show how effectively can optimise the time and investment over the operation of tug boats.*
Technological factors:
1) *Usage*
2) *Power generation*
3) *Propulsion system*
4) *Hull form*
5) *Operational ability*

Economic factors:
1) *Cost of operation*
2) *Risk factor*
3) *Other usage include rescue and salvage*
4) *Optimisation of working time*

Keywords : *Tug Harbour, LNG Bollard NOx* CO_2

I. Introduction

Tugs have become a key element around the seaports globally for carrying out a variety of operations. Today a modern tug has become a multipurpose floating platform as defined by its ability to effectively perform a large variety of operations including guidance in mooring operations, firefighting, oil spill response, and icebreaking. Bustling about harbours, pushing, pulling and directing large ships in docking and undocking, tugs help large vessels to steer at slow speeds in restricted areas. In some ports tugs have to escort large tankers compulsorily, in order to respond to a distress call, if any, in short time. They are inseparable part of any salvage operation in case of grounding, capsizing or sinking of marine platforms. Yet tugs have not attracted much attention of researchers around the world as other vessels due to a variety of reasons. Even today many tugboat design modifications are happening based on owners requirements without much consideration of hydrodynamics of hull form. While bollard pull performance, controllability, maneuverability and compactness remain critical matters in design, additional attention needs to be paid, in today’s circumstances, to energy efficiency, environmental aspects and ease of operation. Designers are frequently challenged by requirements of lower maintenance, lesser noise in machinery spaces, better safety, reduced fuel consumption and avoidance of hazardous emissions. This paper investigates recent trends in technical and economic advancements in the design and operation of tugs around the world. Novel methods and innovations in design of tugs as studied by various agencies in the last two decades throughout the world to equip a modern tug meet the growing challenges are analyzed .This study ends with a data analysis of tugs operating in India and manufacture of tugboats in Indian shipyards.

II. Relevance of Tugboats in the shipping sector

Tugs are characterized as that family of marine vessels with disproportionately large power compared to their size. This large power, however, is utilized only for a short time of its operations while towing or pushing other floating platforms. A modern tugboat is supposed to carry out a large variety of operations each of which have a different power requirement from very low power like standing by, waiting for pilots order etc. to very high power requirements like arresting the momentum of a large ship and all points in between (in transit, during ship berthing, barge towing and so on).In case of any emergency at any location the vessel has to quickly traverse at maximum speed to the spot in minimum time. Operational requirements for tugs are becoming increasingly challenging and put high demands on the reliability and efficiency of both the ships and their crews. The general increase in size of merchant ships requires harbour tugs to have a higher bollard pull, which in turn increases the forces on the towing equipment, the fendering system and the ship structure (in particular the towing equipment foundations and push bow), while simultaneously pushing up the installed propulsion power. In addition, authorities and offshore terminal operators demand increased deploy-ability of escort and offshore terminal tugs, which have to assist ever larger ships in more severe weather conditions, including ice and arctic conditions.These aspects have to be improved upon without significant changes in maneuverability of the vessel.

Table 1 shows historical evolution of tugboats. Most of these developments have happened as a result of strong demands of industry in respect with changes in type and size of ships, types of cargo, growth in size of ports and more recently environmental regulations and cost savings.

Table 1: Timeline of developments in the Design of tugs [1]

Timeline	Development
Early 19th Century	Barges being towed by horses walking along canals
1842	First steam engine tug
1932	First Diesel engine Tug Zwarte Zee III
1999	First Rotor Tug Design Concept
2000	Start of Azimuth stern ASD tugs
2002	Introduction of carousel tug
2006	Concept of LNG tugs
2008	Trend for environment friendly tugs begins.

III. Classification of tugs

Some of the key parameters defining the performance of a tugboat are Bollard pull towing capacity in ahead and astern condition, Maximum free running speeds (Very critical to empower the vessel in meeting any emergency situation), Time taken to achieve maximum free running speed from rest. Distance covered to crash stop (Preferably less than the vessels LOA), time taken to complete a 360^o turn in its own axis, sound proofing of Machinery spaces etc.

3.1) Harbour tugs are used to assist ships while entering or leaving a port and during berthing and unberthing operations. A large ship navigating in confined waters is faced with many hazards, including the risk of collision or grounding which may have severe environmental consequences. The crew is very familiar with the operating area and shore side facilities for maintenance; repairs, spare parts, etc. are directly available and need to be highly skilled .Also each ship to tow would have its unique steering characteristics. In case of any calamity shore side assistance is available nearby. Those specifically used for pushing are called pusher tugs and have more rigid construction of hull and fender. An interesting application of this is the tug barge system which is becoming more relevant in many coastal shipping and inland sea transportation.

3.2) Seagoing tugs are used to assist ships in ports as well as at sea. Seagoing tugs can either operate without any restriction (deep sea towage, in any sea area and any period of the year) or within short distance from shore (coastal towage) or at a specified location (offshore terminal tugs). Good sea keeping characteristics is an additional requirement compared with other type of tugboats. For coastal towage and offshore terminal tugs, the crew is considered to be familiar with the operating area and shore side facilities for maintenance, repairs, spare parts, etc. are readily available. It is also considered that in case of emergency, shore side assistance is readily available if the tug does not proceed in the course of the voyage more than four hours at operational speed from a place of safe sheltered anchorage. For deep sea towage the crew is not necessarily familiar with the operating area and shore side facilities for maintenance, repairs, spare parts, etc. are generally not readily available. It is also considered that in case of emergency shore side assistance is not readily available.

Fig. 3 A Seagoing Tugboat operated by the Indian Navy [2]

3.3) Escort tugs are a relatively recent development in response to the risk of pollution caused by the grounding of a laden oil tanker [3]. Accidents have occurred in the past, which have led to major oil damages, which accelerated pressure toward improvements in safety in marine oil transports. Some of these accidents lead to oil damage which resulted from an oil tanker that lost either its maneuverability or propulsive thrust at a critical moment. As a consequence of such oil accidents, the requirements concerning tanker structures have been tightened, inter alia, so that a double bottom structure is required to be built in tankers. In addition, development of tug boats of a novel type has been necessary to provide assistance to and escort tankers in dangerous and coastal waters, i.e., outside of safe harbors. While escort towing, the tug boat is intended to assist at high speed the steering and arresting properties of a vessel to be assisted by means of a tow rope coming from the towing winch and connected to the vessel being assisted. While working in the harbor, the tug boat can be applied to normal towing and buffering tasks. The tug's role is to be available to bring a disabled oil tanker rapidly and safely under control in the event of a machinery system failure while imposing the minimum possible effect on the tanker's normal operations. Since the risk of environmental impact due to grounding increases dramatically with proximity to a coastline, escort operations only occur within fairly confined waters. Escort tugs can generate forces for steering and braking a disabled tanker which are greater than the bollard pull delivered by the propulsion system. This is achieved by using a hull shape and appendages that can generate very high forces at yaw angles up to 45 degrees, combined with an azimuthing propulsion system to resist the resulting yaw moments generated from the hydrodynamic forces. This mode of operation is known as indirect steering or braking and results in a high degree of interaction between the flow around the hull and the flow due to the propellers. The market for tugboats provides a lot of challenges to the propulsion system designer. Since the risk of environmental impact due to grounding increases dramatically with proximity to a coastline, escort operations only occur within fairly confined waters. Since time is one of the most important elements in an escort operation, a tug operating tethered will always result in a faster and hence safer response than for one that is not. The magnitude of the forces and the manner in which the tug should react to control the situation is highly dependent on the speed of the operation. Table 2 below shows various modes of operation of an escort tug and its description.

Table 2: Modes of operation for an Escort tug [abid]

Speed(Knots)	Mode	Description
6 or below	Direct	Forces from the tug's propulsion system will dominate
6-8	Transition	The most effective means of control will depend upon the type of propellers
	Transverse arrest	For tugs with azimuthing propellers- thrust from the drives is oriented normal to the tugs centerline axis
Over 8 knots	Indirect	Hydrodynamic forces from the hull begin to dominate

Classification society requirements for escort tugs citing Det Norske Veritas (DNV) Regulations [1] for example include:

- o The hull of the tug shall be designed to provide adequate hydrodynamic lift and drag forces when in indirect towing mode. Due attention shall be paid to the balance between hydrodynamic forces, towline pull and propulsion forces
- o The towing winch shall have a load reducing system in order to prevent overload cause by dynamic oscillation in the towing line, and
- o The propulsion shall be able to provide ample thrust for maneuvering at higher speeds for tug being in any oblique angular position
- o The vessel shall be designed so that forces are in equilibrium with a minimum use of propulsive force except for providing forward thrust and balancing transverse forces during escorting service
- o In case of loss of propulsion, the remaining forces shall be so balanced that the resulting turning moment will turn the escort tug to a safer position with reduced heel[5]

Tug efficiency T_e depends on the size and configuration of the tug, the sea state considered and the towing speed achieved. In the absence of alternative information T_e may be estimated for good ocean going tugs according to the Table 3.However tugs with less sea-kindly characteristics will have significantly lower values of T_e in higher sea states.

Table 3 Values for tug efficiency T_e

Continuous Bollard Pull(BP),tonnes	Tug Efficiency,Te%			
	Calm	H_{sig}=2m	H_{sig}=3m	H_{sig}=5m
BP≤30	80	50+BP	30+BP	BP
30<BP<90	80	80	52.5+BP/4	7.5+0.75*BP
BP≥90	80	80	75	75

IV. Marine Pollution

As per the International mortality and asthma attacks. The presence of these pollutants has local and global impacts. Impacts on local air quality are mainly linked to pollutants such as PM, NO_x and sulphur, while gases like CO_2 have a global impact on climate. The negative effects on local air quality and human health are largely dominated by the presence of NO_x and PM, acid deposition and nitrogen deposition. NO_x emissions also can cause nutrient overload in water bodies, which can result in eutrophication. The excess of nutrient nitrogen can be detrimental to the fragile balance of ecosystems, including marine ecosystems. SO_2 emissions also negatively impact public health; in particular, sulphate particles can induce asthma, bronchitis and heart failure. Sulphur and nitrogen compounds emitted from ships can also produce impacts not directly linked to human health. Emissions of these compounds at sea can exert an influence on vegetation and land-based objects many thousands of kilometers away [6]. Health effects can result in the reduction of oxygen delivery to the body's tissues and organs (such as the heart and the brain). CO can have significant cardiovascular effects on those who suffer from heart disease. The central nervous system can also be affected. Breathing high levels of CO can result Energy Agency statistics released in 2009, India stands behind China, US and Russian Federation as the 4th largest CO_2 emitter in the world with 1427.6 million tonnes as compared to world's 28348 million tonnes. The emissions from Transportation sector stands at 17% of which the share of Sea Transportation amounts to around 7%. Shipping is responsible for a very substantial part of total global emissions of CO_2. According to the International Maritime Organization (IMO), shipping was responsible for 2.7 percent of global carbon emissions in 2007, but that could double or even triple by mid-century if no action is taken now. The IMO's Environmental Protection Committee concluded at a weeklong meeting that all ships built in the future must reduce pollution from today's averages.Though one may argue that since tugboats comprise of small percentage of global fleet their pollution is less significant compared to other ships. But one fact underlines the emission from tugs that since these vessels ply in ports and coastal regions their pollution affects local ecosystems in land very adversely. It has been found that marine vessels comprise of main contributor in air pollution of major port cities. Port areas been worldwide, developed in very close proximity to urban areas, and port operations can affect the people living and working in these areas. As a result, especially in port areas, ships contribute to harmful levels of pollutants such as particulate matter ozone (O_3) and nitrogen oxides. PM can contribute many serious health problems including premature in blurred vision, reduced ability to work or learn, and reduced manual dexterity. CO also contributes to the formation of smog [7]. At the global level, carbon dioxide is the most significant trace constituent that has an effect on global climate change. Table 3 shows emission from one such region from different type of ships. This study was conducted on 200 commercial vessel encounters in the Gulf of Mexico and the Houston-Galveston region of Texas. It clearly shows that NO_x and CO emissions are comparatively higher from tugs which can be detrimental to the ecology of coastal areas. NO_x emissions are influenced by Combustion temperatures in engines and can cause acid rain leading to over-fertilization of lakes as well as smog formation. [8]

Table 3: Emission Factor Statistics by Vessel Category [9]

TYPE OF SHIP	NO_X EMISSION (g NO_x/Kg fuel)		SO_2 (g SO_2/Kg fuel)		CO (g CO/Kg fuel)	
	Speed=0	Speed>0	Speed=0	Speed>0	Speed=0	Speed>0
Bulk Carrier	48.7	84.4	16.7	17.3	5.3	5.6
Container and Vehicle carrier	44.5	64.0	23.1	29.6	5.0	8.5
Crude oil carrier	24.3	60.8	47.8	23.2	2.6	9.0
Oil products and LPG tankers	39.5	74.4	27.3	27.2	5.4	6.4
Passenger and supply vessels		57.3		5.9		11.5
Tugs and tows	75.2	57.8	3.9	3.1	8.3	7.2

IMO recently released a document that outlines new standards for emission of NO_X, SO_2, and PM globally [10]. In addition, standards for establishment of emission control areas (ECA) have been revised which allow considerable local and regional reductions in ship emissions [11] Sulphur ECAs (SECA) have been in place for a number of years for the North Sea and Baltic Sea regions. The sulphur content of standard marine fuel is 2700 times higher than that of conventional diesel for cars [12]. Table 4 gives an overview of sulphur limits globally and in ECAs.

Table 4: MARPOL Annex VI fuel sulphur limits [10]

<table>
<tr><th rowspan="2">Date</th><th colspan="2">Sulphur limit in fuel</th></tr>
<tr><th>Global</th><th>ECA</th></tr>
<tr><td>2000</td><td rowspan="2">4.5%</td><td>1.5%</td></tr>
<tr><td>2010</td><td rowspan="2">1.5%</td></tr>
<tr><td>2012</td><td rowspan="2">3.5%</td></tr>
<tr><td>2015</td><td rowspan="2">0.1%</td></tr>
<tr><td>2020*</td><td>0.5%</td></tr>
<tr><td colspan="3">*Final date subject to review</td></tr>
</table>

IMO Marine Pollution (MARPOL) emission regulations came into force in 2000, initially limiting exhaust emissions of NO_X. Table 4 describes IMO NO_x emission limits and introduction dates. By 2011, the admissible NO_X emissions on newly-installed engines has decreased by approximately 20 per cent and in 2016, Tier 3 will further reduce the limit in emission controlled areas (ECA) by approximately 80 per cent, compared to Tier 1. [abid] Implementation of these regulations would be a welcome step in reduction of emission from ships and has triggered renewed interest in research including better fuels, refined engines, hull geometry, alternate fuels etc.

V. Technical Advancements in Tugs

The primary concern in the design of a tugboat is that a tug has to work in different modes wherein the requirement of power is different for different modes. Also the vessel being expected to ply in restricted and confined waterways makes space availability less for machinery in order to minimize vessel size. In order to improve the utilization of the vessel during off time modifications have been made to equip the vessel for firefighting, search and rescue (SAR), oil spill response etc. Today, tug propulsion systems are being optimized with regard to power and efficiency, while the level of automation on board has increased dramatically. Finally, it is now widely acknowledged that environmental and energy efficiency issues, relating to the need for cleaner and more efficient tugs, need to be addressed. To this end a number of design and operational initiatives have been taken by the tug industry, such as the development of alternative propulsion systems (LNG propulsion, fuel cell powering and hybrid propulsion systems) [13].This section discusses about various advancements which have led to evolution of conventional tugboats to the next level.

5.1) Advancements in Propulsion

A tugboat is essentially a floating powerhouse and its primary mission is to help other vessels to maneuver in restricted quarters or to tow them to their destinations. A typical harbor tug engines typically produce 500 to 2,500 kW while seagoing tugs can have power ratings up to 20,000 kW and usually have an extreme power/tonnage-ratio as shown in table 5.

Table 5: Comparison of Power to weight ratio of vessels [14]

Type of ship	Power to weight ratio (kW/GRT*)
Sea going ship	0.35-1.2
Seagoing tug	2.2-4.5
Harbour tug	4.0-9.5

*GRT-Gross Rated Tonnage

Accordingly, most of its power is absorbed on the towline and only a small percentage is used for the propulsion of the boat itself. As size of ships increased so did the demand for larger and more powerful tugs for handling this ships.A simple technique used to achieve this is by making larger tugs with larger engines. Advancements in non conventional fuelled propulsion devices equipped propulsion engineers with more tools to enhance tug performance especially improved maneuvering. This together with demands to reduce running costs, reduce noise levels in crew working spaces lead to many studies being conducted to optimize vessel performance. Some of the ideas are discussed below. It is projected that the CO_2 reduction options using alternative fuels would range between 38 million tons to 157 million tons by the year 2050 depending upon a number of scenarios projected. [15]

5.1.1) Diesel Electric Propulsion

The system combines smaller main engines (compared to a conventional vessel of equal capability) with electric propulsion motors. It allows engines to shut down when not required, keeps engines at or near their design points when running, and engages its electric motors to provide the difference between available engine power and required power across the speed range. Energy stored in batteries is used to meet low-end power requirements and bridge transient periods when power is not yet at speed. [16]

5.1.2) Hybrid Tug

Many concepts of hybrid tugs are gain wide acceptance in the industry. The system combines smaller main engines (compared to a conventional vessel of equal capability) with electric propulsion motors. It allows engines to shut down when not required, keeps engines at or near their design points when running, and engages its electric motors to provide the difference between available engine power and required power across the speed range. Energy stored in batteries is used to meet low-end power requirements and bridge transient periods when power is not yet at speed [17]

5.1.3) LNG as marine fuel

One of the main reasons which fuelled exploration of LNG as a marine fuel has been stricter regulations in ECA as per Annex VI of MARPOL. LNG fuel is a viable alternative to standard marine fuels. LNG as a fuel has no sulphur-oxide emissions and very less CO_2, NO_X and PM compared to standard marine fuels. Liquefied natural gas takes up about $1/600^{th}$ the volume of natural gas in the gaseous state. It is odorless, colorless, non-toxic and non-corrosive. Hazards include flammability, freezing and asphyxia. The liquefaction process comprises of removal of foreign matter like dust, acid gases, helium, water, and heavy hydrocarbons. The natural gas is then condensed into a liquid at close to atmospheric pressure (maximum transport pressure set at around 25 kPa by cooling it to approximately −162 °C. The heat value depends on the source of gas that is used and the process that is used to liquefy the gas. A surge in exploration and transportation of LNG around the world and the growth of LNG terminals has increased the availability of this fuel. There exist strict regulations in use of tugboats in LNG terminals like vessels to be equipped with gas detectors and gastight dampers on all air inlets and outlets, while all of the electrical deck equipment is to be of explosion proof design. All of the non-explosion proof electrical equipment, such as the radar, searchlight, and window wipers, should be enabled to be switched off with a single button in the event of a gas alarm. All the essential electrical equipment has to be certified as being explosion proof and require gas detection and ventilation with gastight damper control systems, so that they can be isolated in the event of gas leakage. They serve as a reminder that tug research and development is continuing to focus very much on operational safety – which in many ways is the essence of the tug business. [18]

5.1.4) Use of bio fuels

Bio fuels are made by blending petroleum fuels with new and used vegetable oils and animal fats. Since tugboats operate in the vicinity of the ports, they would benefit greatly from the reduced emissions profile of biofuels. Moreover, no modifications to tug engines would be needed because this is a diesel type fuel and there would be no power loss as is the case with other alternative fuels such as LNG and electricity. While neat biodiesel is more expensive than a blended fuel, it has far greater emission benefits. Biodiesel is a renewable fuel that can be manufactured from new and used vegetable oils and animal fats. The use of biofuels on board ships is technically possible; however, use of first-generation biofuels poses some technical challenges and could also increase the risk of losing power (e.g., due to plugging of filters). These challenges are, nevertheless, overshadowed by limited availability and unattractive prices that make this option appear unlikely to be implemented on a large scale in the near future. This is especially important for tugboats as peak power is needed to man oeuvre the latest generation megaships in tight spaces. The so called first generation biodiesels are produced through a process known as transesterfication known as FAME (Fatty Acid Methyl Ester). In the process the feedstock oil reacts with methanol at high temperature and pressure over an alkaline catalyst. This stage is followed by numerous separation stages (also including neutralization with acid) which yield the biodiesel product and a crude glycerol by-product. From one litre of feedstock oil and 0.1 litre of methanol, the FAME process can produce ~0.95 litres of biodiesel and 0.1 kg of glycerol. FAME biodiesel can be used pure (B100) but is typically blended with regular diesel at 5% (B5) or 20% (B20). The quality of biodiesel varies considerably depending on the feedstock. The cetane number for biodiesel produced from certain feedstocks (e.g. soybean and sunflower) is lower than allowed in some regions. FAME biodiesels tend to have poor cold weather performance (palm derived biodiesel in particular) since they form gels at relatively high temperatures. FAME biodiesels can also be unstable, i.e. prone to degradation by oxidation. Despite these drawbacks, biodiesels have the advantage of virtually zero sulphur and ash content and have a very similar energy density to regular diesel. Second-generation biofuels are beginning to reach the commercial stage. Second-generation technologies are not based on edible crops and include a diverse range of pathways and products. The products are made from almost any combustible biomass using gasification and synthesis technologies. Logistical challenges can be solved as well, as tugs generally bunker in the port they are operating in. [19]

Algae can also be used to produce biodiesel, ethanol, butanol and aviation biofuels. It requires CO_2 (at fairly high concentrations) and nutrients (including nitrogen, phosphorous, iron and silicon) as feedstock. The technology is still at the research stage. It is also possible to produce biodiesel, gasoline and aviation biofuel from a sugar source using genetically modified organisms; this is also at the research and development stage.Second-generation ethanol is indistinguishable from first-generation ethanol. Butanol has many advantages over ethanol: it has higher energy density (close to gasoline); it is less corrosive and can be transported in existing pipelines; it can be blended at high levels in gasoline without requiring modification to vehicles; and it can also be blended with diesel.[20]

5.2) Developments in Hydrodynamics

The past 20 - 25 years design of harbor tugs has concentrated on developing and improving the propulsion and the associated maneuverability. Propulsion moved from single to double prop, various nozzles and rudder types were introduced and finally the propulsion developed into omnidirectional thrust by two or more thrusters [21], [22] or Voith Schneider Propeller [23] Recent technical developments include hull form optimization to increase the hydrodynamic lift on the hull of escort tugs (including special design skegs).A rapid growth in Offshore industry demands more vessels like seagoing tugs and Anchor handling Tug Supply(AHTS) Vessels to be used near these offshore installations which are mostly in regions of rough sea. Vessel Designs which incorporate trimaran hull form have also been recommended to be used in ice class tugboats.

5.3) Carrousel Tug

In this revolutionary design by Novatug BV, the hull direction is always kept in line with the towing wire and rotating the thrust force 360-degree around. This design can be characterized by rotating the hull direction free from the towing wire. This carrousel consists of a large horizontal ring, rotating around the accommodation and fitted with the towing wire. The attachment in the side reduces the heeling moment sharply and enables to use the full extent of the dynamic hull forces for escorting (steering and braking) to be used. This enables fully omnidirectional propulsion with ever increasing bollard pull and with to a lesser extent use of hydrodynamic forces by skegs and/or box keels [24] and [25]. The carrousel ring can rotate freely all around without limitations and towing operations can be freely changed from bow to stern use or vice versa as shown in figure 4. Traditionally tug design concentrated on towing over the stern behind the accommodation offering a free range of slightly more than 180 degrees for the towing wire. However, for many jobs more freedom is required and therefore the hull is turned 180 degrees. Modern ASD tugs use the same principle and rotate the whole hull and towing wire around the thrusters. The carrousel is based on the same principle as a radial hook, but now extended to the full ship's width. Hereby a large increase in stability is achieved, which can be used to increase the hydrodynamic forces. The stability feature enables to position the carrousel right above the center of the lateral resistance and thereby maximize the towline forces and minimize the need for steering propulsion on the tug. The carrousel is independent of the propulsion type and can therefore be applied to any type of tug design and propulsion type.

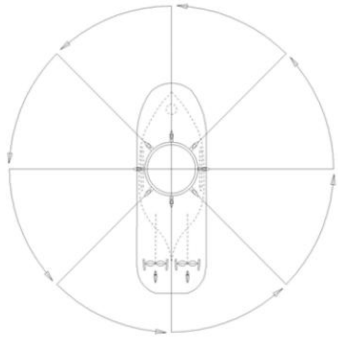

Fig. 4 All around flexibility around carrousel [26]

VI. India's Maritime sector

India is a major maritime country with a peninsular coastal line of 7517 Kilometers with over 13 major and 176 minor ports. Many of these ports are at geostrategic locations either on the world's busiest shipping routes or closer to it. India is also one among the largest crude oil importers in the world. Over 90% by volume and 70% by value of India's international trade happens by sea. Total number of ships handled in 2012-2013 financial year in major ports of India was 20402. [27] Cargo traffic achieved Compound annual growth rate (CAGR) of 4.4% during 2009-10 to 2014-15.Table 3 shows the breakup of types of cargo being handled by ships in Indian ports. With a consistent growth in Gross Domestic Product (GDP) of over 6% in the coming years it is eminent that the marine traffic would increase in the coming decade. A fast expanding middle class would trigger a big surge in demand of various commodities leading to enhanced trade by sea. Rapid growth in consumption and globalization of world trade is fuelling national seaborne trade at a high level.

Table 5: Type of Cargo in Percentage of total Trade in financial year 2014-15

Type of Cargo	Description	Percentage
Dry bulk	Iron ore, fertilizer, food grains	34
Liquid Bulk	Petrol,Oil,Lubricants	33
Break bulk	Goods loaded individually	17
Container	Cargo transported in standardized containers	16

A large emphasis being laid to the growth of coastal shipping and inland navigation would also help the economy to minimize transportation costs and enable a faster, easier and cheaper method of transfer of goods. Table 4 shows the rise in Exim trade and growth forecast in the near future.

Table 6: Growth in Cargo handling pattern in major seaports of India [28]

Period	Cargo-handling capacity of major ports(Million Metric tonnes)
2008-09	*575*
2014-15	*871*
2021-22 (Projected)	*1695*

For this, additional cargo handling capacity of 901 million metric tonnes is required to be created in Indian Ports in the next 6 to 7 years. Special Economic Zones (SEZs) are being developed in close proximity to several ports – comprising coal-based power plants, steel plants and oil refineries. [29] This would lead to more vessels in Indian ports in the next decade which would trigger larger requirements of tugboats for towing, pushing, salvage and firefighting. Indian navy and Indian Coast guard which is rapidly increasing their family of assets including aircraft carriers, submarines, minesweepers, frigates etc in view of acquiring blue water capability are also facing a larger requirement of tugboats of different designs and capabilities. Indian navy is particularly keen on specialized vessels capable of salvage and rescue of assets like submarines which are in need of help.

As on 31 December 2014 *324* tugs with *312222* GRT are registered as Indian fleet ,37 tugs with *208625* GRT exist as overseas fleet and *287* tugs with *103597* GRT exist as coastal fleet under Indian flag[30].

Table 7: Overview of New building Tugs Acquired by Indian companies from 2000-2013[31]

TYPE OF TUG	NUMBER
Escort Tug	176
Anchor Handling Tug Supply	82
Seagoing Tug	7
Articulated Pusher Tug	2
TOTAL	267

As a shipbuilding nation India has proven its might in manufacture of tugs of different size and type as per the demands of the industry. Both major public sector and private sector yards have delivered vessels for local and foreign clients in a time phased manner. The increased delivery of AHTS vessels to foreign clients is a testimony of this fact. However non standardization of design, lack of domestic ship design capability and lack of availability of local machinery as per global standards is an issue which needs to be rectified. School of maritime Design and Research (SMDR), a unit of Indian Maritime University Vizag campus is working on standard design of harbor and escort tugs suited for the Indian requirements .Another interesting point from this analysis is the lack of escort and seagoing tugs under Indian flag. In the event of a major ship accident like capsize or sinking of a vessel in Indian ports, lack of local expertise in salvage operations is a very serious issue which has to be corrected by due action from government and industry alike. Figure 5 shows the market share of various shipyards in India.

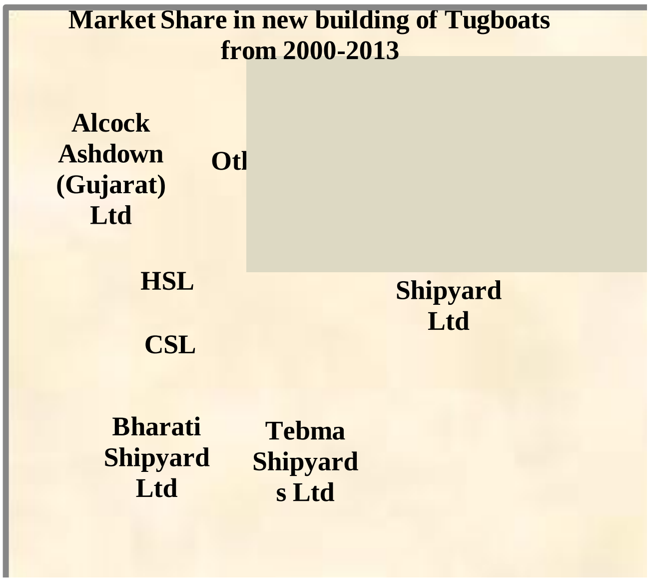

Fig. 5 Market Share for New building of Tugs of Indian Shipyards

VII. Conclusion

Tugboat design is evolving to the next generation adapting to new market demands both technicaly and economically.The new technical advances in design need to be adopted worldwide and attempts have to be made this floating platform more economically viable,environment friendly and safe.Indian shipbuilding industry which has proved its might in manufacture of tugs have to open its doors to these new technical advancements and take steps to take due benefit out of them.More emphasis to be laid to indegenious design of hullform and manufacture of machinerysuitabile for local conditions.

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