MODELING AND ANALYSIS OF LABOUR COST ESTIMATION FOR SHIP REPAIRING: A CASE STUDY IN CHITTAGONG DRY DOCK LIMITED

by

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Declaration

This is to certify that the thesis work entitled "*Modeling and Analysis of Labour Cost Estimation for Ship Repairing: A Case Study in Chittagong Dry Dock Limited*" has been carried out by *Mohammad Sajedul Karim* in the Department of *Industrial Engineering and Management*, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of the work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

With the increase of international trade activities through sea and resulting exponential growth of number of ships calling on coastal nations' ports, ship repair is becoming an increasingly attractive opportunity for littoral countries. Being a coastal nation, there were rapid growth of number of local shipyards in Bangladesh for past couple of years. This factor put CDDL faced with tremendous competition in ship repair arena in the national market. Besides, docking of ships and ship repairing work, are, by nature labor intensive. Labour cost contributes significantly to total repair cost. Besides acquiring market information, CDDL must estimate labor cost accurately to give competitive quotations in order to obtain ship repair orders. Lower labour cost value allow shipyards and ship owners to get higher productivity and lower final invoice respectively.

Forecasting estimated labor cost will allow CDDL to stay competitive among the ship repair industries. In this project paper, attempt has been made to identify the number of those independent variables that influence ship repairing labour (dependent variable) and their inter-relationship. Since labor cost for ship repair can be expressed as a function of ship's age, deadweight, displacement, type of ship and various repair works, so a multiple linear regression model is developed to construct a labor cost estimation model. From 2002 to 2019, ship repairing labour (man-days) related information for 43 sets for fishing vessel, 30 sets for oil tanker, 51 sets for multipurpose cargo ship, 40 sets for warship, 11 sets for dredger/barge and 15 sets for tugboat of various ages, sizes and types were collected from data storage of CDDL to construct models for each ship group. Regression coefficients are found out by applying "Method of Least Squares" in regression analysis. CDDL can use this mathematical model as a guiding tool to forecast labour cost estimates more realistically for ships to be under repair.

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CHAPTER I

Prelude

1.1 Background

Chittagong Dry Dock Limited (CDDL) was established on the bank of river Karnaphuli on 48 acres of land as a complementary facility to Chittagong Port Authority (CPA) to cater for regular and emergency repair needs of national flag carrier vessels as well as vessels touching Chittagong Port. Design and construction project of CDDL were done with the then Yugoslav technical assistance. CDDL commercially started its operation from July 1985. CDDL is the only dry dock in Bangladesh. Its grave dock can dock vessels up to 22,000 DWT. Length, breadth and depth of the graving dock are 183m, 27.2m and 13.1m respectively. Besides, CDDL can perform complete renovation and conversion works of ships and carry out medium to heavy engineering works to support local industries.

CDDL was an enterprise of BSEC. On 23rd December 2015, CDDL was placed under the management of Bangladesh Navy (BN) as state owned Ltd company. CDDL, being the only dry dock of Bangladesh, is able to undertake any kind of repair works of all types of ships belonging to public and private owners of Bangladesh as well as foreign ships except some Panamax size ships (able to enter Panama Canal). Availability of repair facility for all types of the said ships near Chittagong Port is vital to ensure vibrant operation of Chittagong Port and activities of blue economy. It is noteworthy that location of CDDL near CPA and availability of enough depth of water of Karnafully river adjacent to CDDL qualify this yard to be a place where various types and sizes of ships can be docked for repair. Availability of workforce and cheap labour lead to growth of more shipyards/ship repairers in Bangladesh. As such, huge competition dictates CDDL to come up with accurate quotations to stay competitive in the national market particularly in respect of labour cost, which creates variation in ship repair cost.

1.2 Requirements of Effective Labour Cost Estimation

The purpose of the study is to investigate the prevailing factors for labor cost by empirical analysis and a comprehensive analysis to construct labor cost estimation models for ship repair at CDDL. According to an empirical analysis, the effects of factors, such as, ship's age, deadweight, displacement, type of ship and various repair works for ship repair have been confirmed. Similar kind of empirical analysis for CDDL will be analyzed in case of those factors like ship's age, deadweight, displacement, type of ship and different types of ship repair works, namely general services, steel plate renewal, hull cleaning and painting, piping, underwater fittings, above water fittings, equipment and machinery. The comparison between the actual and estimated values of man hours for the said factors will be made. Application of these models is likely to provide forecasting of more accurate labor cost estimation and allow decisions to be made more accurately, thus enhancing competitiveness and profitability.

1.3 Objectives of the Thesis

The objectives of this thesis are as follows:

i) To investigate and identify the prevailing factors for labor cost of ship repair by empirical analysis.

ii) To verify and explore various factors involved in labor cost estimation for ship repair at Chittagong Dry Dock Ltd by statistical analysis.

iii) To develop and construct labor cost estimation models for ship repair at Chittagong Dry Dock Ltd by regression analysis.

1.4 Statement of the Problem

Providing ship-repair facilities is becoming an increasingly attractive opportunity for coastal nations with the exponential growth of number of ships calling on their ports as international trade activities through sea is increasing. Thousands of ships enter and leave Chittagong Port annually. On the other hand, SDG 14 of Bangladesh will entail involvement of special purpose ships/ platforms to have full access to marine resources and small-scale artisanal fishers of blue economy of Bangladesh by 2030. Availability of repair facility for all types of the said ships near Chittagong Port is vital to ensure vibrant operation of Chittagong Port and activities of blue economy. From these perspectives, CDDL needs to exploit such ship repair opportunities. But CDDL confronts serious competition in the national market. CDDL must acquire market information and give accurate quotations in order to obtain ship repair orders.

The estimation of labor cost for ship repair is very important during the quotation stage. Because, the cost of ship repair includes direct material cost, direct labor cost, direct expense and indirect expense. The direct material share of the total ship repair cost is 55% to 60%. However, most of the direct materials are imported from foreign countries and fluctuation in foreign exchange rates is an uncontrollable factor. On the other hand, direct labor cost and indirect expenses which can be estimated from direct labor cost, account for 30% to 35% of the total ship repair cost. Therefore, direct labor cost plays a significant role in the total cost of ship repair. Generally, labor cost equals man-hours multiplied by wage rate. So, CDDL require to eye on controlling labour cost i.e. man hour/man day with a view to quote reasonably competitive offer for ship repair in comparison to other ship repairers. Without investigating the prevailing factors for labour cost at CDDL and constructing viable labour cost estimation models for ship repair at CDDL, forecasting cost estimation and giving competitive accurate quotations for ship repair appear to be quite cumbersome. Besides, if there is limitation in these regards, then it will create hindrance to CDDL to exploit foreseeable huge ship repair opportunities in Bangladesh.

1.5 Significance

This study will allow CDDL to identify and examine the prevailing factors for labor cost of ship repair at CDDL by statistical analysis and construct labor cost estimation models for ship repair at CDDL. Application of these models is likely to provide forecasting of more accurate labor cost estimation and allow decisions for ship repair to be made by CDDL management more accurately. This will enhance competitiveness and profitability of CDDL in the field of ship repair in comparison to other shipyards.

CHAPTER II

Literature Review

2.1 Dry Docking Operation for a Ship for Repair

Dry or graving docks are used to enable the ship's bottom and underwater fittings to be inspected and worked on [1]. They normally consist of a basin dug into the shore of a body of water and provided with a watertight gate on the waterside, used for major repairs and overhaul of vessels [2]. When a ship is to be docked, the dry dock is flooded, and the gate opened. After the ship is brought in, positioned properly, the gate is closed and the dock is pumped dry, bringing the ship gradually to rest on supporting keel and side blocks anchored to the floor [3].

2.2 Ship Repair Demand Outlook

2.2.1 Blue Economy

Sylvia Alice Earle, an American marine biologist commented, "No water, no life. No blue, no green". Gunter Pauli's book, "The Blue Economy: 10 years, 100 innovations, 100 million jobs" (2010) brought the Blue Economy concept into prominence. Blue economy is all about resources and services of ocean and seas. These are food (fish and other sea food), renewable blue energy production from wind, wave, tidal, thermal and biomass sources, energy (oil and gas), transportation (shipping), mineral, water, leisure (tourism) and health (pharmaceuticals and cosmetics). Concept of blue economy as defined by the European Commission (2012) is all economic activities related to the oceans, seas and coasts. It also covers the closest direct and indirect supporting activities required for functioning of these economic sectors, which can be located anywhere, including in landlocked countries.

2.2.2 Blue Economy - Bangladesh Perspective and Ship Repair Opportunity

Rapid economic growth coupled with a rising population is putting immense pressure on the environment, ecology and natural resources in Bangladesh. Blue economy has opened a new horizon for economic development of the coastal countries through utilizing sea and marine resources at national and international level [4]. Moreover, Bangladesh is blessed due to geographically located by the Bay of Bengal and Blue Economy is very much suitable for Bangladesh by considering the maritime area and its connection with the people of Bangladesh as well as its economy [5]. Bangladesh will explore blue economy to have balanced socio-economic development while maintaining the balance in nature and ensuring sustainability for future generations. Bangladesh will take the opportunity to solve its problems, like shortage of energy, unemployment issue etc and increase its GDP by exploiting resources of blue economy. Bangladesh has sovereign rights over the living and nonliving resources of the Bay of Bengal in the Exclusive Economic Zone within 200 nm and in the continental shelf beyond 200nm. Bangladesh has also sovereign rights on all the living and mineral resources of the Continental Shelf extending up to 354 nautical miles. SDG 14 of Bangladesh puts use and conservation of the ocean and its resources into the wider sustainable development context that will entail involvement of special purpose ships/platforms to have full access to marine resources and small-scale artisanal fishers of blue economy of Bangladesh by 2030 [6]. So huge fleets of artisanal fishing boats, special purpose ships/ platforms and passenger ships will be involved to exploit sea resources like other sea food, oil and gas, mineral, health benefit products and tourism. These huge fleets of artisanal fishing boats, special purpose ships/ platforms and passenger ships will need repair facilities.

2.2.3 Involvement of More Ships in Sea Borne Trade

Ocean contains 80% of earth’s life. It produces more than half of the oxygen we breathe and provides a livelihood for an estimated three billion people who depend on marine and coastal areas, including fishing, tourism, trade, transport and energy. Market value of marine and coastal resources is 5% of world’s GDP. 350 million jobs worth of $3 trillion are linked to ocean. Two thirds of the world’s surface is sea water and quite simply 80% of the world's trading goods are carried by ships of all designs [7]. Vessels trading the high seas simply keep the world moving. Despite the global economic crisis, world seaborne trade has grown to 8.7 billion tonnes contributing USD 435 billion per year to global economy and provides 14 million jobs. The fastest maritime trade growth is between the emerging economies of South Asia, Far East and economies of China, Japan, Africa and America. Expected container traffic will be triple by 2030. So, more ships will be involved to cater for more container traffic. Coastal countries will get more repair opportunities as movement of more ships will be needed for more container traffic to cater for this growing trade.

2.2.4 Sea Borne Trade – Bangladesh Perspective and Ship Repair Prospect

Export and import value (2013-14) Bangladesh was at about USD 67 billion and 2500 foreign ships visited our ports for carrying most of these goods. Importers, exporters and buyers paid USD 95 billion as freight and related charges to shipping companies and air lines to carry goods in and out of Bangladesh. Only 74 registered Bangladeshi merchant ships existed in 2014 were significantly insufficient to carry such cargo. According to an assessment carried in 2014, considering the average import growth rate of 15.79% (last 10 years) and export growth rate of 15.43% (last 10 years), projected freight value for next ten years would be around USD 435 billion [8]. In order to retain parts of the USD 435 billion in the country, over the ten years, Bangladesh must facilitate local shipping companies to add more ships to the existing fleet, freight operators to establish freight services including container liner services to carry goods to/from Bangladesh using our own as well as chartered ships and freighters. At present, around 600 ships arrive in Bangladesh per year and anchor in the ports of Chittagong and Mongla. Arrival of huge number of ships in the sea ports of Bangladesh is very much expected to meet the requirements of growing trade coupled with new opening of blue economy. Therefore, prospect of ship repair order is likely to rise. So, there will be huge competition among ship repairers to avail such ship repair orders.

2.3 Ship Repair Time and Cost

2.3.1 Duration of Ship Repair

Repairing works refer to the category and quantity of works carried out during the repairing time. Labor cost will vary with time of completion of these works. Flag legislation and classification society rules require the vessel to be in a shipyard/ dry dock/floating dock/slipway for an intermediate or special survey with an interval of 24 - 30 months and for a major classification survey at every five years. Repairing time consists of time inside the dock (docking time) and time at the quayside (quay time). Bottom surveys and underwater jobs, which cannot be done in afloat conditions, are carried out during docking time. All other jobs, except underwater one, are continued during quay time. It is noted that inaccuracy in estimating the duration of the ship maintenance in dry dock is still common. There are three dry docking works that can be used to classify the dry docking duration, which are propeller (underwater fittings), washing (hull cleaning) and plate works [9]. If the estimated duration of maintenance is too long, then shipyard becomes uncompetitive. So, inaccuracy in estimating the duration of completing these works will lead to wrong estimation of labour cost. This will result in preparation of inaccurate quotation, which may affect the competitiveness with that of other shipyards.

2.3.2 Ship's Maintenance/Repair Cost

Ship maintenance can be carried out in the ship repair yard for major routine ship maintenance, which requires a dry dock/shipyard to maintain the underwater part of the vessel. In the shipyard, typically 75% of the work involves routine ship maintenance, and the remaining 25% is for damage repair and ship conversion [10]. Since major economics stagger to get back on their feet and emerging economies try hard to adapt, trading environment for ship managers has been extremely difficult. So it is imperative for ship managers to have all the necessary information about ship's operating cost, which will allow them better planning and monitoring to enhance their performance. Therefore operating cost of a ship have taken on a greater significance in the pursuit of shipping business survival, with the softer targets, such as repair and maintenance, personnel and administration taking center stage [11].

In general, a ship‘s operating costs vary according to type, size, and age of the vessel. Ship maintenance and operation costs include all the costs related to equipment and materials, personnel, replacement inspection, overhaul, and repair. Ship maintenance cost can be classified as one part of the ship’s operating costs. A case study of data presented on a six-year-old, 75,000-ton bulk carrier, maintenance costs account for the largest proportion of operation costs (40%) based on the sample surveyed [12]. Ship maintenance costs can be defined as those costs incurred in the organization execution, and control of work undertaken for safe operation of the ship. In the marine industry, ship maintenance and ship repair can be completed in two different ways. Firstly, they can be undertaken in the ship repair yard when the ship is due for dry docking to survey the underwater parts and when it is due for its classification survey. Secondly, maintenance can be conducted during the ship‘s day-to-day operations. Dry docking repair cost is a part of the ship’s maintenance costs. For the purpose of this paper, dry docking repair will mean both repair works carried out in dry dock as well as in quay immediately after undocking from dry dock.

2.3.3 Cost Estimation

In order to properly develop the bid, shipyard management needs to know the level of accuracy of the cost estimate or level of uncertainty of the estimate. Uncertainty may be quantified either through the application of margin or the provision of confidence levels. Instead of margins, cost estimating approach uses confidence levels. Reason being, confidence levels provide the ship repairer with quantified insight into the accuracy of the estimate. Attention may be focused to increase confidence levels on certain parts of the estimate having low confidence levels with a view to increase the accuracy of the estimate. Generally, confidence levels are assigned to the engineering quantities (e.g., reflecting a 90% confidence that the weight of structure is correct as reported) and also to the cost estimating relationships (e.g., reflecting 95% confidence in the estimated cost per weight factor). The two confidence levels are multiplied to arrive at an overall confidence level (e.g., 90% x 95% = 86%) [13]. Ability to estimate ship repair cost as accurately as possible is necessary for the commercial success of a shipyard. Shipyard will be out of the competitive range if an estimate is too high. On the contrary, too low an estimate will result in a financial loss.

2.3.4 Estimated Labour Cost

In order to best serve the shipyard needs, the cost estimating approach follows the above mentioned convention by producing estimates for material and labor [14]. Ship's repair and maintenance cost takes center stage of the ship's operating cost [15]. The cost of ship repair includes direct material cost, direct labor cost, direct expense and indirect expense. The direct material share of the total ship repair cost is 55% to 60%. However, most of the direct materials are imported from foreign countries and fluctuation in foreign exchange rates is an uncontrollable factor. On the other hand, direct labor cost and indirect expenses which can be estimated from direct labor cost, account for 30% to 35% of the total ship repair cost [16]. Therefore, direct labor cost plays a significant role in the total cost of ship repair. Generally, labor cost equals man-hours multiplied by wage rate. As the ship repair industry is largely labour-intensive, the most important challenge is that of labour. Ship repair industry is guided by labour legislation and trends, such as the basic conditions of employment, skills development, etc, that exist in the country. These conditions needs to follow the conditions and skills levels of labour of competitive ports like Singapore, as the input cost of labour is one of the most important factors influencing the competitiveness of a country's ship repair facilities [17]. The estimation of labor cost for ship repair is very important during the quotation stage. Labour man-hours will vary for similar jobs carried out under different conditions, such as world location, working conditions, environment, type of labour, availability of back-up labour, etc. For example, the output of a worker for a particular work carried out in a hot and humid country can fall to 50% than that of the same worker working in soothing climate in a separate country [18]. However, there might be deviation between the actual labor cost and the estimated labor cost.

2.4 Definitions

2.4.1 Displacement

Displacement or displacement tonnage of a ship is its weight based on the amount of water its hull displaces at varying loads. Loaded displacement is the weight of the ship including cargo, passengers, fuel, water, stores, dunnage and such other items necessary for use on a voyage [19]. These bring the ship down to its "load draft", colloquially known as the ‘waterline’.

2.4.2 Full Load Displacement

Full load displacement and loaded displacement have almost identical definitions. Full load displacement is defined as the displacement of a vessel when floating at its greatest allowable draft (designated by its ‘waterline’). Warships have arbitrary full load condition established.

2.4.3 Lightweight Displacement

Lightship or lightweight measures the actual weight of the ship with no fuel, passengers, cargo, water, crew, provisions and the like on board.

2.4.4 Deadweight Tonnage

Deadweight tonnage (also known as deadweight or, DWT) is a measure of how much weight a ship can carry and does not include the weight of the ship itself. DWT is the sum of the weights of cargo, fuel, water, provisions, passengers and crew. DWT is the displacement at any loaded condition minus the lightship weight [20].

CHAPTER III

SWOT Analysis

3.1 Strength and Opportunity for CDDL

3.1.1 Strength

CDDL has strategic geographical location. It is located very near to Chittagong Port. It is only 3nm from the sea and has direct access to sea. It is situated on the bank of Karnafuly river where depth of water is 10m. Its connectivity (by sea land and air) with other places of Bangladesh and other countries is smooth and trouble free. International trade activities through sea is increasing. Providing ship-repair facilities is becoming an increasingly attractive opportunity for coastal nations like Bangladesh with the exponential growth of number of ships calling on their ports as international trade activities through sea is increasing [21]. At present, thousands of ships enter and leave Chittagong Port annually. Availability of repair facility for all types of the said ships near Chittagong Port is vital to ensure vibrant operation of Chittagong Port and activities of blue economy now and in near future. Unlike shipbuilding or shipping, ship repair yards generally have continuous and consistent flow of business. Only CDDL has graving dock with associated facilities in Bangladesh. Mentionable, graving dock is the only platform where all kinds of repair of bigger sized ships can be carried out [22]. From this point of view, CDDL can repair all types of ships.

3.1.2 Weakness

Since CDDL has only one graving dock, so it puts limitation on CDDL to carry out repair and construction of ships at the same time as construction takes prolonged and more time than that of repair. Scope of construction of ships at only one graving dock is very much limited as ships are repaired almost continuously throughout the year. Besides, total number of ships expected to be repaired to maintain yearly turnover counts less than that is required. So, CDDL exploits other industrial opportunity and perform medium to heavy engineering works to support local industries with a view to increase turnover and profit margin after meeting all the expenditures of man and material.

3.1.3 Opportunity

CDDL has plenty of space to strengthen its infrastructure. At present, Bangladesh Navy looks after the management of CDDL. Large skill base is available for providing suitable manpower for conventional shipbuilding as well as ship repair. Availability of engineers, technicians and workers (welder, fitter, carpenter, foundry man etc.) are praiseworthy in Bangladesh. Labour is also cheap. These factors will help CDDL in ship repair business.

Resources in land is not enough compared to increasing population in Bangladesh. Economy will be affected if blue economy is not exploited in near future. At present, there is no purpose oriented ships in Bangladesh to exploit blue economy. 'Agreement on Coastal Shipping 2015', between India & Bangladesh will facilitate the use of vessels of River Sea Vessel (RSV) category for Indo-Bangladesh coastal shipping [23]. These two countries are also holding Shipping Secretary-level talks on issues relating to the memorandum of understanding on passenger and cruise vessel movement. CDDL can repair these above stated ships in future.

China and India that were doing ship repairs earlier have graduated to more lucrative shipbuilding [24]. A trend of ship repair business shifting towards third world nations has started to be visible on the horizon. From these perspectives, CDDL needs to exploit such ship repair opportunities. Generally, the dock and its associated workshops play a significant role in the employment of local shipwrights and tradesmen and provides a thriving centre maintaining the local ship building industry [25]. Ship repairers of Bangladesh, in particular CDDL, will be able to take advantage of its availability of local workforce and cheap labour in Bangladesh.

3.1.4 Threat

If ship repair/ shipbuilding industry is not recognized by government as an important strategic industry and not benefitted subsequently from subsidy, tax concessions and tax holidays, it is difficult for it to grow and compete with shipbuilding giants like China, South Korea and the new entrant Vietnam.

China, South Korea, India and Vietnam may capture upcoming Indo-Bangladesh coastal shipping market and purpose oriented ships to exploit blue economy of Bangladesh if CDDL does not enhance its capacity.

Very less localization of most ship parts and unavailability of industrial base for manufacture of machinery/ equipment of ships in Bangladesh will decrease profit margin of CDDL in ship repair/ shipbuilding venture. Hence, the same may lead to loss in competition with the shipyards of China, South Korea, India and Vietnam in capturing ship repair/ shipbuilding projects.

3.2 Challenges for CDDL

For the last few years, there is rapid growth of number of local shipyards in Bangladesh. According to Shipyard Statistics, 2012, out of 124 shipyards in Bangladesh registered with the Department of Shipping, approximately 70% are located in and around Dhaka and Narayangong alongside of the river bank of Buriganga, Shitalakha and Meghna, 20% shipyards of Chittagong division are located alongside of Karnaphuli river, 6% are located along the bank of Poshur river of Khulna division and remaining 4% are located in Barishal division. Almost all inland/ coastal/ bay crossing ships are constructed and repaired locally in these local shipyards. Most of these yards are not equipped with standard facilities, equipment and machinery of a shipyard. As a matter of fact, there are some ship repairers, who purchase some land adjacent to the bank of the river and build slipway with rails to take ship on land beside river and then carry out repair. Private entrepreneurs always take opportunity to repair their ships from these types of ship repairers with much cheaper rates than that of a standard shipyard/dockyard. Besides, there are also some government owned as well as private shipyards in the country. Karl Fredrik Skorge Hansen pointed out that now-a-days ship owners maintains software, which stores previous cost and estimates data of various shipyards regarding ship repair allowing them to verify the quotations given by the shipyards and compare with other yards [26]. In fact, ship repair revenue generation is more predictable, but often prone to pulls and pressures of market forces and cyclic change. As such, CDDL confronts serious competition from the said ship owners/ ship repairers in the national market. CDDL must acquire market information and give accurate quotations in order to obtain ship repair orders.

3.3 Comparison of Labour Costs among Various Countries

Table 1 - Labour Costs of Various Countries

Ser	Name of the Country	Labour Cost	Source of Information and Remarks
1.	USA	23 €/hr	According to Drewry Shipping Consultants Ltd, the referred labour rate from serial No. 1 to 10 was effective in 1996 and the same from serial No. 11 to 14 was effective in 1999 [27].
2.	Germany	32 €/hr	
3.	France	31 €/hr	
4.	Netherland	More than 22 €/hr	
5.	Finland	More than 22 €/hr	
6.	Italy	23 €/hr	
7.	Greece	14 €/hr	
8.	Croatia	12 €/hr	
9.	Japan	More than 22 €/hr	
10.	Poland	6 €/hr	
11.	Slovenia	ca. 9 €/hr	
12.	Hungary	Over 4 €/hr	
13.	Czech Republic	ca.5 €/hr	
14.	Estonia	2 €/hr	

Ser	Name of the Country	Labour Cost	Source of Information and Remarks
15.	South Korea	21.29 US$/hr	The referred labour rate was effective in 2009 [28].
16.	China	1.97 US$/hr	
17.	Singapore	3 US$/hr	The referred labour rate was effective in 2010 [29].
18.	India	1 US$/hr	
19.	Bangladesh	0.5 US$/hr	

CHAPTER IV

Hypothesis

4.1 Age

Age of a ship is calculated from the date on which the ship is delivered by the building shipyard to her owners. With the elapse of time, older ships experience higher wear than newer ships. Moreover, flag and class have higher criteria for surveys of older ships. As such, older ships demand more extensive repair and maintenance than younger ships. Therefore, the first hypothesis is that the age of the ship is positively associated with the extent of repair cost.

4.2 Size

A big size ship means greater dimensions with larger machinery and equipment. This analogy can be translated into the fact that bigger ships need longer repairing time and more man-days for repairing/maintenance works than that of smaller ones. The size of a ship can be defined either by its dimensions (length, breadth and depth) or by its capacity (gross tonnage, net tonnage, deadweight, full load displacement, lightweight etc). Thus, the second hypothesis is that the size of a ship has a positive impact also on repairing labour (and hence labour cost) independently and the relation is assumed to be linearly dependent.

For simplicity, cargo ships, oil tankers, fishing trawlers and dredgers are classed in to same group. Since all these vessels are carrying cargo of different sort, so it is reasonable that their sizes be stated by deadweight tonnages as per the definition of the same. Strictly speaking, their sizes may also either be stated by full load displacement or lightweight displacement.

Warship doesn't carry cargo. As such, stating size of the same by deadweight tonnage may not be fitting. Logically, it will be appropriate to nominate size of warship either full load displacement or lightweight displacement. The same correlation is applicable to tugs and other ships (pilot boat, anchor boat etc).

4.3 Type

The type of ship mainly refers basically to the category of ship defined by the purpose of the ship or the duty it carries out. In this paper, there are different types of ships, such as, cargo ship, oil tanker, fishing trawler, dredger, tug, anchor boat, pilot vessel and warship. The configurations of ships vary widely including machinery and equipment according to the type of ships. There are inherent differences among machinery and equipment, piping arrangement, tank arrangement, geometrical configurations, cargo handling facilities, etc amongst different types of ships. This factor leads to a logical thinking that the different types of ships require different repairing time (days) and labour (man-days). Therefore, the third hypothesis is ship repairing labour is a function of the type of a ship and considered to be linearly associated.

Although, cargo ships, oil tankers, fishing trawlers and dredgers are classed in to same group, yet these vessels will differ in type because of different kinds of cargo they carry. On the other hand, there are also different types of warships, such as, frigate, corvette, offshore patrol vessel, minesweeper, auxiliary ship etc.

4.4 Scope of Repairing Works

Repairing works refer to the category and volume of works carried out during the repairing period. In this paper, mainly, seven areas (category) are considered such as, general service works, plate works, hull cleaning & painting works, piping works, above water fitting works, underwater fitting works and machinery & equipment works. It is natural that higher volume of repairing works requires more repairing time and labour. So, the fourth assumption is that the volume of repairing works has a positive impact on the repairing labour (man-days) independently and the relation is assumed to be linearly dependent.

Since labor cost equals man hours (man-days) multiplied by wage rate (USD/man-day), man-days will be used as a dependent variable instead of labor cost.

CHAPTER V

Procedure/ Methodology

5.1 Statistical Equations

According to an empirical analysis, Arun Kr Dev and Makaraksha Saha opined that theoretically ship repairing labour cost is a function of age, deadweight, type of ships and ship repairing works [30]. It has been highlighted that ships' age, deadweight, type and scope/quantity of ship repairing works are directly, positively and linearly associated with the corresponding labour (man-days). Similar kind of empirical analysis for CDDL has been explored and verified in case of the factors (independent variable) like ship's age, deadweight, displacement, type of ship and different types of ship repair works, namely general services works, steel plate renewal works, hull cleaning and painting works, piping works, underwater fittings works, above water fittings works and equipment & machinery works by statistical analysis through finding correlation coefficients between dependent (labour cost) and each independent variable.

As such, ship repairing labour (dependent variable) is a linear function of the independent variables, namely, age, deadweight/full load displacement/ lightweight displacement, type and scope of repairing works (independent variables). Mathematically, the above assumptions can be expressed in the form of equation, y = mx +c, which the form equations 1-10 for ship repairing labour and the said independent variables as follows:

$LC_1 = y_1 = f(x_1) = f(D) = a_1 + b_1 * D$ ………………………………………. (1)

$LC_2 = y_2 = f(x_2) = f(A) = a_2 + b_2 * A$ ………………………………………. (2)

$LC_3 = y_3 = f(x_3) = f(T) = a_3 + b_3 * T$ …………………………………...…. (3)

$LC_4 = y_4 = f(x_4) = f(GS) = a_4 + b_4 * GS$ …………………………………....... (4)

$LC_5 = y_5 = f(x_5) = f(PL) = a_5 + b_5 * PL$…………………………….……… (5)

$LC_6 = y_6 = f(x_6) = f(HCP) = a_6 + b_6 * HCP$ …… …………………..……..... (6)

$LC_7 = y_7 = f(x_7) = f(P) = a_7 + b_7 * P$…….…………………………………… (7)

$LC_8 = y_8 = f(x_8) = f(UWF) = a_8 + b_8 * UWF$ …… ……..…………………..... (8)

$LC_9 = y_9 = f(x_9) = f(AWF) = a_9 + b_9 * AWF$ ……… ………………..……... (9)

$LC_{10} = y_{10} = f(x_{10}) = f(ME) = a_{10} + b_{10} * ME$ … …………………………… (10)

Where,

LC = y = Ship repairing labour cost (expressed in man-days as dependent variable)

D = x_1 = Deadweight/ Full Load Displacement/ Lightweight Displacement of a ship (tonnes)

A = x_2 = Age of a ship (years)

T = x_3 = Value for Type of ship

GS = x_4 = General Service works

PL = x_5 = Plate Works

HCP = x_6 = Hull Cleaning & Painting works

P = x_7 = Piping works

UWF = x_8 = Underwater Fitting works

AWF = x_9 = Above Water Fitting works

ME = x_{10} = Machinery & Equipment works

5.2 Model Construction

Purpose of forecasting is to calculate and offer the best available basis for the management to predict future events or conditions and understand the implications for alternative courses of action (Milne 1975). Forecasting estimated labor cost allow shipyard to assess its competitive edge in the ship repair market. There are three types of forecasting methods, namely, qualitative techniques, time series analysis and projection, and casual models [31]. Qualitative techniques may or may not take the past into consideration and use qualitative data (expert opinion, for example) and information about special events. This deals principally with methods of forecasting the broad context of the future, including societal alternatives and patterns of values on which normative judgments rest [32]. Time series analysis and projection focuses exclusively on pattern change and thus depends on fully on historical data. Casual models reflect past and use highly refined and specific information about relations between systems elements. Casual models are powerful enough to take special events formally into account. The process by which labor cost is estimated are indeed numerous, including operational analysis, craft analysis, the use of cost returns, unit labor rates, and the empirical formula method. Since labor cost for ship repair may be affected by the factors, like age, deadweight and type of ship as well as repairing works of hull steel weight, piping, coating, structural fittings, machinery and equipment as stated above, so labor cost can be expressed as a function of these factors. As there is casual relationship between them as explained above and hence multiple regressions can be used to construct a labor cost estimation model. Regression coefficients can be found out by applying "Method of least squares" in regression analysis, and IBM SPSS statistics software is adopted.

The model is constructed as follows. First, the independent variables that affect labor cost for ship repair are selected. Then, the relevant data for the dependent and independent variables are collected, finally, the multiple regression model is constructed for each ship group and the parameters are estimated. The regression equation is constructed for estimating the quantitative relations between labor cost and other independent variables for each type of ship. If the model passes the test and meets the practical considerations, CDDL may adopt it. Owing to the high variety and low volume characteristics of the ship repair industry, the observation data for each type of ship are quite different. From 2002 to 2019, there are 43 sets for fishing vessel, 30 sets for oil tanker, 51 sets for multipurpose cargo ship, 40 sets for warship, 11 sets for dredger/barge and 15 sets for tugboat selected to construct model for each ship group.

5.3 Collection of Data and Methodology

5.3.1 Collection of Sample Data

43 sets for fishing vessel, 30 sets for oil tanker, 51 sets for multipurpose cargo ship, 40 sets for warship, 11 sets for dredger/barge and 15 sets for tugboat docked and repaired at CDDL during the period from 2002 to 2019 were selected. Data of their repairing labour, age, deadweight, type of ship and repairing scopes were collected from CDDL, gathered and used in order to develop the ship repairing labour cost function and verify the assumptions.

5.3.2 Methodology

Since individually the independent variables are linearly associated with the dependent variable as per initial assumptions, the following function of the linear equation is used to establish the relationship between the ship repairing labour (man-days) and its independent variables:

LC_{repair} = f (D, A, T, GS, PL, HCP, P, AWF, UWF, ME)

Where,

LC_{repair} is expressed in Ship repairing labour (man-days). These are the total number of men utilized for repairing a ship. It is calculated by adding the number of men engaged each day for ship repair.

D is Deadweight/Full Load Displacement/ Lightweight Displacement of a ship (ton).
A is Age of a ship (years) at the time of docking. The age of a ship is calculated from the date of delivery of the ship by the builder to its owner up to the time of docking.

T is Type of ships like the fishing vessel, cargo vessel, oil tanker, barge, frigate, corvette, offshore patrol vessel, minesweeper, patrol craft, tug, pilot vessel etc.

GS is quantity of general service works include docking, undocking, berth preparation, mooring and unmooring, fire watchman, security watchman, fire main line, fire line connection & disconnection, electrical shore power connection & disconnection, crane services, garbage disposal and temporary lighting. It is measured in Days.

PL is quantity of metal plate renewal works. It includes cutting old metal plates and fitting & welding of new metal plates. It is measured in terms of weight (ton).

HCP is quantity of hull cleaning & painting works. It covers cleaning by light and hard scrapping, hose down with fresh water, sand blasting, tank cleaning, painting, marking by painting (draft, plimsoll marks, ship & port name). It is measured in terms of area (m^2).

P is quantity of piping works. It consists of works of cargo pipeline, fire pipeline, fuel pipeline, oil pipeline, fresh water pipeline, sea water pipeline and air pipeline. It is measured in terms of running length (rm).

AWF is quantity of above water fitting works. It comprises works of hatch cover, manhole cover, mooring eye, bollard, rubber fender, armaments, equipment & sensors etc. Its quantity is measured in number.

UWF is quantity of above water fitting works. It encompasses works of zinc anode renewal, sea chests opening & refitting, rope guard, propeller shaft, rudder unshipping & refitting, drain plug and sea valve. Its quantity is measured in number.

ME is quantity of machinery and equipment works. It includes works of engine repowering, overhauling of generators, motors, compressors etc. It is measured in kW.

5.3.3 Multiple Linear Regression Analysis

Regression analysis method is a mathematical procedure to establish mathematical relationship between dependent and independent variables using the past data the relationship. In simple linear regression analysis, the dependent variable is predicted against a single independent variable, whereas multiple linear regression analysis determines dependent variable against a set of independent variables (involving more than one independent variable).

In this thesis, following multiple linear regression model is chosen to represent the relationship expressed in equation (11).

$$LC_{repair} = b_0 + b_1*D + b_2*A + b_3*T + b_4*GS + b_5*PL + b_6*HCP + b_7*P + b_8*UWF + b_9*AWF + b_{10}*ME \quad \ldots\ldots \quad (11)$$

Here,

D= Ship's Deadweight/Full Load Displacement/ Lightweight Displacement (ton)
A= Age of Ship at the Time of Docking (year)
T= Value for Type of ship (number)
GS=General Service Works (days)
PL= Quantity of Plate Works (ton).
HCP=Quantity of Hull Cleaning & Painting Works (m^2)
P= Quantity of Piping Repair Works (m)
UWF= Quantity of Under Water Fittings Works (number)
AWF= Quantity of Above Water Fittings Works (number)
ME = Machinery and Equipment Works (number)
b_0, b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10}………. are regression coefficients
i= 1, 2, 3, 4, 5 ……….. n
n= sample size.

By using the method of least square (Ref) the following simultaneous equations are obtained

$$n*b_0+b_1\sum_{i=1}^{n} D_i+b_2\sum_{i=1}^{n} A_i+ b_3\sum_{i=1}^{n} T_i+ b_4\sum_{i=1}^{n} GS_i+b_5\sum_{i=1}^{n} PL_i+ b_6\sum_{i=1}^{n} HCP_i+ b_7\sum_{i=1}^{n} P_i +b_8\sum_{i=1}^{n} UWF_i+b_9\sum_{i=1}^{n} AWF_i+b_{10}\sum_{i=1}^{n} ME_i= \sum_{i=1}^{n} LC_{repair} \text{………..10}$$

$$b_0\sum_{i=1}^{n} D_i+b_1\sum_{i=1}^{n} D^2{}_i+ b_2\sum_{i=1}^{n} D_iA_i+ b_3\sum_{i=1}^{n} D_iT_i+b_4\sum_{i=1}^{n} D_i\, GS_i+b_5\sum_{i=1}^{n} D_i\, PL_i+b_6 \sum_{i=1}^{n} D_i\, HCP_i+b_7 \sum_{i=1}^{n} D_i\, P_i+b_8\sum_{i=1}^{n} D_i\, UWF_i+b_9\sum_{i=1}^{n} D_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} D_i\, ME_i= \sum_{i=1}^{n} D_iLC_{repair} \text{………………………..11}$$

$$b_0\sum_{i=1}^{n} A_i+b_1\sum_{i=1}^{n} A_iD_i+ b_2\sum_{i=1}^{n} A^2{}_i+ b_3\sum_{i=1}^{n} A_iT_i+b_4\sum_{i=1}^{n} A_iGS_i+ b_5\sum_{i=1}^{n} A_i\, PL_i+ b_6 \sum_{i=1}^{n} A_i\, HCP_i+b_7 \sum_{i=1}^{n} A_i\, P_i+b_8\sum_{i=1}^{n} A_i\, UWF_i+b_9\sum_{i=1}^{n} A_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} A_i\, ME_i= \sum_{i=1}^{n} A_iLC_{repair} \text{………………………..12}$$

$$b_0\sum_{i=1}^{n} T_i + b_1\sum_{i=1}^{n} T_iD_i + b_2\sum_{i=1}^{n} T_iA_i + b_3\sum_{i=1}^{n} T^2{}_i + b_4\sum_{i=1}^{n} T_iGS_i + b_5\sum_{i=1}^{n} T_i\, PL_i + b_6 \sum_{i=1}^{n} T_i\, HCP_i + b_7 \sum_{i=1}^{n} T_i\, P_i + b_8\sum_{i=1}^{n} T_i\, UWF_i + b_9\sum_{i=1}^{n} T_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} T_i\, ME_i = \sum_{i=1}^{n} T_iLC_{repair} \ldots\ldots 13$$

$$b_0\sum_{i=1}^{n} GS_i + b_1\sum_{i=1}^{n} GS_iD_i + b_2\sum_{i=1}^{n} GS_iA_i + b_3\sum_{i=1}^{n} GS_iT_i + b_4\sum_{i=1}^{n} GS^2{}_i + b_5\sum_{i=1}^{n} GS_i\, PW_i + b_6 \sum_{i=1}^{n} GS_i\, HCP_i + b_7 \sum_{i=1}^{n} GS_i\, P_i + b_8\sum_{i=1}^{n} GS_i\, UWF_i + b_9\sum_{i=1}^{n} GS_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} GS_i\, ME_i = \sum_{i=1}^{n} GS_iLC_{repair} \ldots\ldots 14$$

$$b_0\sum_{i=1}^{n} PL_i + b_1\sum_{i=1}^{n} PL_iD_i + b_2\sum_{i=1}^{n} PL_iA_i + b_3\sum_{i=1}^{n} PL_iT_i + b_4\sum_{i=1}^{n} PL_iGS_i + b_5\sum_{i=1}^{n} PL^2{}_i + b_6 \sum_{i=1}^{n} PL_i\, HCP_i + b_7 \sum_{i=1}^{n} PL_i\, P_i + b_8\sum_{i=1}^{n} PL_i\, UWF_i + b_9\sum_{i=1}^{n} PL_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} PL_i\, ME_i = \sum_{i=1}^{n} PL_iLC_{repair} \ldots\ldots 15$$

$$b_0\sum_{i=1}^{n} HCP_i + b_1\sum_{i=1}^{n} HCP_iD_i + b_2\sum_{i=1}^{n} HCP_iA_i + b_3\sum_{i=1}^{n} HCP_iT_i + b_4\sum_{i=1}^{n} HCP_iGS_i + b_5\sum_{i=1}^{n} HCP_iPL_i + b_6 \sum_{i=1}^{n} HCP^2{}_i + b_7 \sum_{i=1}^{n} HCP_i\, P_i + b_8\sum_{i=1}^{n} HCP_i\, UWF_i + b_9\sum_{i=1}^{n} HCP_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} HCP_i\, ME_i = \sum_{i=1}^{n} HCP_iLC_{repair} \ldots\ldots 16$$

$$b_0\sum_{i=1}^{n} P_i + b_1\sum_{i=1}^{n} P_iD_i + b_2\sum_{i=1}^{n} P_iA_i + b_3\sum_{i=1}^{n} P_iT_i + b_4\sum_{i=1}^{n} P_iGS_i + b_5\sum_{i=1}^{n} P_iPL_i + b_6 \sum_{i=1}^{n} P_iHCP_i + b_7 \sum_{i=1}^{n} P^2{}_i + b_8\sum_{i=1}^{n} P_i\, UWF_i + b_9\sum_{i=1}^{n} P_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} P_i\, ME_i = \sum_{i=1}^{n} P_iLC_{repair} \ldots\ldots 17$$

$$b_0\sum_{i=1}^{n} UWF_i + b_1\sum_{i=1}^{n} UWF_iD_i + b_2\sum_{i=1}^{n} UWF_iA_i + b_3\sum_{i=1}^{n} UWF_iT_i + b_4\sum_{i=1}^{n} UWF_iGS_i + b_5\sum_{i=1}^{n} UWF_iPL_i + b_6 \sum_{i=1}^{n} UWF_iHCP_i + b_7 \sum_{i=1}^{n} UWF_iP_i + b_8\sum_{i=1}^{n} UWF^2{}_i + b_9\sum_{i=1}^{n} UWF_i\, AWF_i \quad b_{10}\sum_{i=1}^{n} UWF_i\, ME_i = \sum_{i=1}^{n} UWF_iLC_{repair} \ldots\ldots 18$$

$$b_0\sum_{i=1}^{n} AWF_i + b_1\sum_{i=1}^{n} AWF_iD_i + b_2\sum_{i=1}^{n} AWF_iA_i + b_3\sum_{i=1}^{n} AWF_iT_{ti} + b_4\sum_{i=1}^{n} AWF_iGS_i + b_5\sum_{i=1}^{n} AWF_iPL_i + b_6 \sum_{i=1}^{n} AWF_iHCP_i + b_7 \sum_{i=1}^{n} AWF_iP_i + b_8\sum_{i=1}^{n} AWF_iUWF_i + b_9\sum_{i=1}^{n} AWF^2{}_i \quad b_{10}\sum_{i=1}^{n} AWF_i\, ME_i = \sum_{i=1}^{n} AWF_iLC_{repair} \ldots\ldots 19$$

$$b_0\sum_{i=1}^{n} ME_i + b_1\sum_{i=1}^{n} ME_i D_i + b_2\sum_{i=1}^{n} ME_i A_i + b_3\sum_{i=1}^{n} ME_i T_i + b_4\sum_{i=1}^{n} ME_i GS_i + b_5\sum_{i=1}^{n} ME_i PL_i + b_6\sum_{i=1}^{n} ME_i HCP_i + b_7\sum_{i=1}^{n} ME_i P_i + b_8\sum_{i=1}^{n} ME_i UWF_i + b_9\sum_{i=1}^{n} ME_i AWF_i$$
$$b_{10}\sum_{i=1}^{n} ME^2{}_i = \sum_{i=1}^{n} ME_i LC_{repair} \ldots\ldots\ldots\ldots 20$$

Using the collected data of LC_{repair}, D, A, T, GS, PL, HCP, P, AWF, UWF, ME, the values of the statistical notations, mentioned in these equations, are calculated. They are inserted in equations (10–20) and obtained ten simultaneous equations in terms of regression coefficients. The result of these simultaneous equations yields the estimate of regression coefficients. Subsequently, the statistical testing parameters are calculated to verify the adequacy of the model.

In developing the regression equation, the “stepwise regression” technique is applied using the “forward selection” method [33]. This method ensures the selection of the most effective variable from a set of variables in each step by comparing the contribution of each variable [R (β_j /β_1, β_2, ...β_{j-1})] and F statistic at every step. The final regression estimation passes the statistical quality test by F statistic (calculated value and critical value at 5% significance level) and coefficient of multiple determinations (R^2).

CHAPTER VI

Analysis and Discussion of Data Samples

6.1 Number of Graphs (No. of Ships vs Independent Variables) for Cargo Ship, Fishing Vessel, Oil Tanker, Dredger and Barge

Figure 1 shows the distribution of deadweight of sample data with a mean and standard deviation of 6597.10 and 6739.21 respectively. Figure 1 also shows that majority of samples 98% fall within 17500 tonnes deadweight tonnage and hence the result derived from statistical analysis will not be affected by the samples beyond that deadweight tonnage:

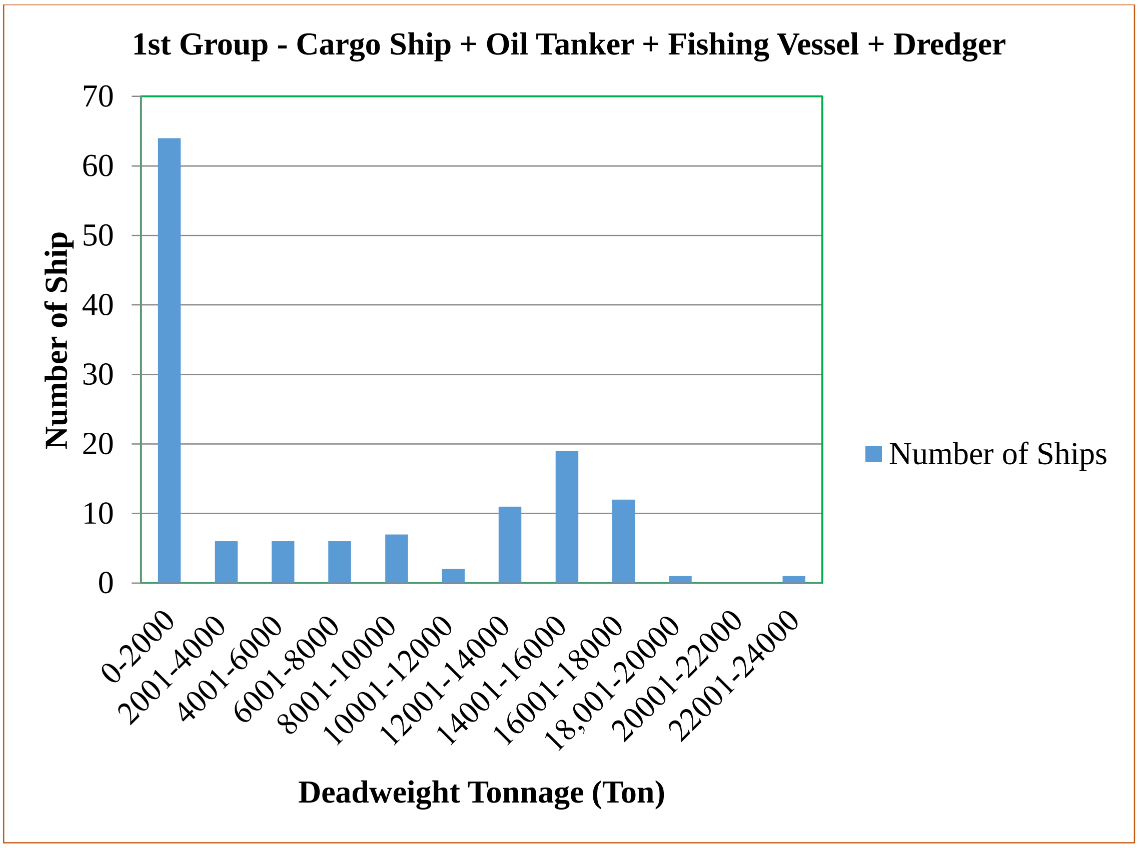


Figure – 1 : Number of Ship vs Deadweight Tonnage

Figure 2 shows that majority of samples 99% fall within 27500 tonnes full load displacement and thus the result derived from statistical analysis will not be affected by the samples beyond that full load displacement:

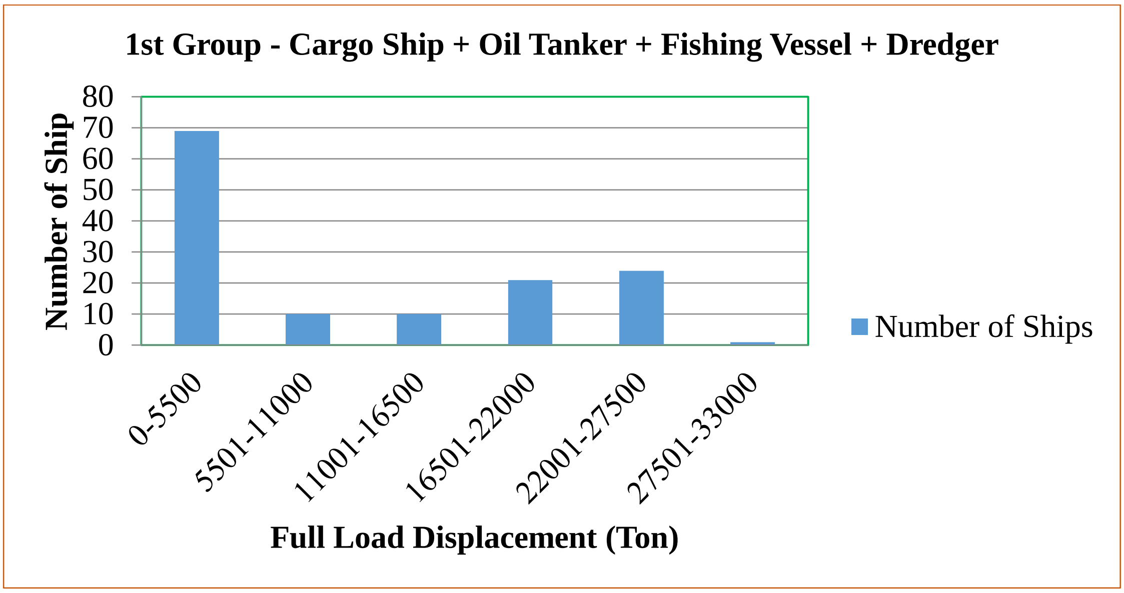


Figure – 2 : Number of Ship vs Full Load Displacement (Ton)

Figure 3 shows that majority of samples 99% fall within 8000 tonnes lightweight displacement and hence the result derived from statistical analysis will not be affected by the samples beyond that lightweight displacement:

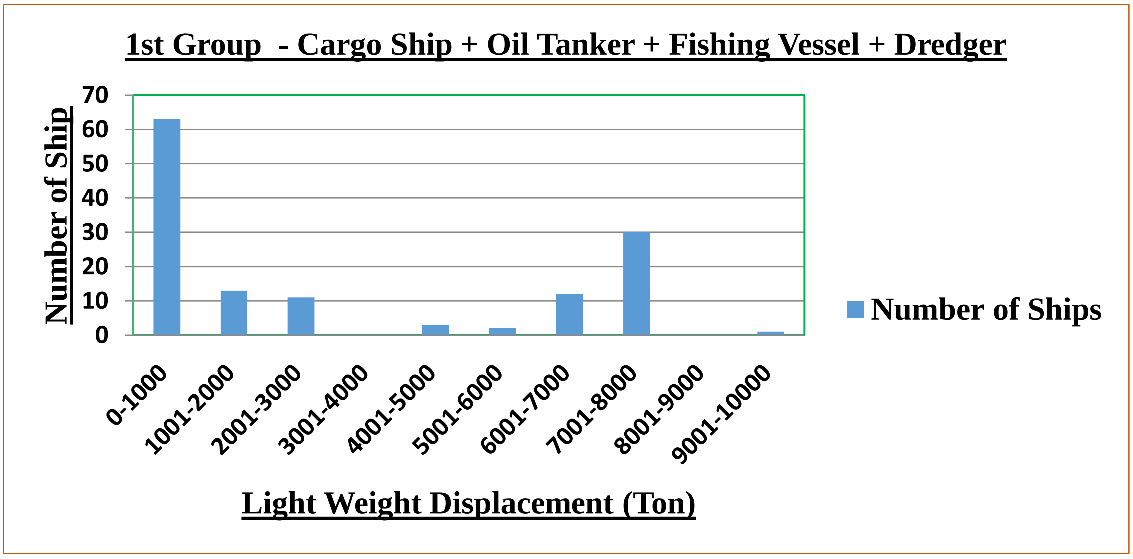


Figure – 3: Number of Ship vs Light Weight Displacement (Ton)

Figure 4 states the distribution of age of sample data with a mean and standard deviation of 22.82 and 9.84 respectively and suggests that majority of samples (96%) fall within 40 years of age. In that case, the result will not be affected by the samples beyond that age.

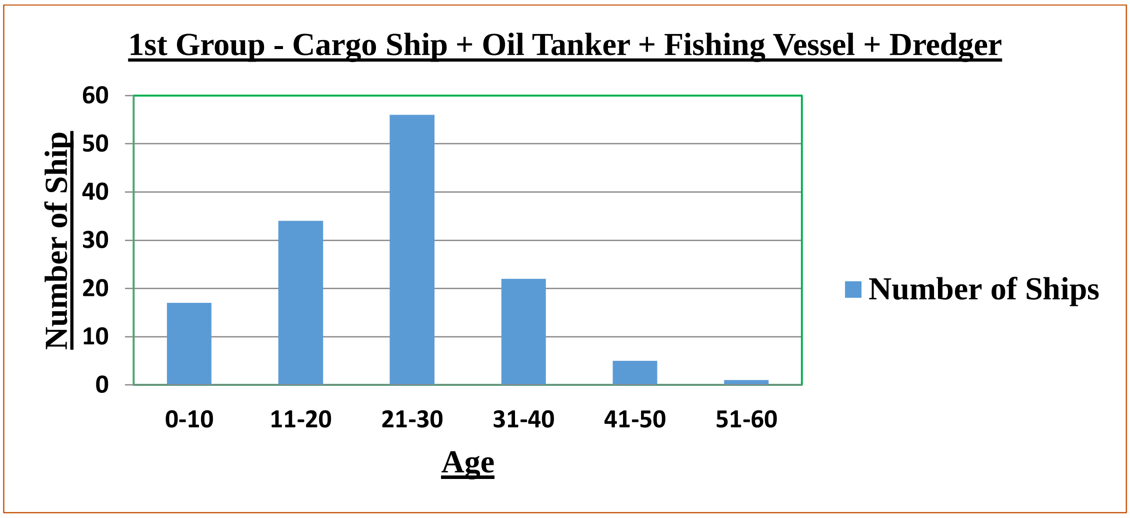


Figure – 4 : Number of Ship vs Age

Figure 5 states the distribution of general services works of sample data with a mean and standard deviation of 247.41 and 126.96 respectively and depicts that 96% of the samples have general services works below 500 days. So the result from these data will not be affected by general services works beyond 500 days:

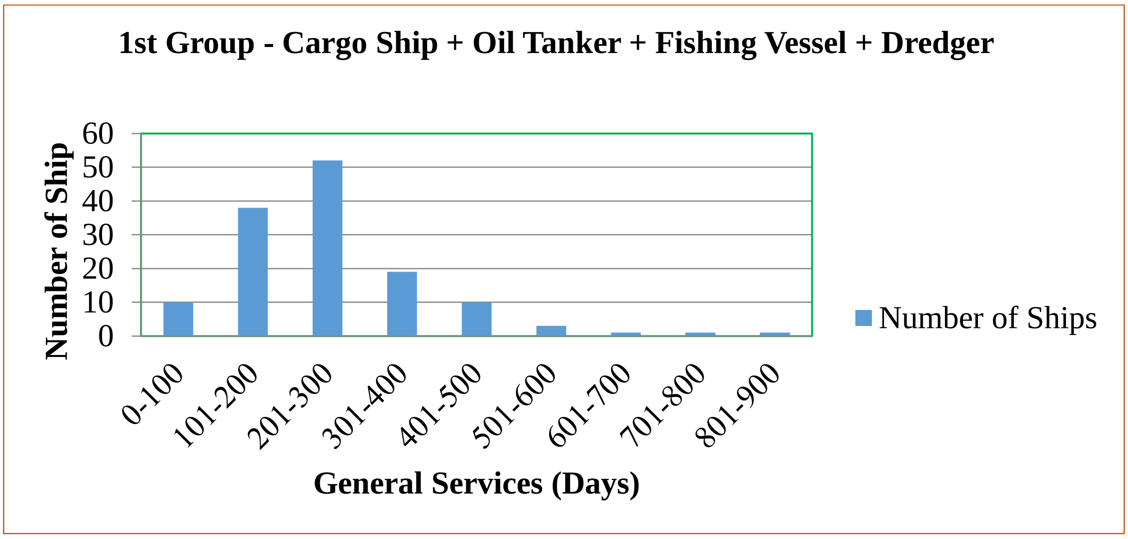


Figure – 5: Number of Ship vs General Services Graph

Figure 6 states the distribution of plate works of sample data with a mean and standard deviation of 10.56 and 28.52 respectively and points out that 96% of the samples have plate works below 50 tons. So the result from these data will not be affected by plate works beyond 50 tons:

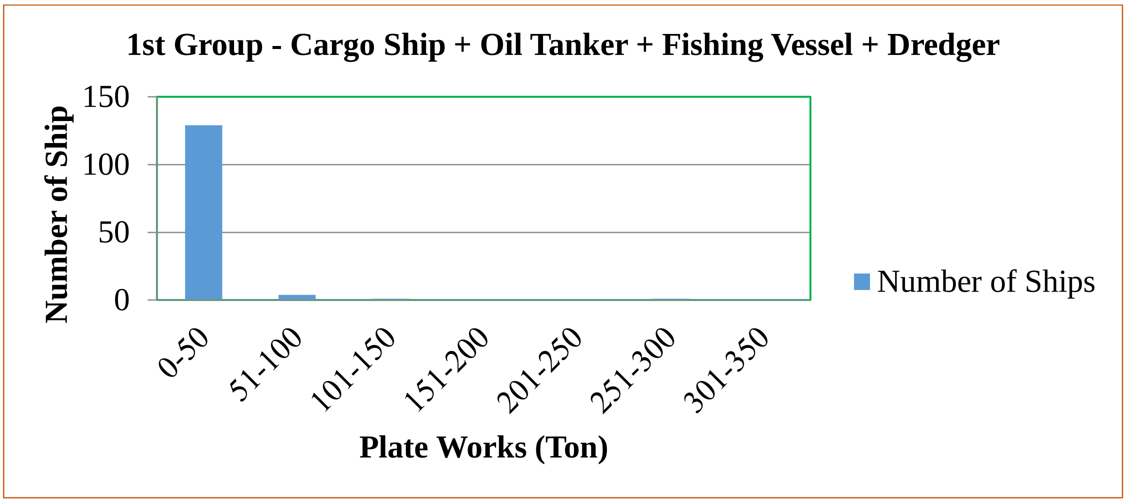


Figure – 6 : Number of Ship vs Plate Works (Ton)

Figure 7 states the distribution of hull cleaning & painting works of sample data with a mean and standard deviation of 7426.92 and 7369.59 respectively and indicates that 96% of the samples have hull cleaning & painting works below 20,000 sqm. Therefore, the result from these data will not be affected by hull cleaning & painting works beyond 20,000 sqm:

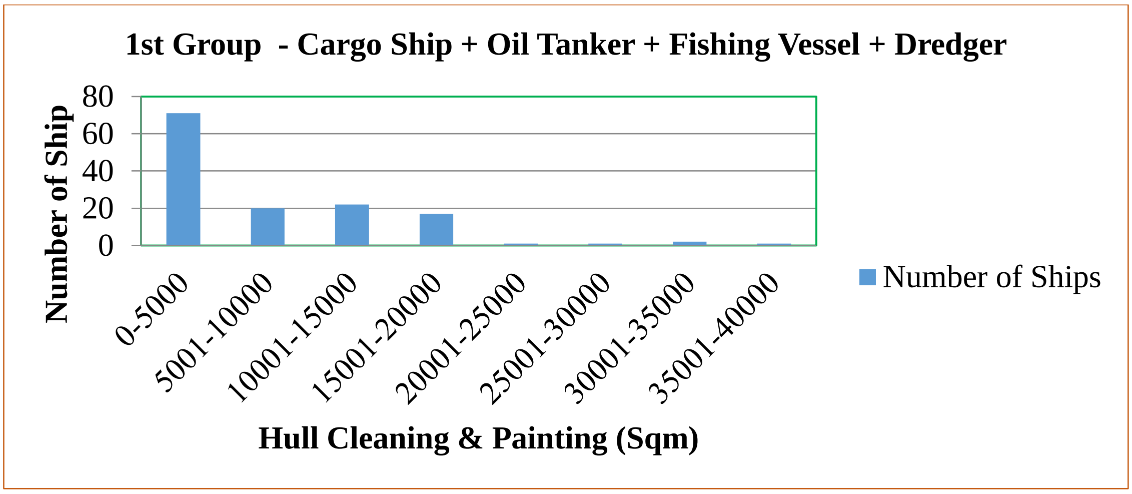
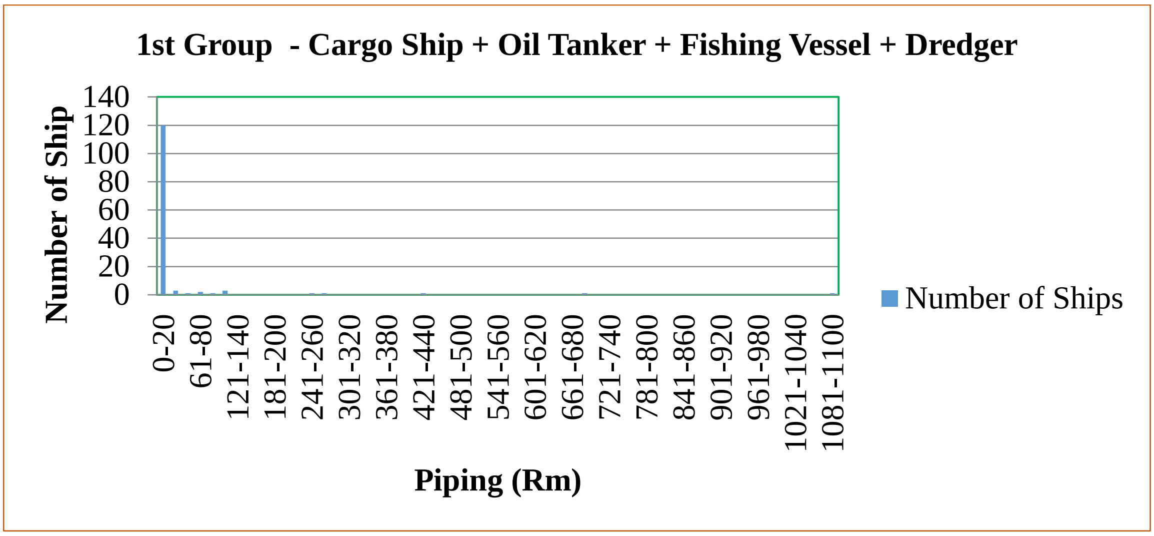


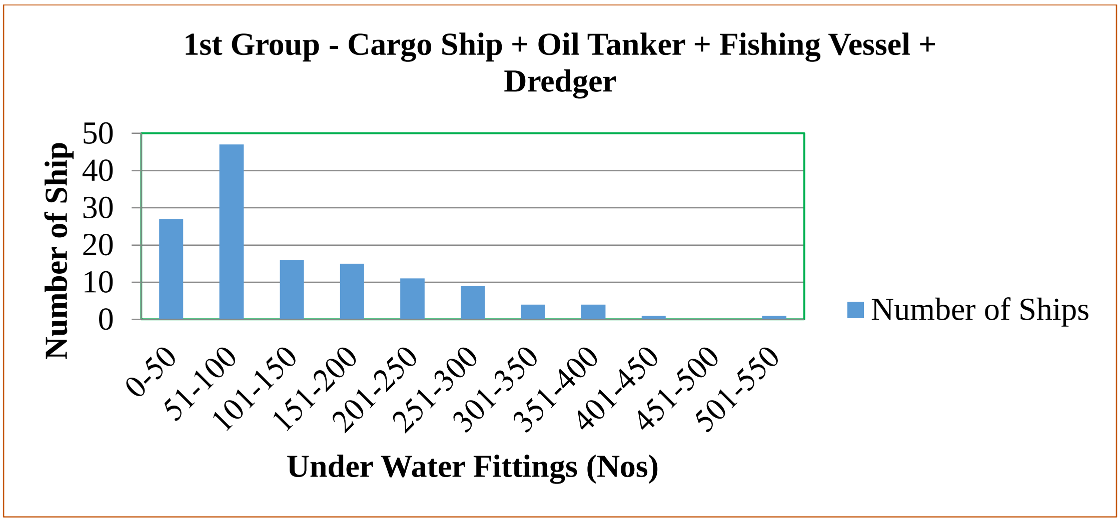
Figure – 7: Number of Ship vs Hull Cleaning & Painting (Sqm)

Figure 8 states the distribution of piping works of sample data with a mean and standard deviation of 28.89 and 128.56 respectively and explains that 88.89% of the samples have piping works within 20 rm. Thus, the result from these data will not be affected by piping works beyond 20 rm:



<u>Figure – 8: Number of Ship vs Piping (Rm)</u>

Figure 9 states the distribution of underwater fittings works of sample data with a mean and standard deviation of 129.92 and 102.07 respectively and explains that 99% of the samples contain underwater fittings works within 400 nos. Thus, the result from these data will not be affected by underwater fittings works beyond 400 nos:



<u>Figure – 9: Number of Ship vs Under Water Fittings (Nos)</u>

Figure 10 states that only 0.74% of the samples contain above water fitting works out of 135 in number sample. Thus, this data will not have any effect on the result:

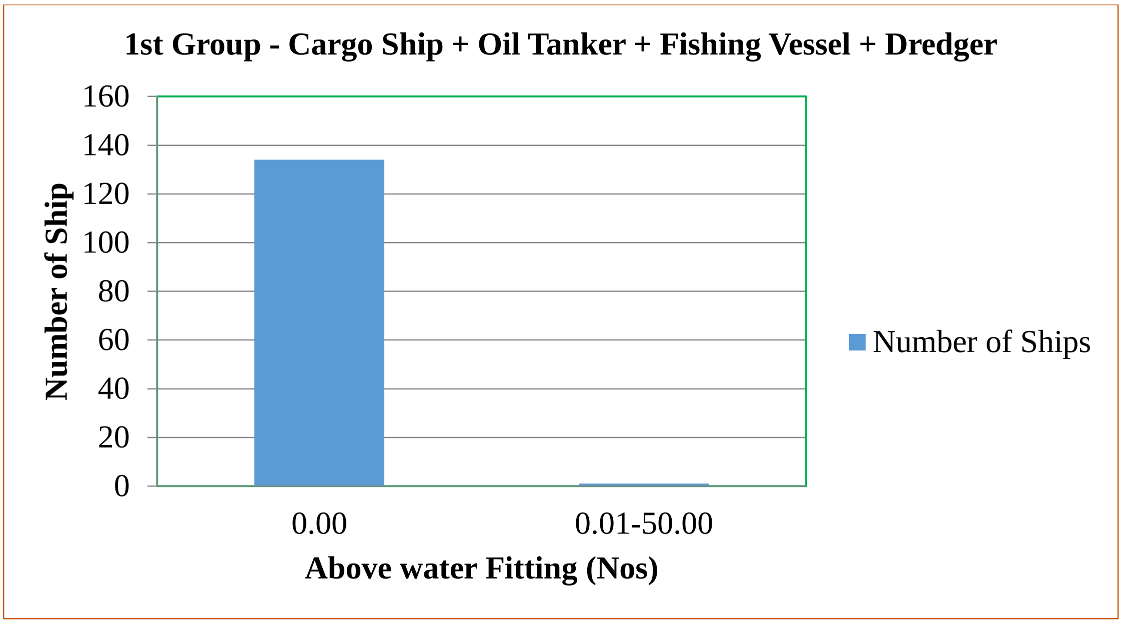


Figure – 10: Number of Ship vs Above water Fitting (Nos)

Figure 11 states that only 1.48% of the samples contain machinery & equipment works out of 135 in number sample. Thus, this data will not have any effect on the result:

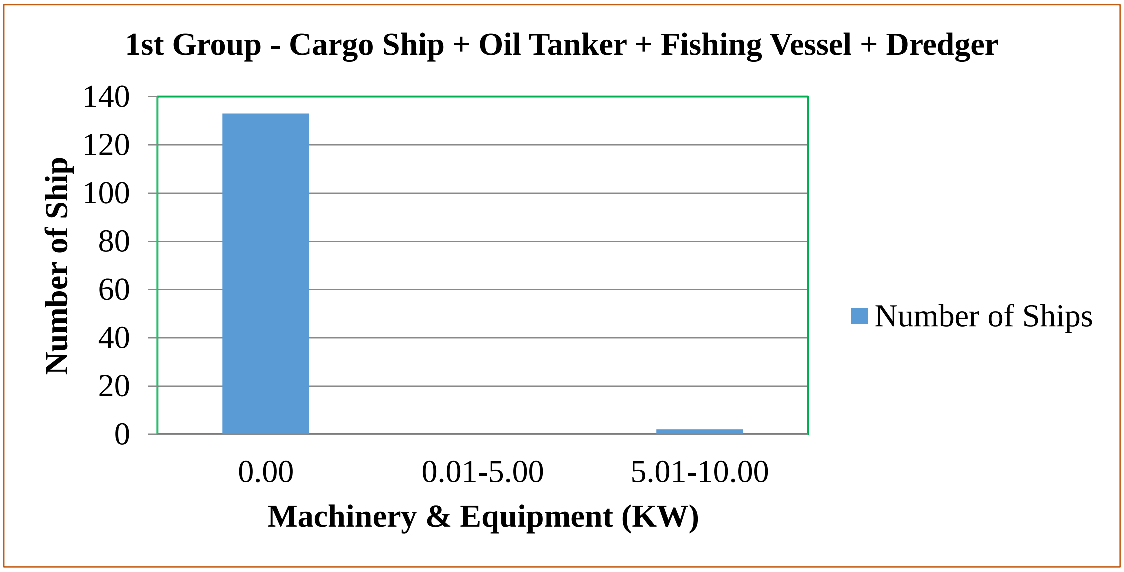


Figure – 11: Number of Ship vs Machinery & Equipment (KW)

6.2 Number of Graphs (Man-day vs Independent Variables) for Cargo Ship, Fishing vessel, Oil Tanker, Dredger and Barge

98% of the samples is within 17,500 tons and a positive and linear relationship exists between ship repairing labour (Man day) and deadweight as depicted in figure 12 below:

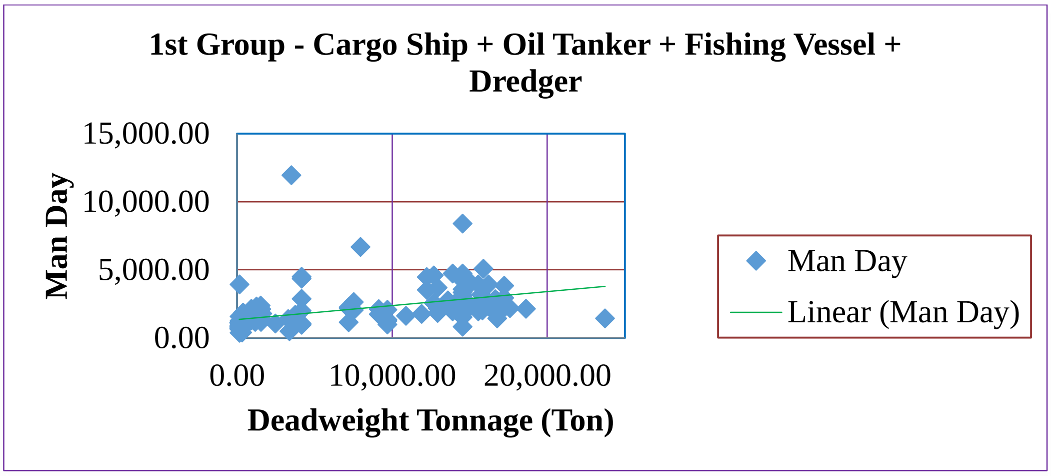


Figure – 12: Man Day vs Deadweight Tonnage (Ton)

99% of the samples is within 27,500 tons and figure 13 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

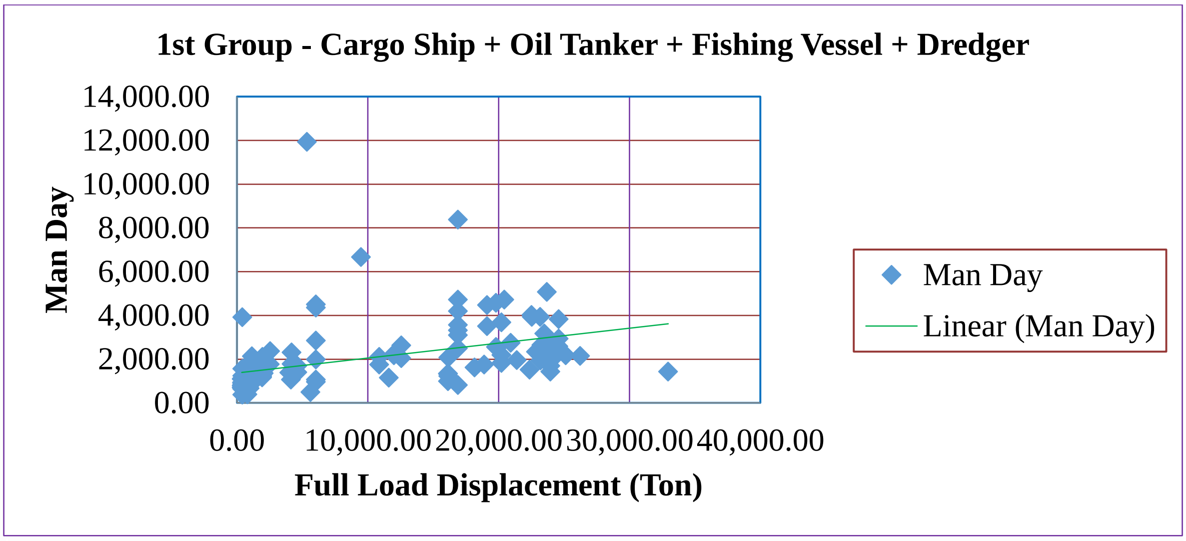


Figure – 13 : Man Day vs Full Load Displacement (Ton)

99% of the samples are within 20,000 sqm and figure 14 indicates positive and linear relationship between ship repairing labour (Man day) and lightweight displacement as follows:

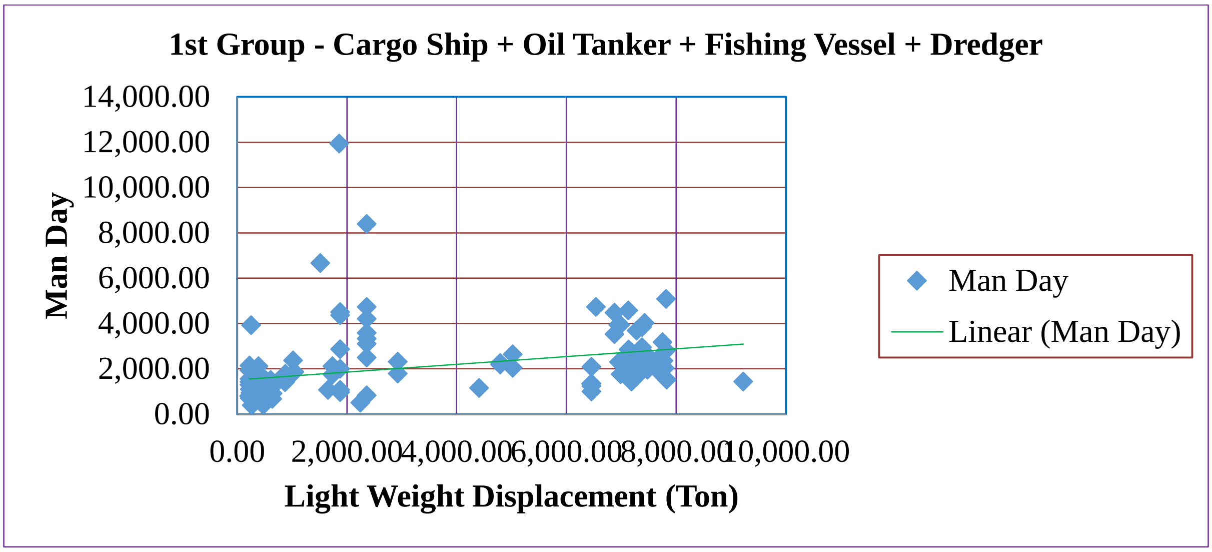


Figure – 14 : Man Day vs Light Weight Displacement (Ton)

96% of the samples fell within 40 years states a positive and linear relationship between ship repairing labour (Man day) and age as shown in figure 15 below:

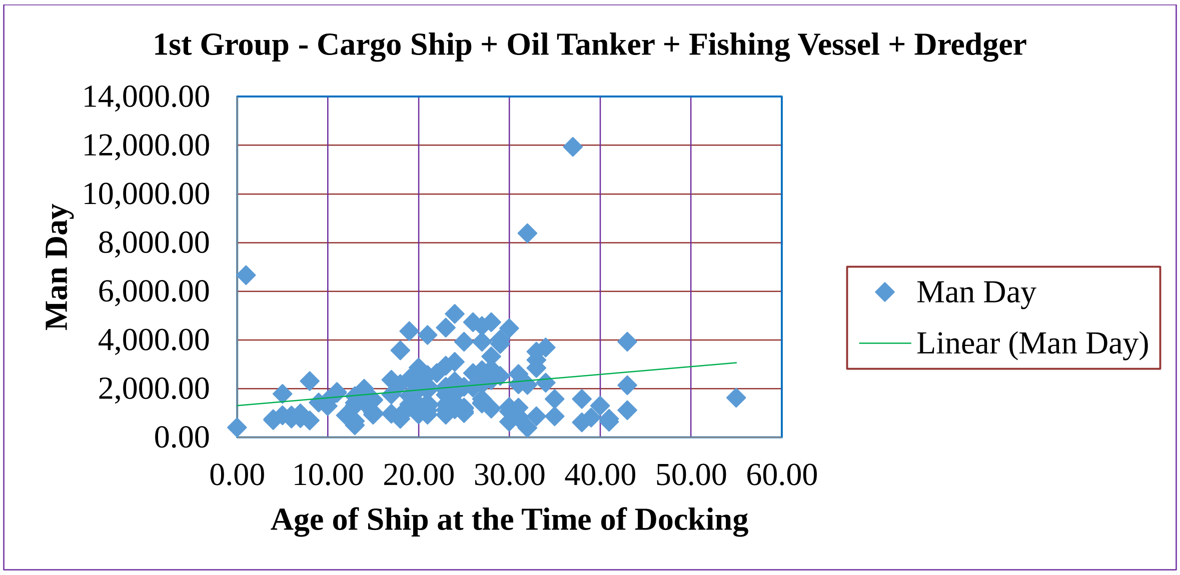
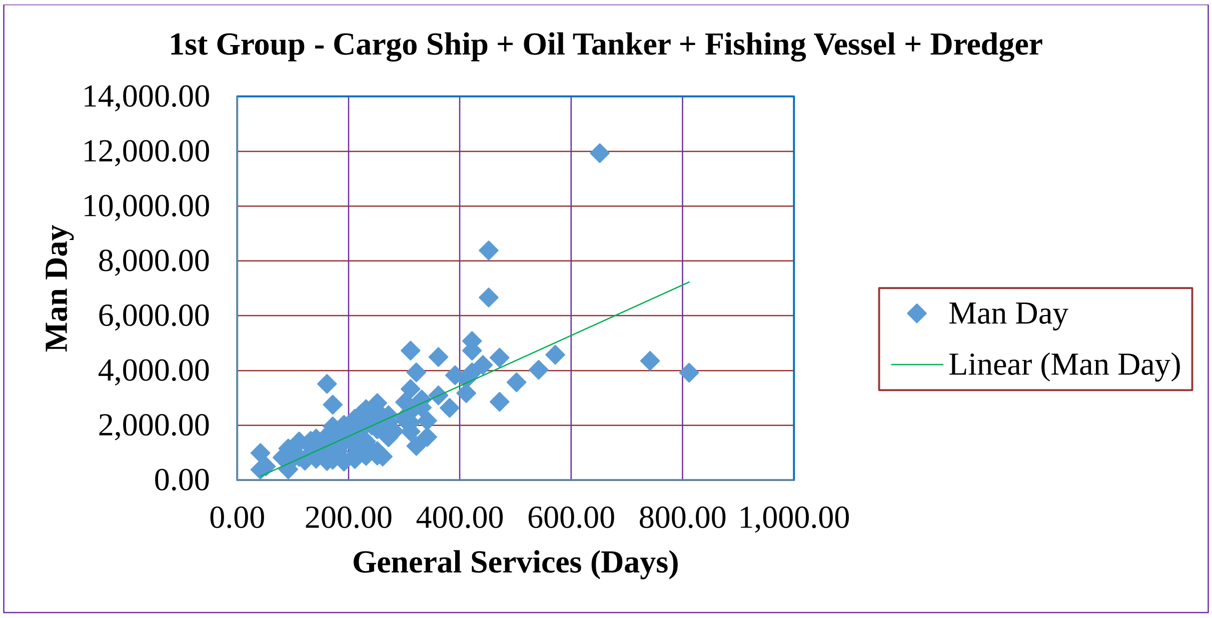


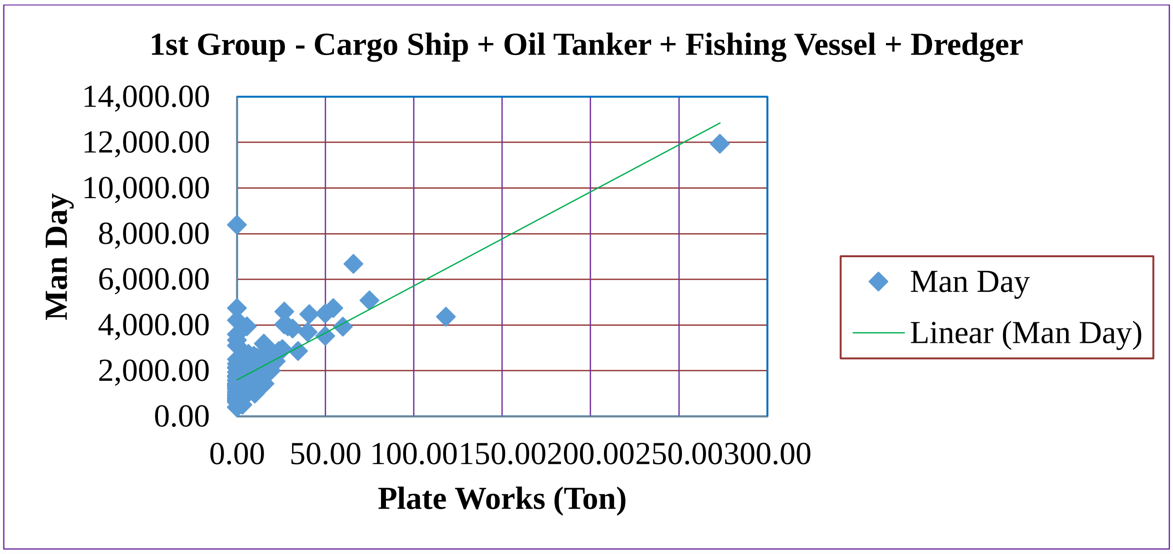
Figure – 15: Man Day vs Age of Ship at the Time of Docking

96% of the samples fell within 500 days shows positive and linear relationship between ship repairing labour (Man day) and general service works as shown in figure 16 below:



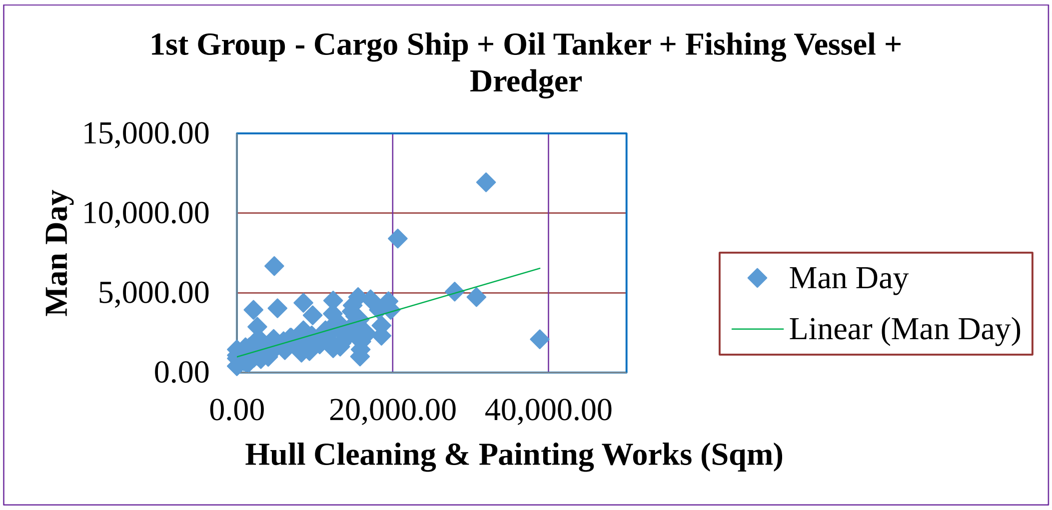
<u>Figure – 16 : Man Day vs General Services (Days)</u>

96% of the samples fall within 50 tons and therefore, positive and linear relationship develops between ship repairing labour (Man day) and plate works as shown in figure 17 below:



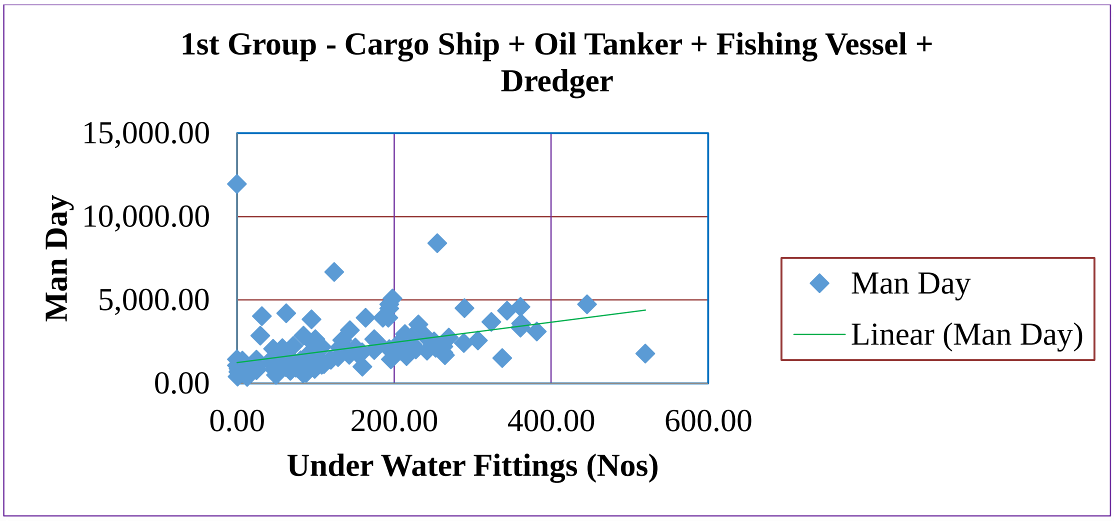
<u>Figure – 17: Man Day vs Plate Works (Ton)</u>

96% of the samples are within 20,000 sqm and figure 18 depicts positive and linear relationship between ship repairing labour (Man day) and full load displacement as follows:



<u>Figure – 18: Man Day vs Hull Cleaning & Painting Works (Sqm)</u>

99% of the samples fall within 400 nos. A positive and linear relationship develops between ship repairing labour (Man day) and under water fittings as shown in figure 19 below:



<u>Figure – 19: Man Day vs Under Water Fittings (Nos)</u>

0.74% of the samples forms data among out of 135 in number samples. That's why, less significant positive relationship exists between ship repairing labour (Man day) and above water fittings as shown in figure 20 below:

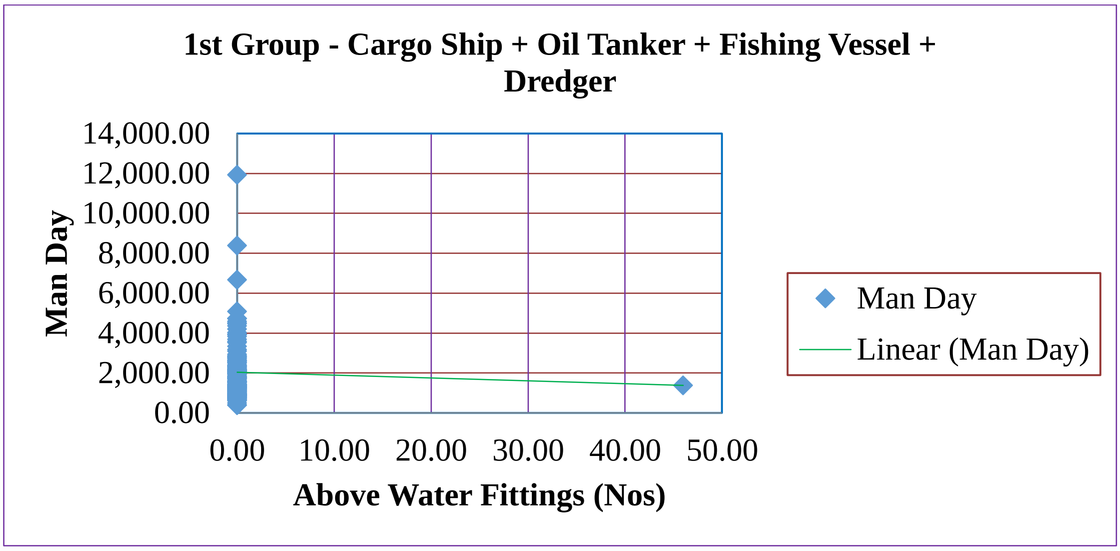


Figure – 20: Man Day vs Above Water Fittings (Nos)

1.48% of the samples forms data among out of 135 in number samples. That's why, less significant positive relationship exists between ship repairing labour (Man day) and machinery & equipment as shown in figure 21 below:

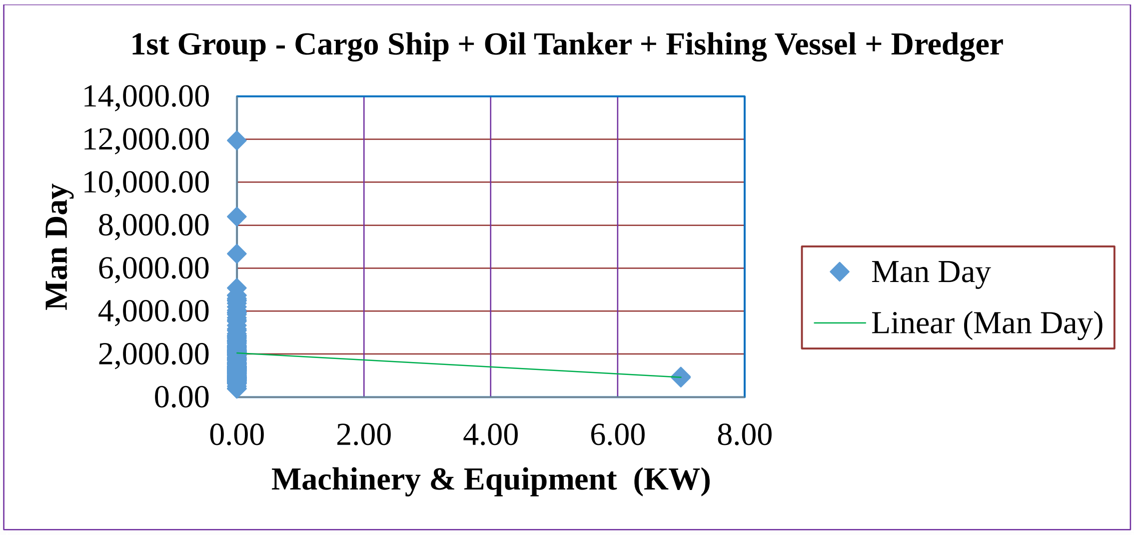


Figure – 21: Man Day vs Machinery & Equipment (KW)

6.3 Number of Graphs (No. of Ships vs Independent Variables) for Warship

Figure 22 states the distribution of full load displacement of sample data with a mean and standard deviation of 851.4 and 896.74 respectively and shows that majority of samples 92.5% fall within 2100 tonnes full load displacement and hence the result derived from statistical analysis will not be affected by the samples beyond that full load displacement:

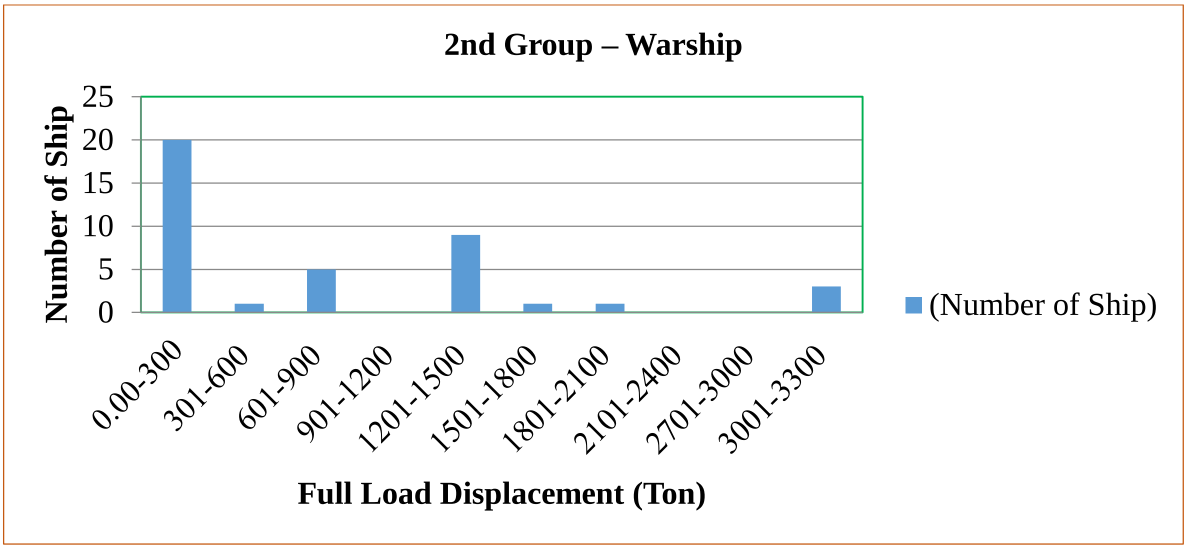


Figure – 22: Number of Ship vs Full Load Displacement (Ton)

Figure 23 shows that majority of samples 92.5% fall within 1785 tonnes lightweight tonnage and hence the result derived from statistical analysis will not be affected by the samples beyond that lightweight displacement:

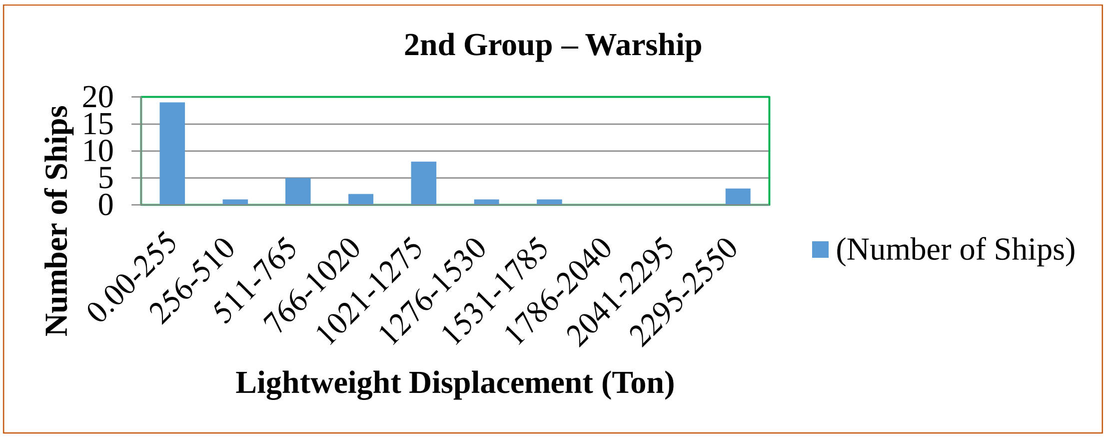


Figure – 23: Number of Ships vs Lightweight Displacement (Ton)

Figure 24 states the distribution of age of sample data with a mean and standard deviation of 28.58 and 10.34 respectively and majority of samples 90% fall within 40 years of age showing the samples beyond that will not be affect the result of statistical analysis:

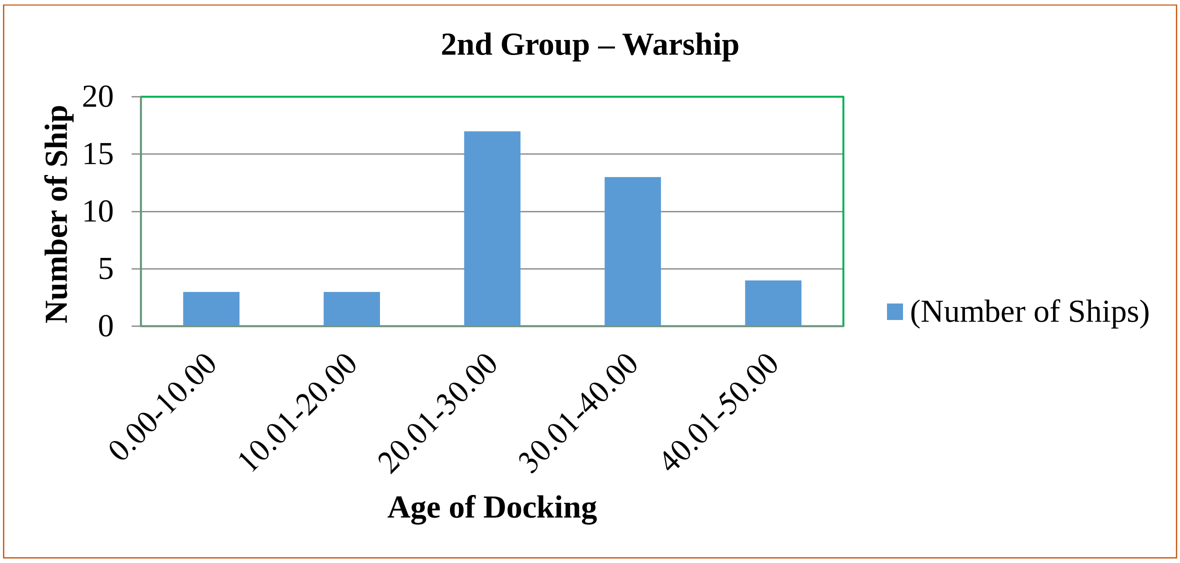


Figure – 24: Number of Ship vs Age of Docking

Figure 25 points out the distribution of general services works of sample data with a mean and standard deviation of 186.25 and 120.08 respectively and that 93% of the samples contain general services works of 350 days. Thus, the result from these data will not be affected by general services works beyond 350 days:

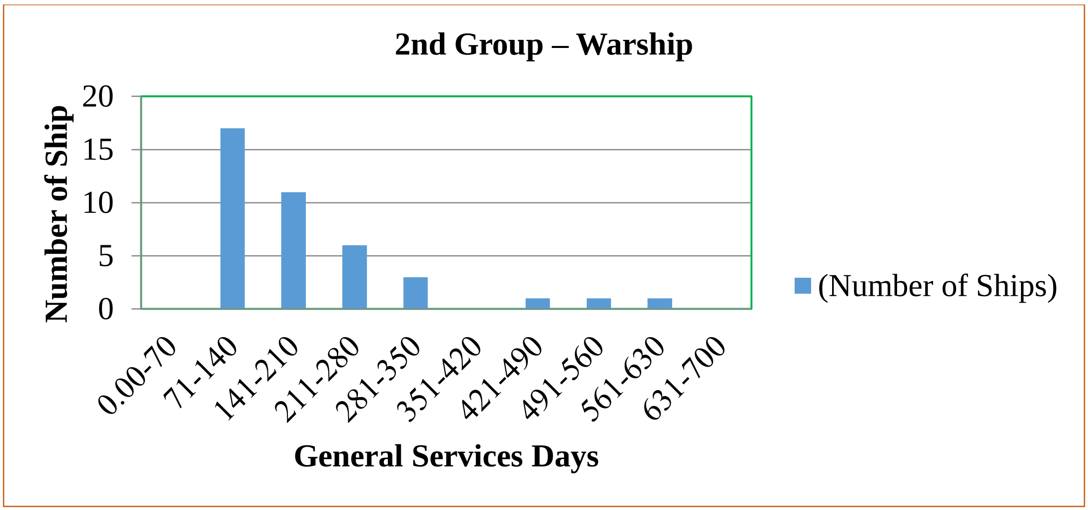


Figure – 25: Number of Ship vs General Services Days

Figure 26 states the distribution of plate works of sample data with a mean and standard deviation of 0.39 and 1.38 respectively and figures out that 98% of the samples contain plate works below 3.6 tons. Thus, the result from these data will not be affected by plate works beyond 3.6 tons:

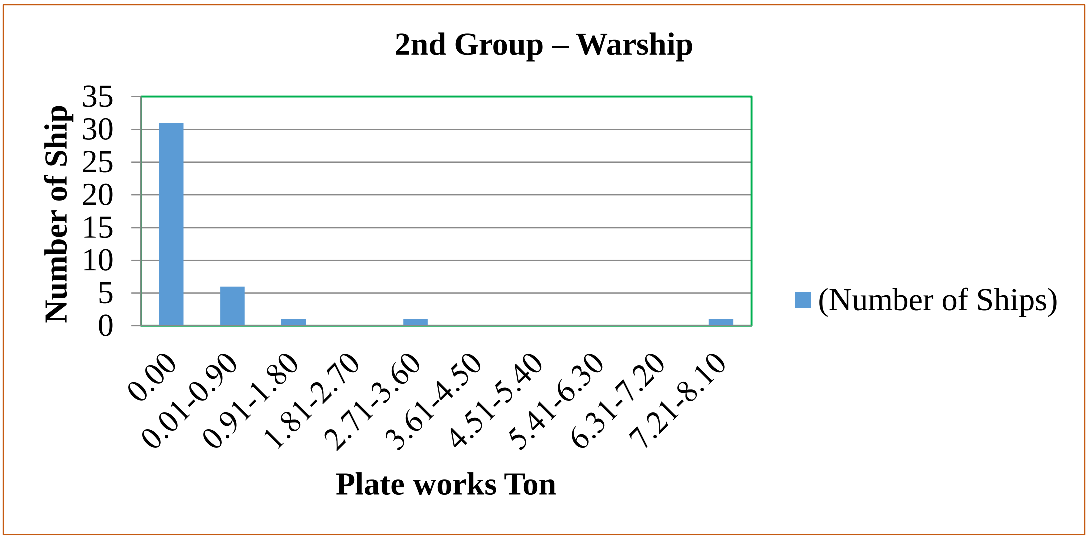


Figure – 26: Number of Ship vs Plate works Ton

Figure 27 states the distribution of hull cleaning & painting works of sample data with a mean and standard deviation of 697.21 and 1051.10 respectively and states that 90% of the samples contain hull cleaning & painting works beyond 2050 sqm. Thus, the result from these data will not be affected by hull cleaning & painting works beyond 2050 sqm:

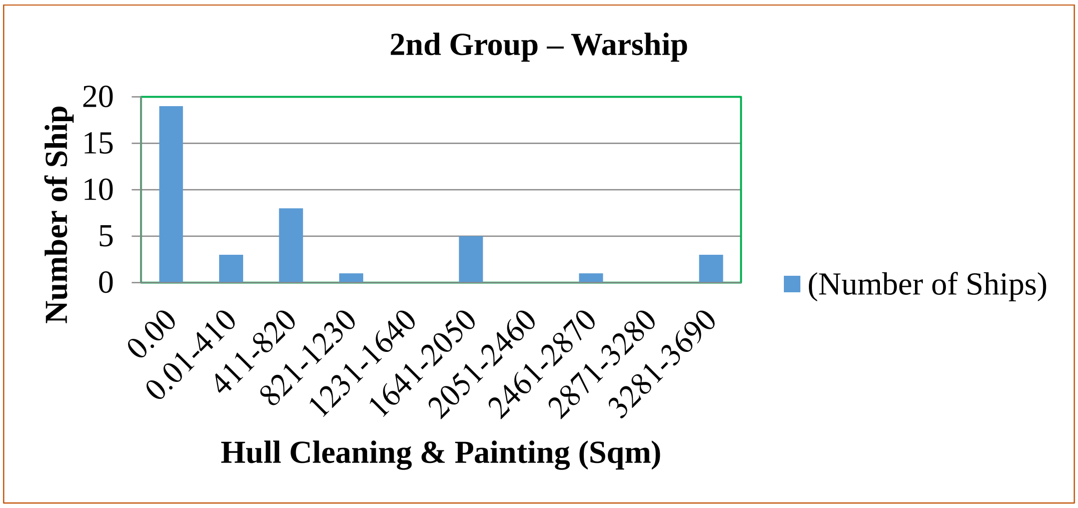


Figure – 27: Number of Ship vs Hull Cleaning & Painting (Sqm)

Figure 28 shows the distribution of piping works of sample data with a mean and standard deviation of 7.21 and 28.48 respectively and that 95% of the samples contain piping 20 rm. Thus, the result from these data will not be affected by piping works beyond 20 rm:

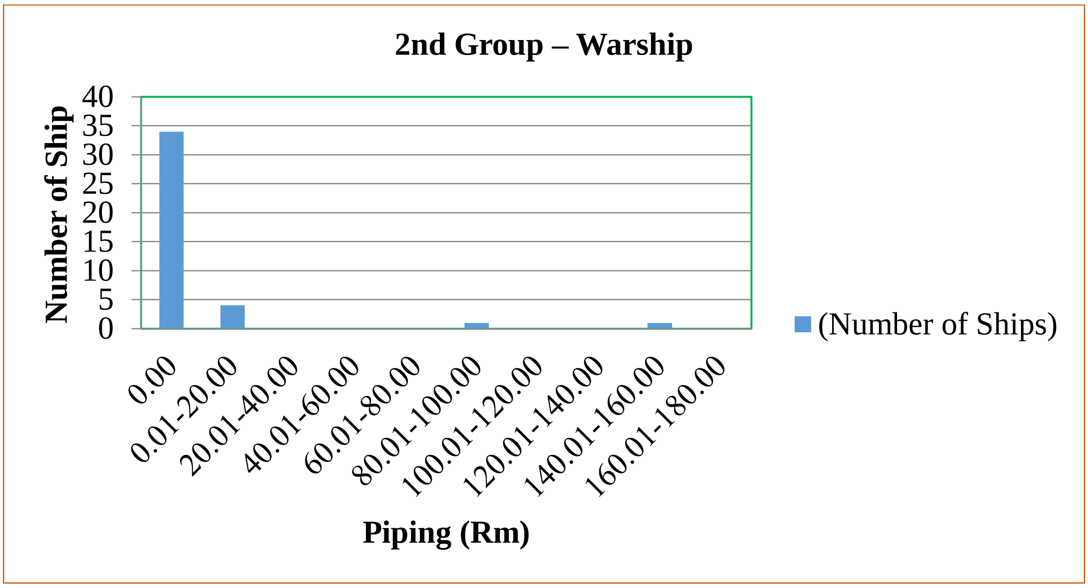


Figure – 28: Number of Ship vs Piping (Rm)

Figure 29 shows the distribution of underwater fittings works of sample data with a mean and standard deviation of 7.25 and 20.03 respectively and that 95% of the samples contain under water fittings 36 Nos. Thus, the result from these data will not be affected by underwater fittings works beyond 36 Nos:

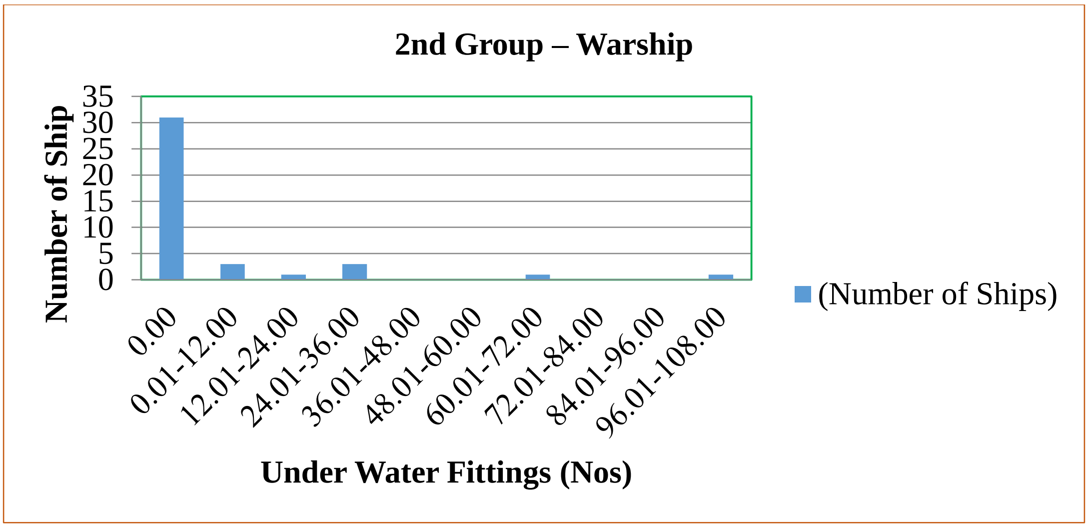


Figure – 29 : Number of Ship vs Under Water Fittings (Nos)

Figure 30 states that no samples contain above water fitting works. Thus, this works will not have any effect on the result:

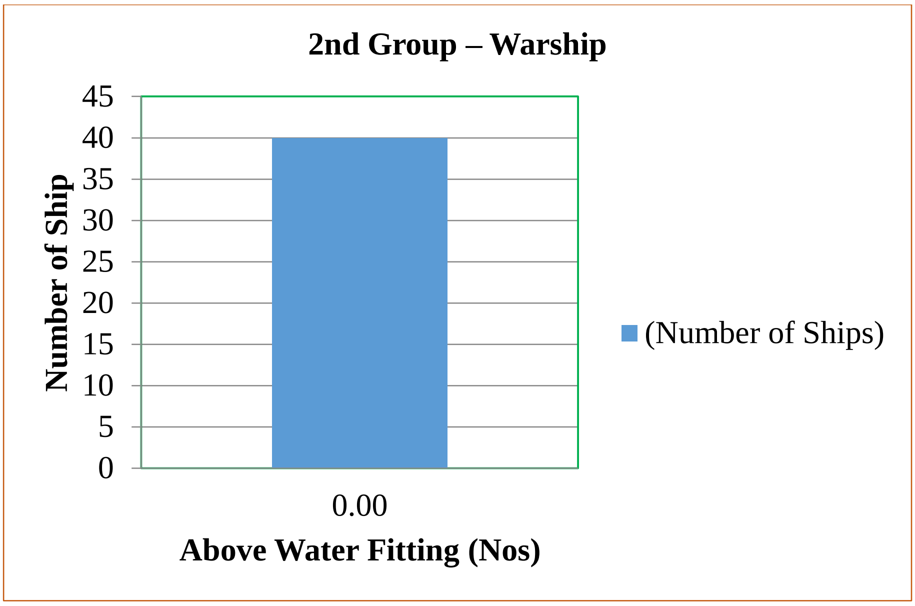


Figure – 30: Number of Ship vs Above Water Fitting (Nos)

Figure 31 states that only 2.5% of the samples contain machinery & equipment works out of 40 in number samples. Thus, this data will not have any effect on the result:

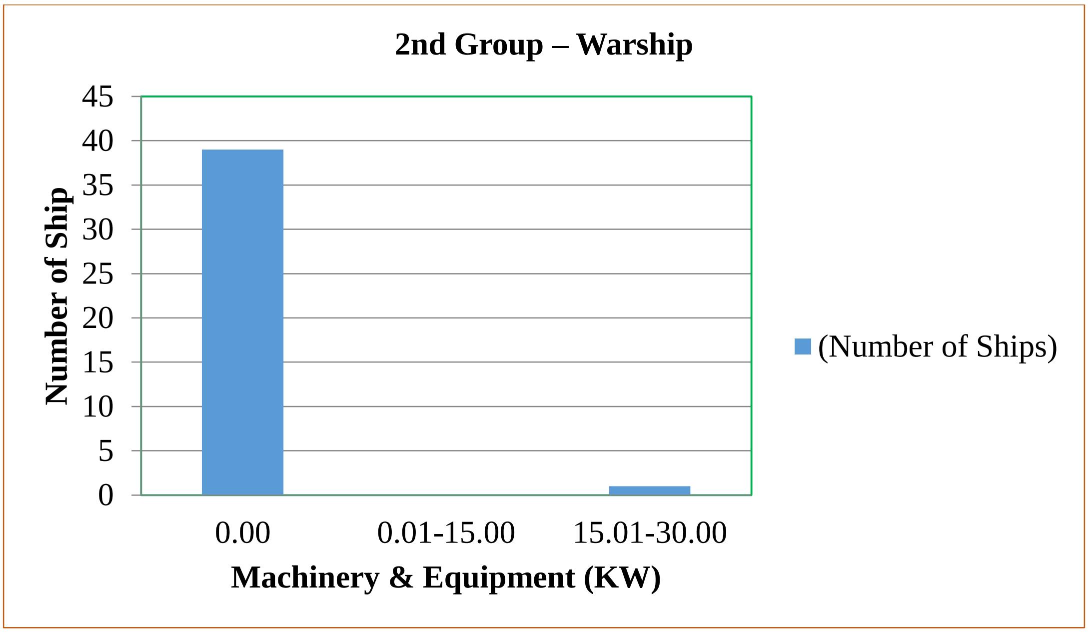


Figure – 31: Number of Ship vs Machinery & Equipment (KW)

6.4 Number of Graphs (Man-day vs Independent Variables) for Warship

92.5% of the samples is within 2100 tons and figure 32 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

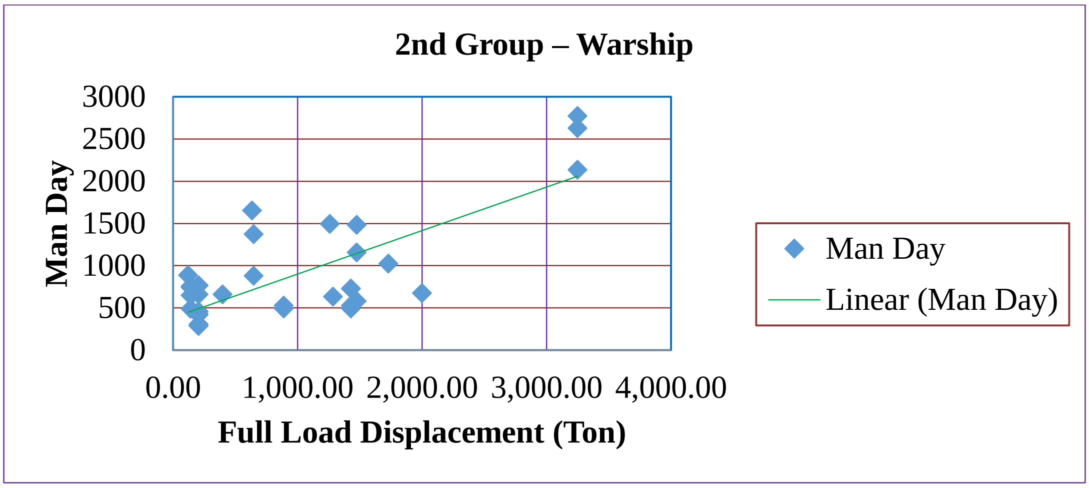


Figure – 32: Man Day vs Full Load Displacement (Ton)

92.5% of the samples is within 1785 tons and figure 33 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

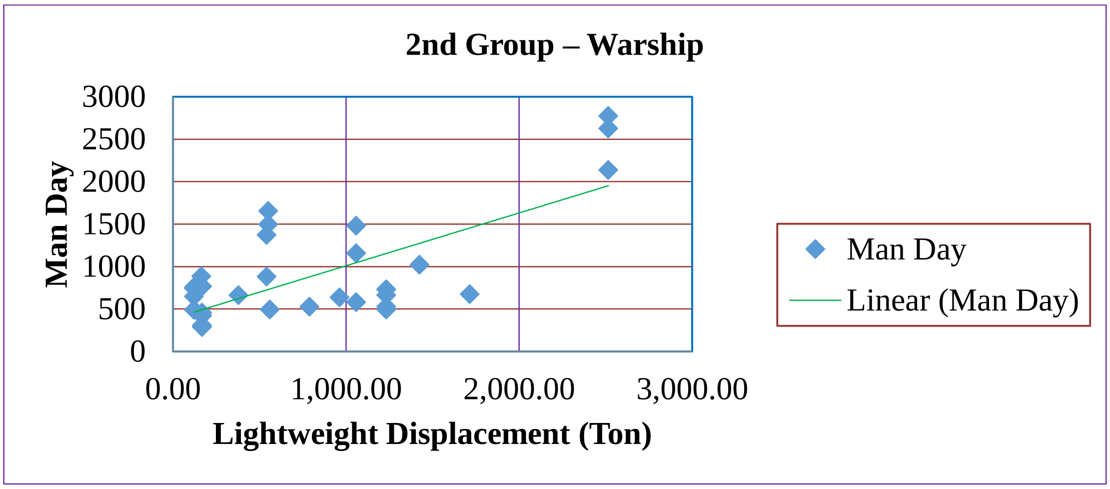


Figure – 33 : Man Day vs Lightweight Displacement (Ton)

90% of the samples is within 40 years and figure 34 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

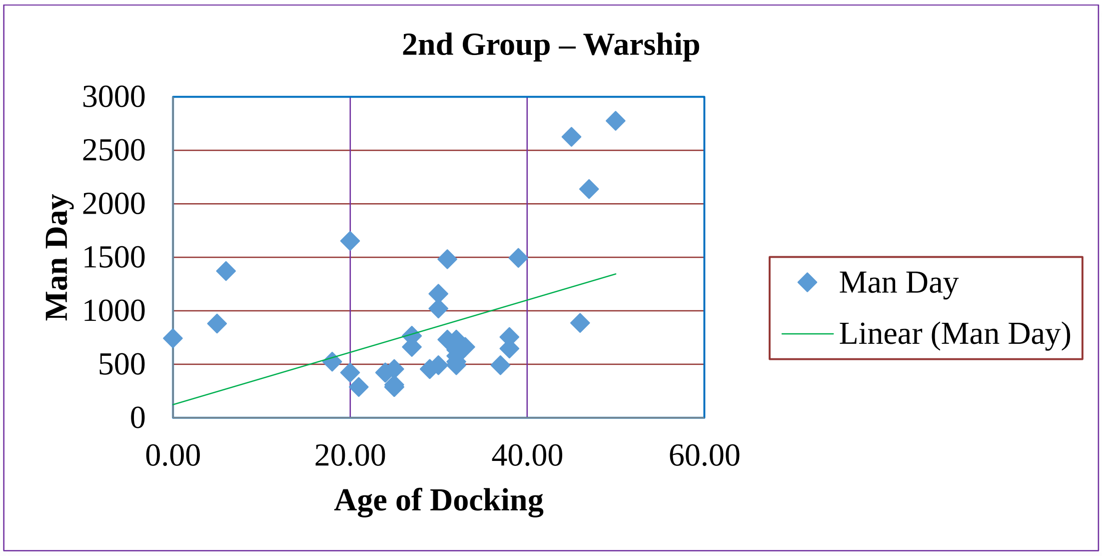


Figure – 34: Man Day vs Age of Docking

93% of the samples is within 350 days and figure 35 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

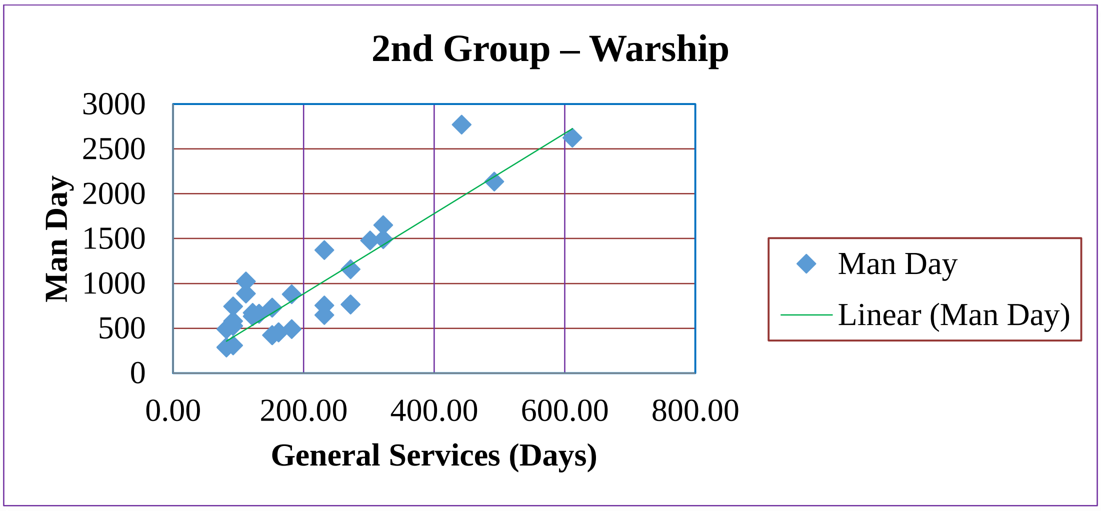


Figure – 35 : Man Day vs General Services (Days)

98% of the samples is within 3.6 tons and figure 36 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

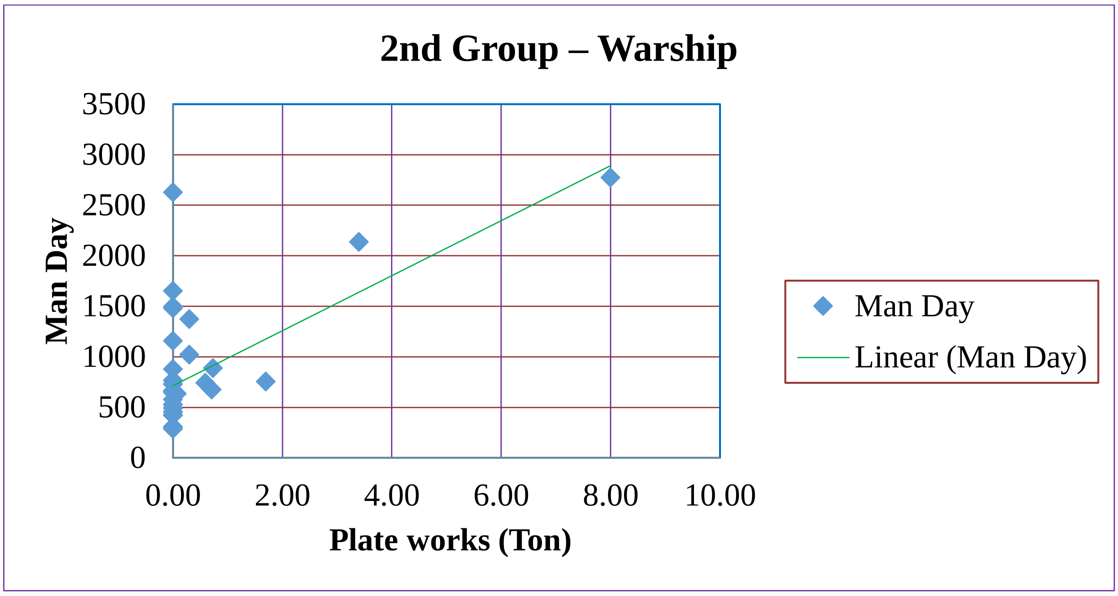


Figure – 36: Man Day vs Plate works (Ton)

90% of the samples is within 2050 sqm and figure 37 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

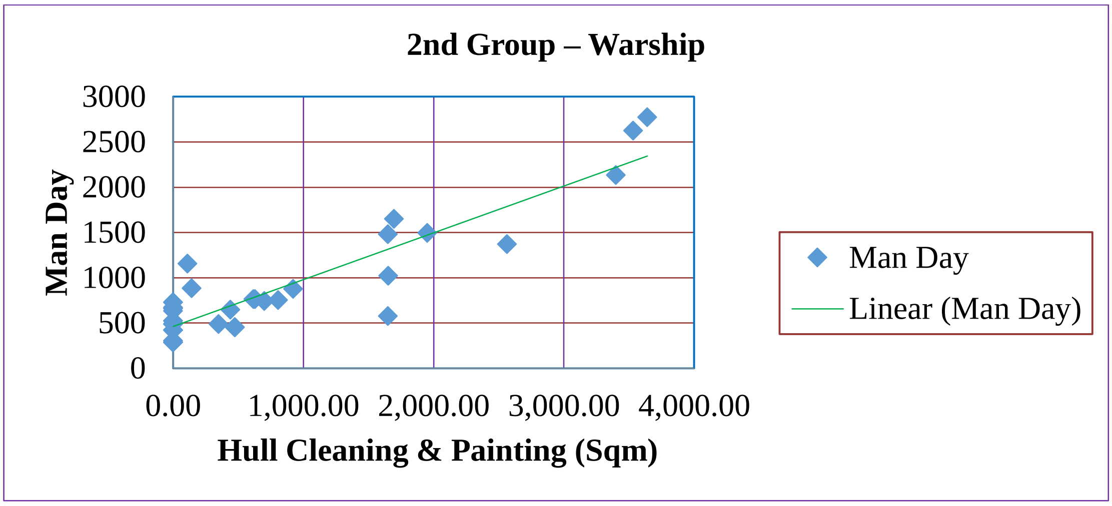


Figure – 37: Man Day vs Hull Cleaning & Painting (Sqm)

95% of the samples is within 20 rm and figure 38 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

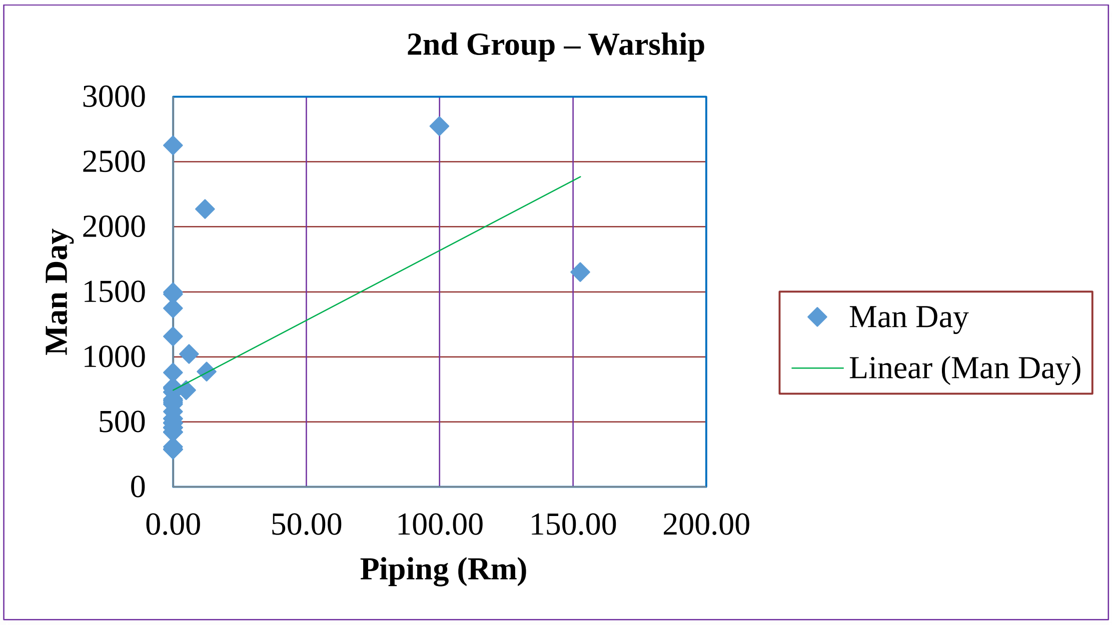


Figure – 38: Man Day vs Piping (Rm)

95% of the samples is within 36 nos and figure 39 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:

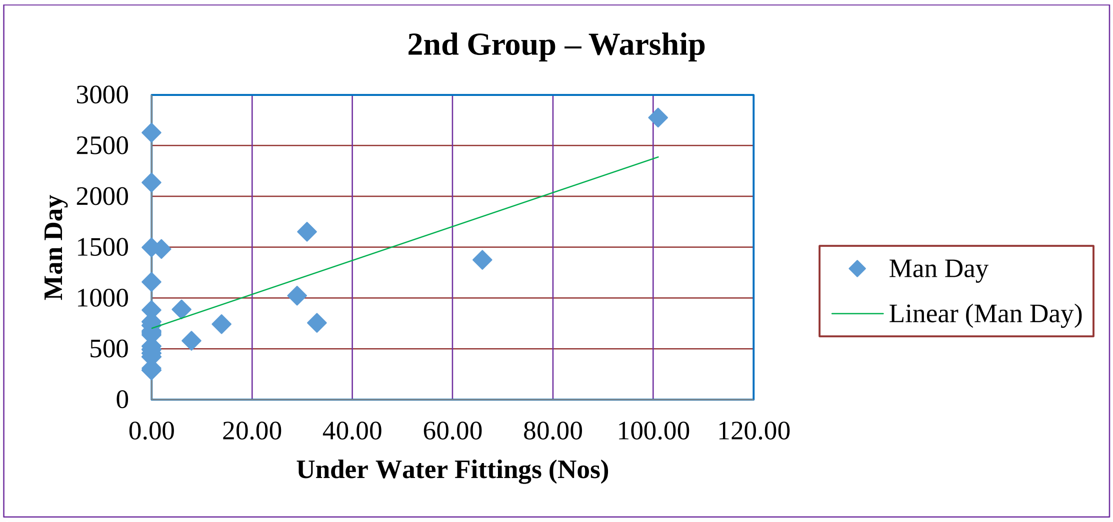


Figure – 39 : Man Day vs Under Water Fittings (Nos)

No samples contain above water fitting works out of 40 in number samples. That's why, no relationship exists between ship repairing labour (Man day) and above water fittings as shown in figure 40 below:

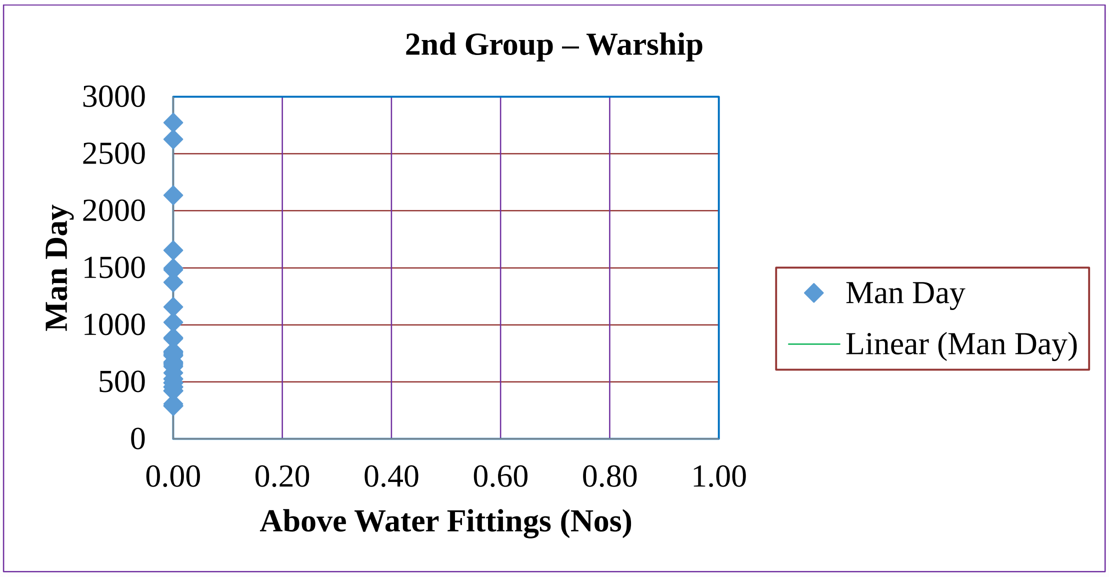


Figure – 40: Man Day vs Above Water Fittings (Nos)

2.5% of the samples forms data out of 41 in number samples. That's why, less significant positive relationship exists between ship repairing labour (Man day) and machinery & equipment as shown in figure 41 below:

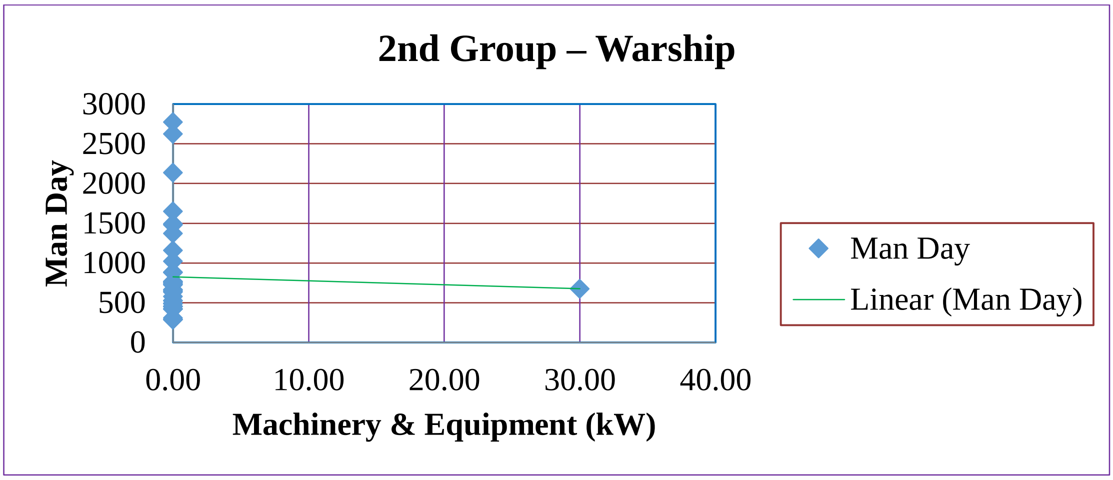


Figure – 41: Man Day vs Machinery & Equipment (kW)

6.5 Number of Graphs (No. of Ships vs Independent Variables) for Tug boat & Other Ships

Figure 42 points out the distribution of full load displacement of sample data with a mean and standard deviation of 1981.06 and 4972.22 respectively and that majority of samples 87% fall within 1000 tonnes full load displacement. Hence the result derived from statistical analysis will not be affected by the samples beyond that full load displacement:

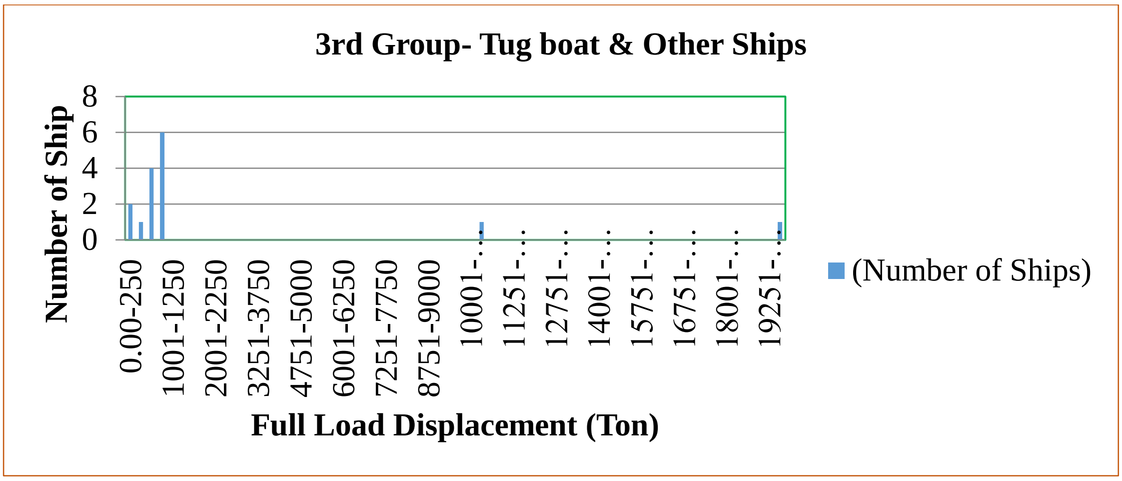


Figure – 42: Number of Ship vs Full Load Displacement (Ton)

Figure 43 shows that majority of samples 93% fall within 805 tonnes lightweight tonnage and hence the result derived from statistical analysis will not be affected by the samples beyond that lightweight displacement:

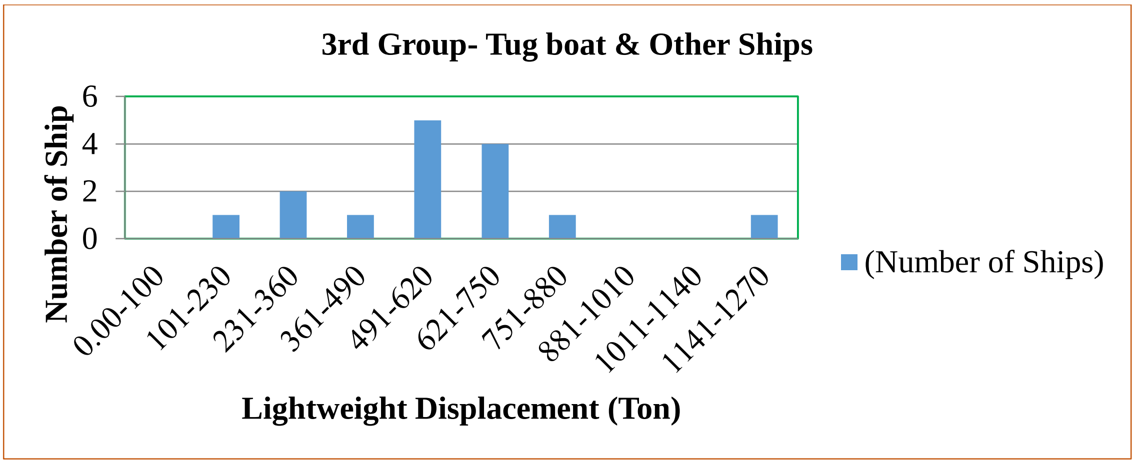


Figure – 43: Number of Ship vs Lightweight Displacement (Ton)

Figure 44 points out the distribution of age of sample data with a mean and standard deviation of 28.73 and 15.29 respectively and that majority of samples 73% fall within 40 years of age. Hence the result derived from statistical analysis will not be affected by the samples beyond that age:

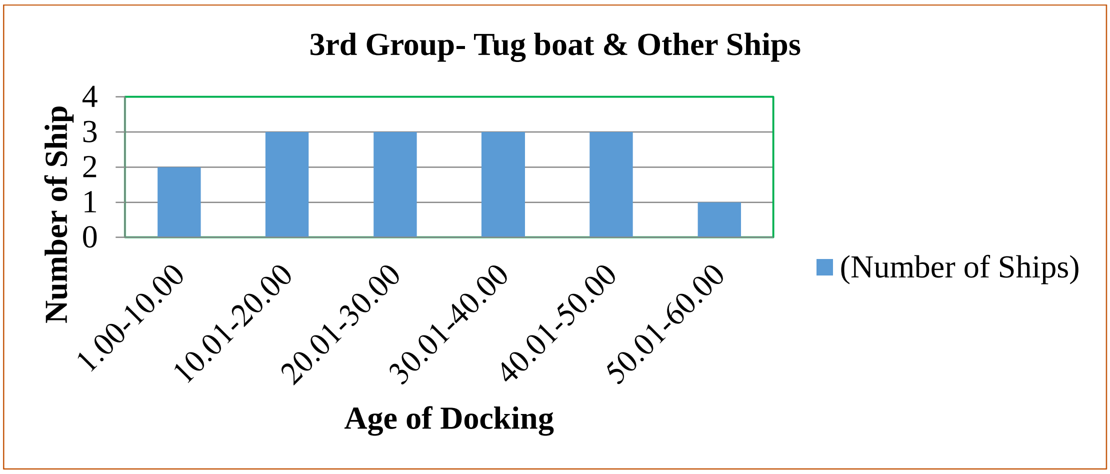


Figure – 44: Number of Ship vs Age of Docking

Figure 45 indicates the distribution of general services works of sample data with a mean and standard deviation of 416.67 and 252.53 respectively and that 93.33% of the samples contain general services works of 800 days. Thus, the result from these data will not be affected by general services works beyond 800 days:

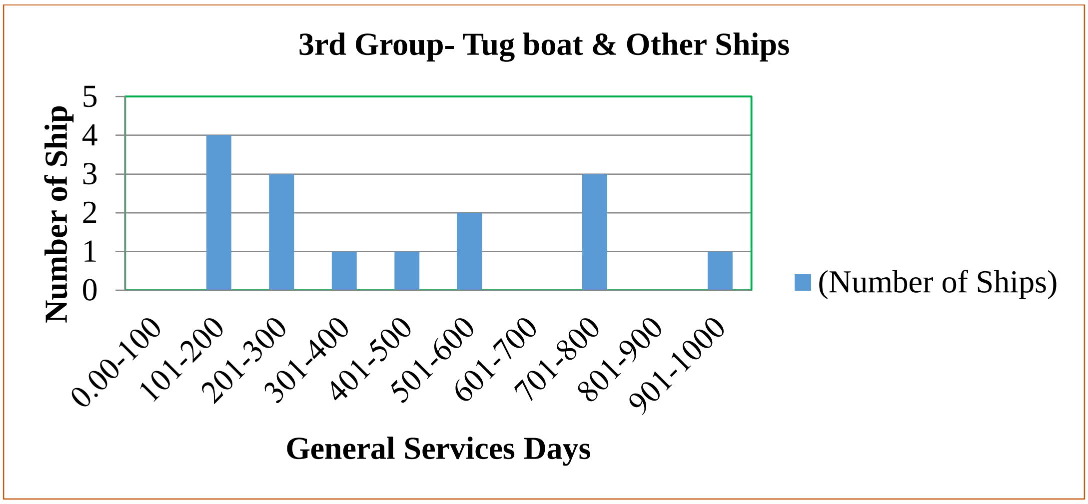


Figure – 45: Number of Ship vs General Services Days

Figure 46 indicates the distribution of plate works of sample data with a mean and standard deviation of 20.43 and 26.98 respectively and that 93.33% of the plate works 50 tons. Thus, the result from these data will not be affected by plate works beyond 50 tons:

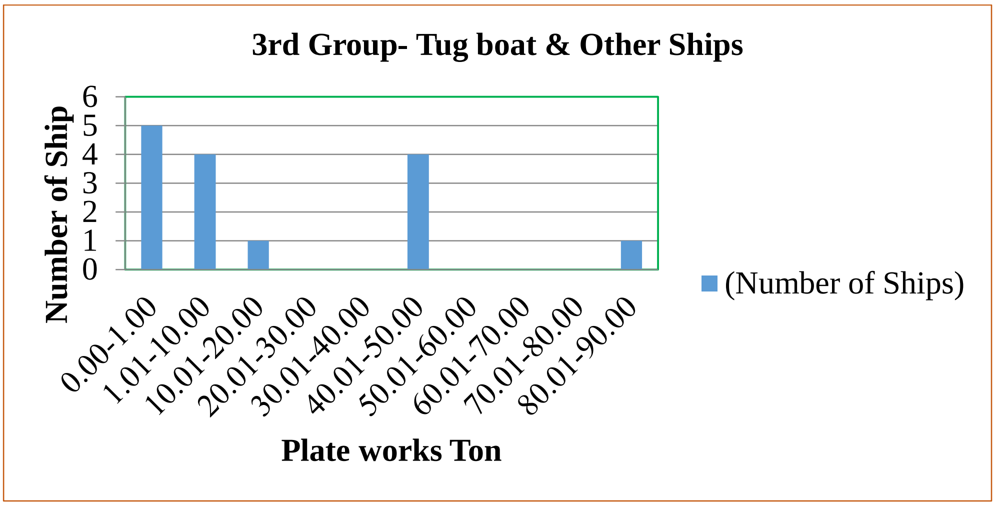


Figure – 46: Number of Ship vs Plate works Ton

Figure 47 indicates the distribution of hull cleaning & painting works of sample data with a mean and standard deviation of 2548.38 and 2909.69 respectively and that 80% of the hull cleaning & painting works 4500 sqm. Thus, the result from these data will not be affected by hull cleaning & painting works beyond 4500 sqm:

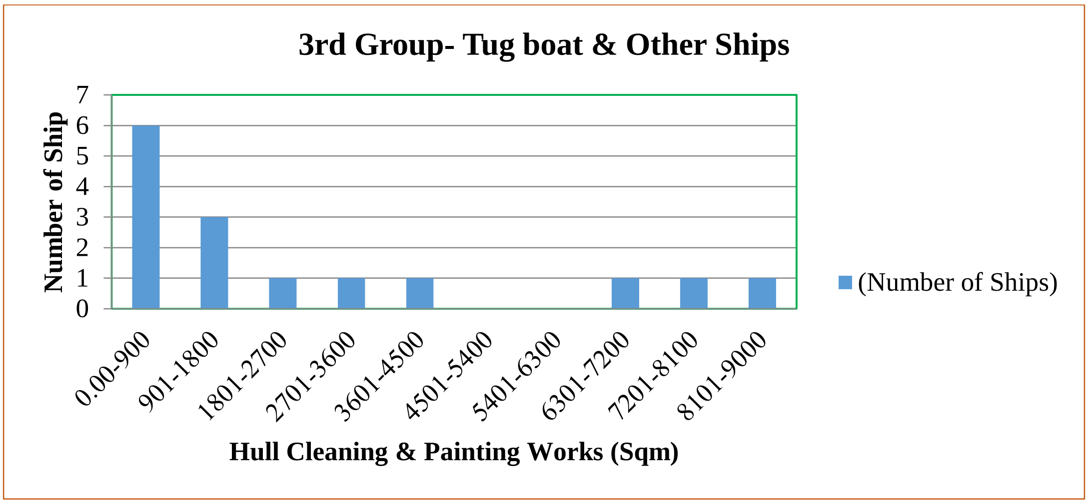


Figure – 47: Number of Ship vs Hull Cleaning & Painting Works (Sqm)

Figure 48 indicates the distribution of piping works of sample data with a mean and standard deviation of 103.30 and 132.25 respectively and that 86.67% of the piping works 270 rm. Thus, the result from these data will not be affected by piping works beyond 270 rm:

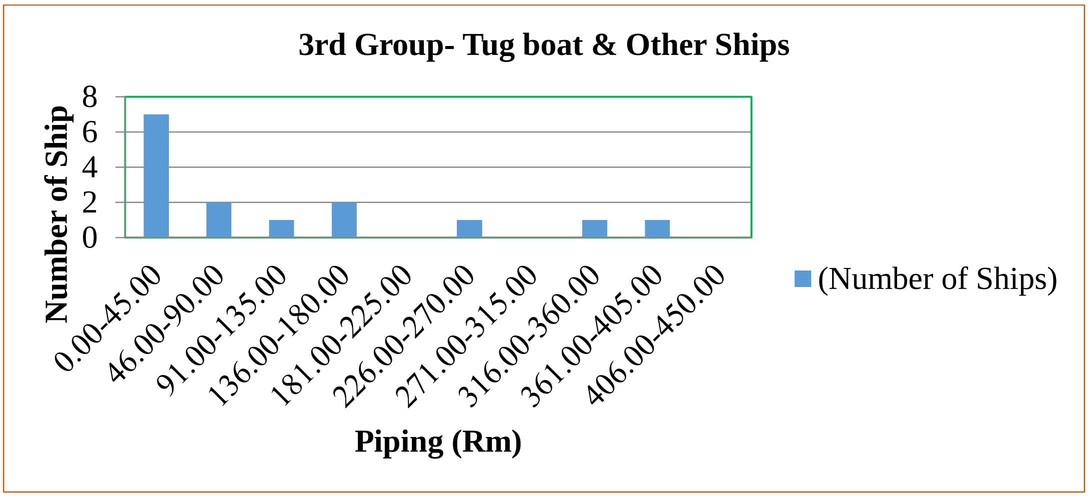


Figure – 48: Number of Ship vs Piping (Rm)

Figure 49 indicates the distribution of underwater fittings works of sample data with a mean and standard deviation of 48.67 and 33.92 respectively and states that 86.67% of the underwater fittings works 77 nos. Thus, the result from these data will not be affected by underwater fittings works beyond 77 nos:

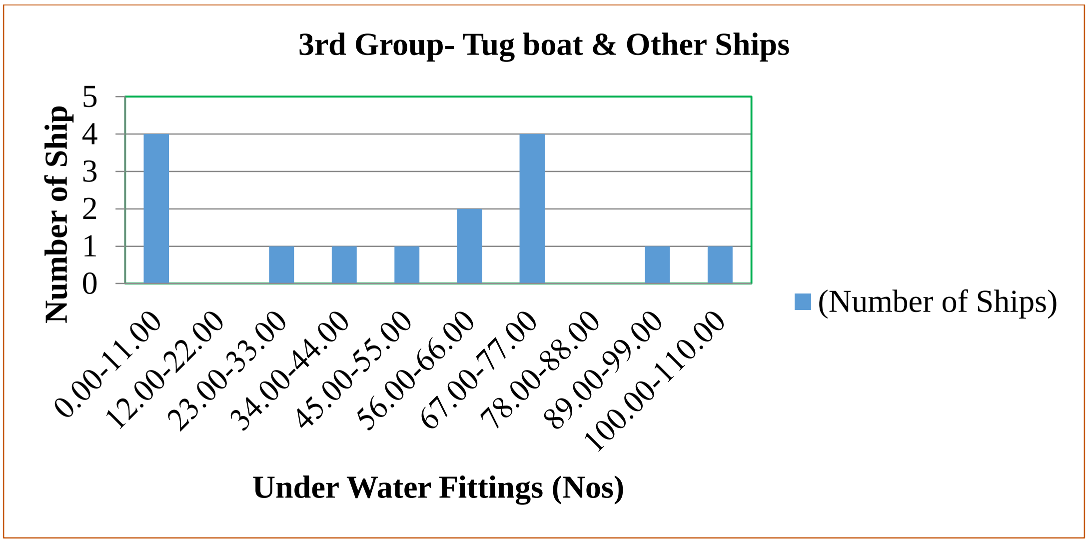


Figure – 49: Number of Ship vs Under Water Fittings (Nos)

Figure 50 indicates the distribution of above water fittings works of sample data with a mean and standard deviation of 8.53 and 14.59 respectively and that 86.67% of the above water fittings works 20 nos. Thus, the result from these data will not be affected by above water fittings works beyond 20 nos:

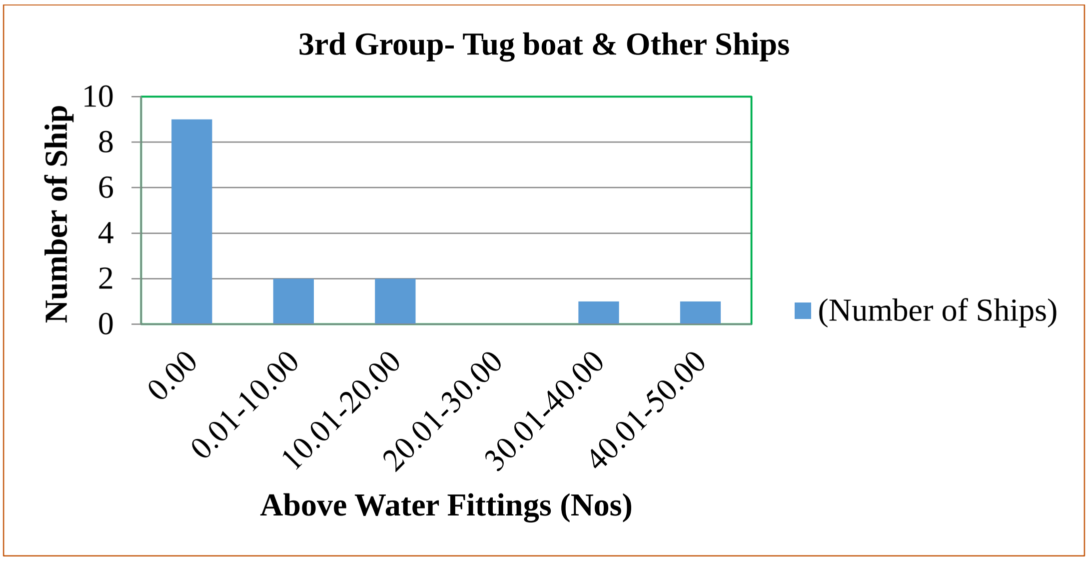


Figure – 50 : Number of Ship vs Above Water Fittings (Nos)

Figure 51 states that only 13.33% of the samples contain machinery & equipment works out of 15 in number samples. Thus, this data will not have any effect on the result:

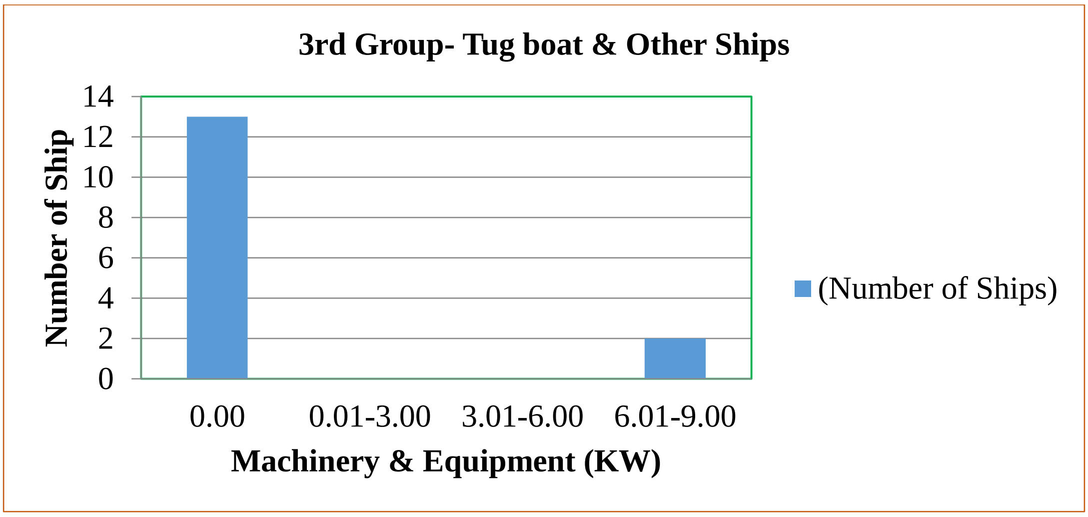
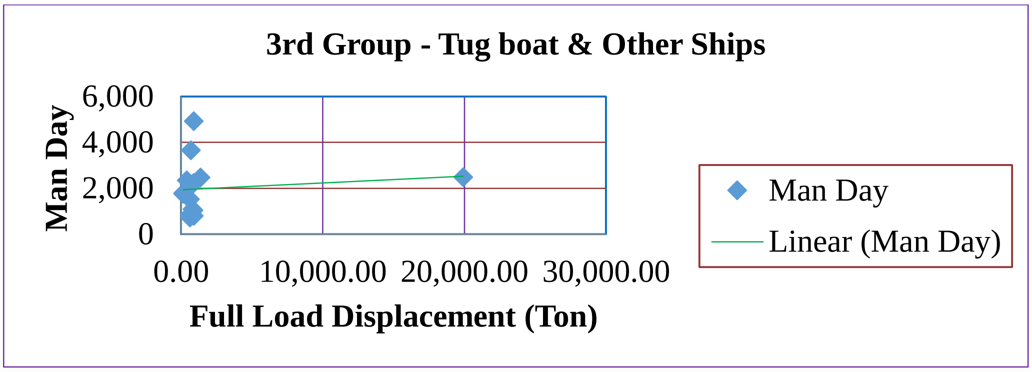


Figure – 51: Number of Ship vs Machinery & Equipment (KW)

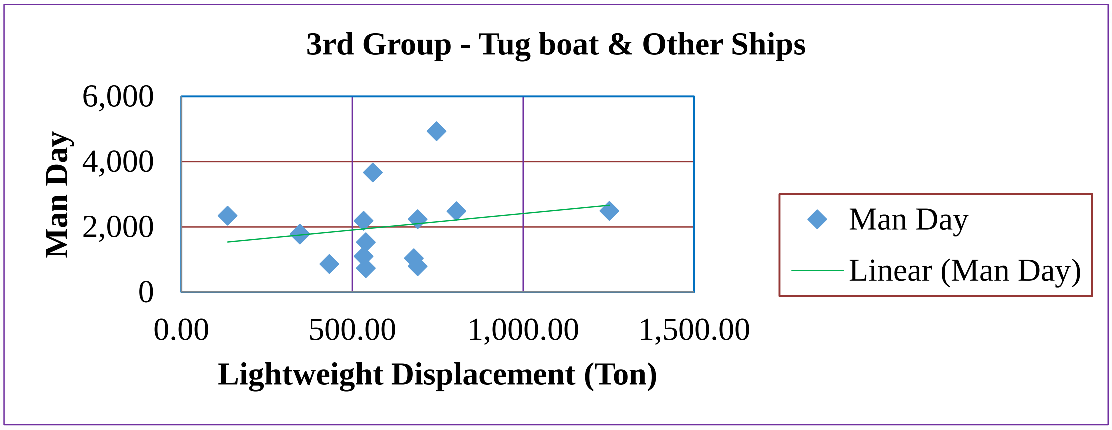
6.6 Number of Graphs (Man-day vs Independent Variables) for Tug Boat & Other Ships

87% of the samples is within 1000 tons and figure 52 shows ship repairing labour (Man day) against full load displacement with a positive and linear relationship as depicted in below:



<u>Figure – 52: Man Day vs Full Load Displacement (Ton)</u>

93% of the samples is within 805 tons and figure 53 shows ship repairing labour (Man day) against lightweight displacement with a positive and linear relationship as depicted in below:



<u>Figure – 53: Man Day vs Lightweight Displacement (Ton)</u>

73% of the samples is within 40 years of age and figure 54 shows ship repairing labour (Man day) against age with a positive and linear relationship as depicted in below:

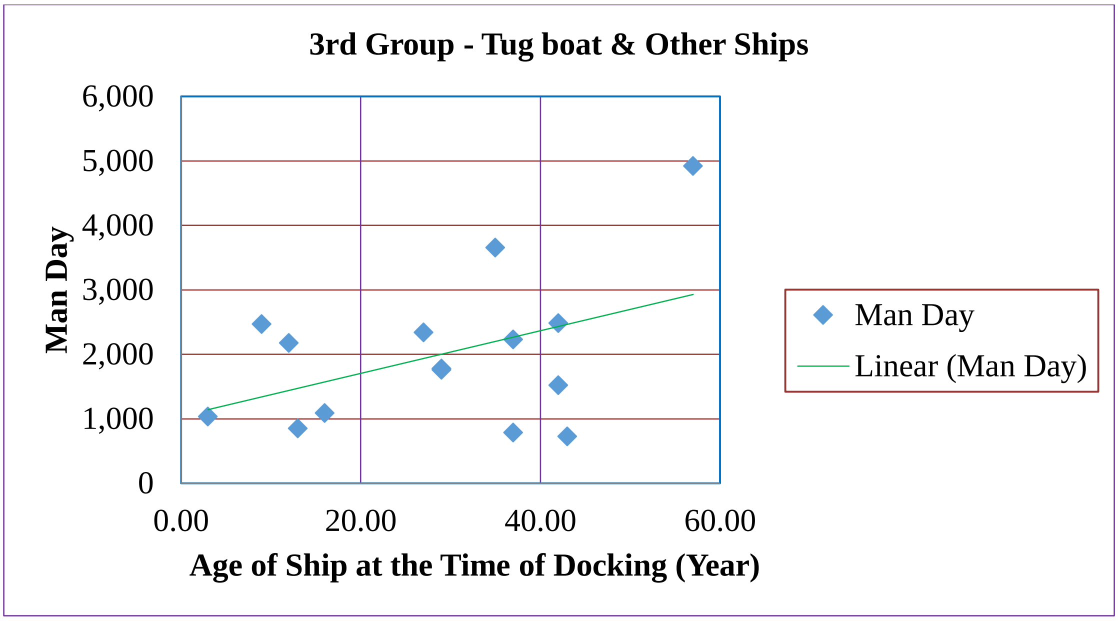


Figure – 54 : Man Day vs Age of Ship at the Time of Docking (Year)

93.33% of the samples is within 800 days and figure 55 shows ship repairing labour (Man day) against general service works (days) with a positive and linear relationship as depicted in below:

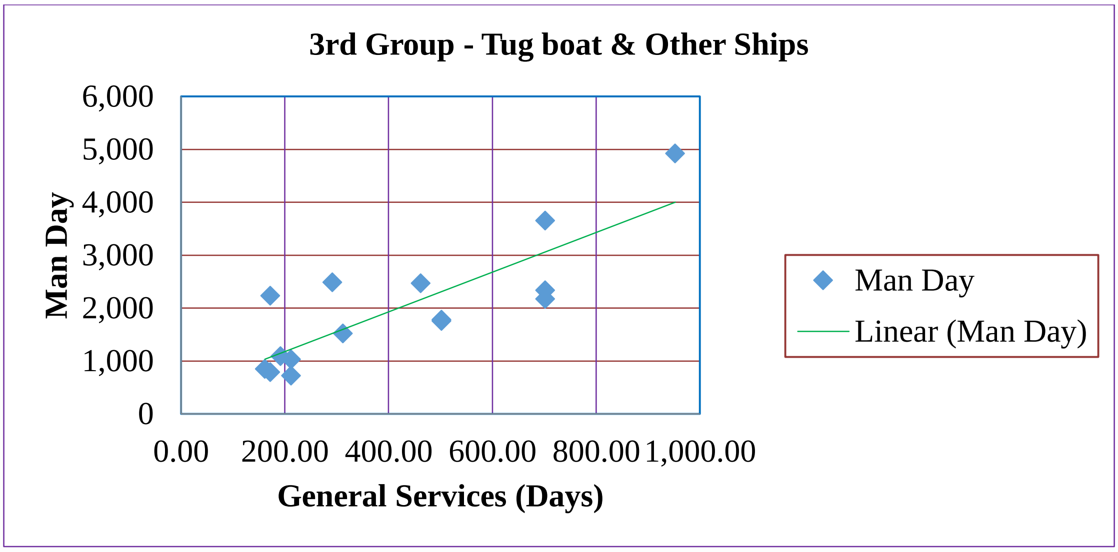


Figure – 55 : Man Day vs General Services (Days)

93.33% of the samples is within 50 tons and figure 56 shows ship repairing labour (Man day) against plate works with a positive and linear relationship as depicted in below:

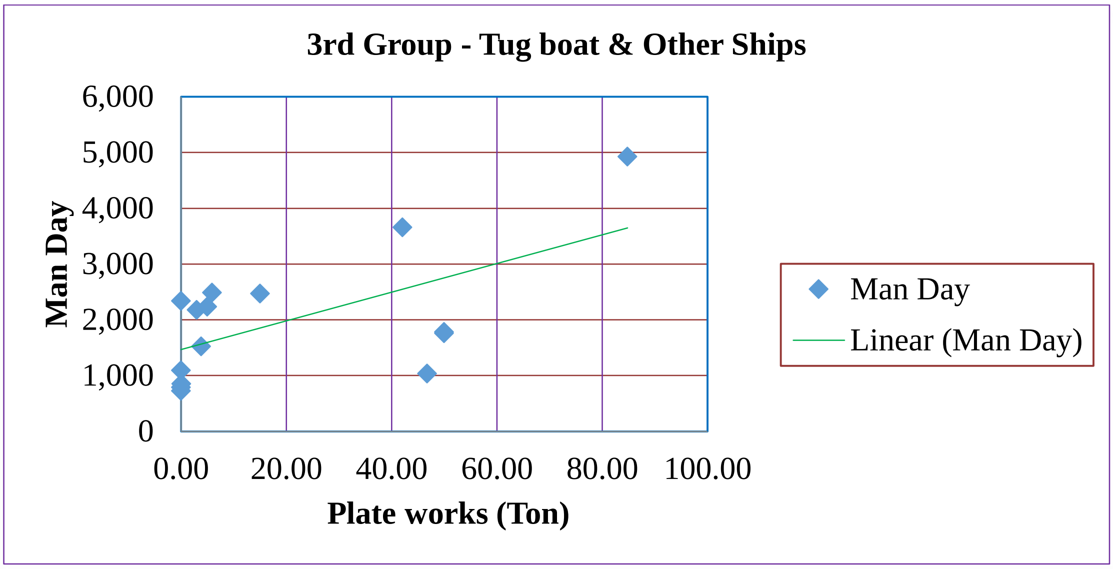


Figure – 56: Man Day vs Plate works (Ton)

80% of the samples is within 4500 sqm and figure 57 shows ship repairing labour (Man day) against hull cleaning and painting works with a positive and linear relationship as depicted in below:

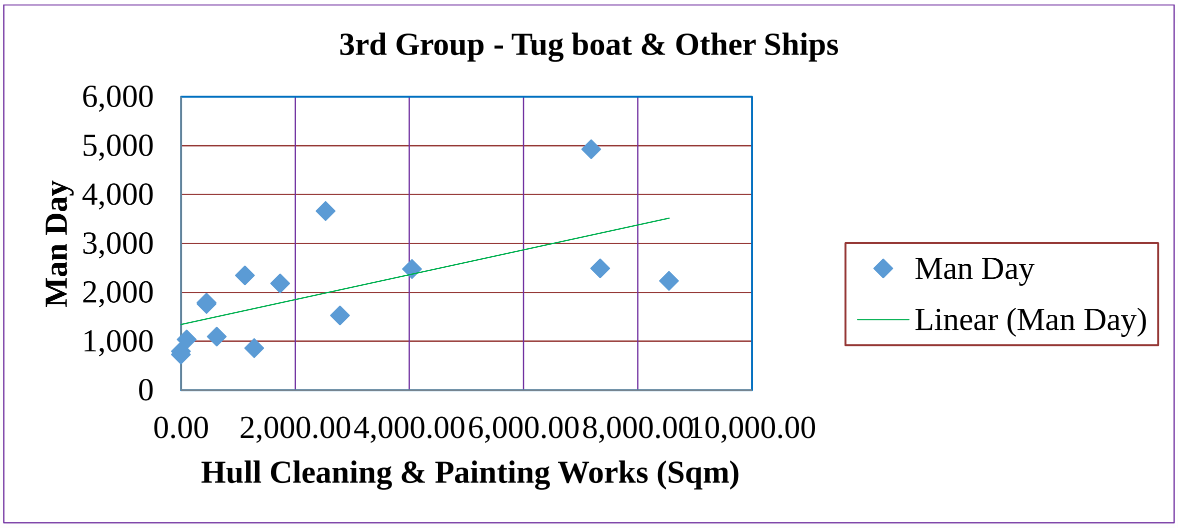


Figure – 57: Man Day vs Hull Cleaning & Painting Works (Sqm)

86.67% of the samples is within 270 rm and figure 58 shows ship repairing labour (Man day) against piping works with a positive and linear relationship as depicted in below:

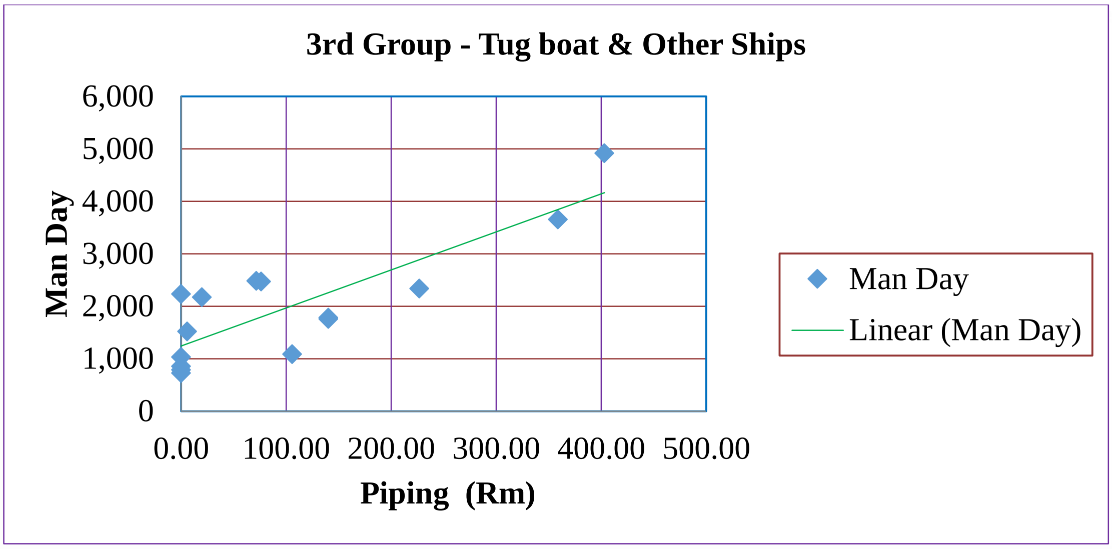


Figure – 58: Man Day vs Piping (Rm)

86.67% of the samples is within 77 nos and figure 59 shows ship repairing labour (Man day) against underwater fitting works with a positive and linear relationship as depicted in below:

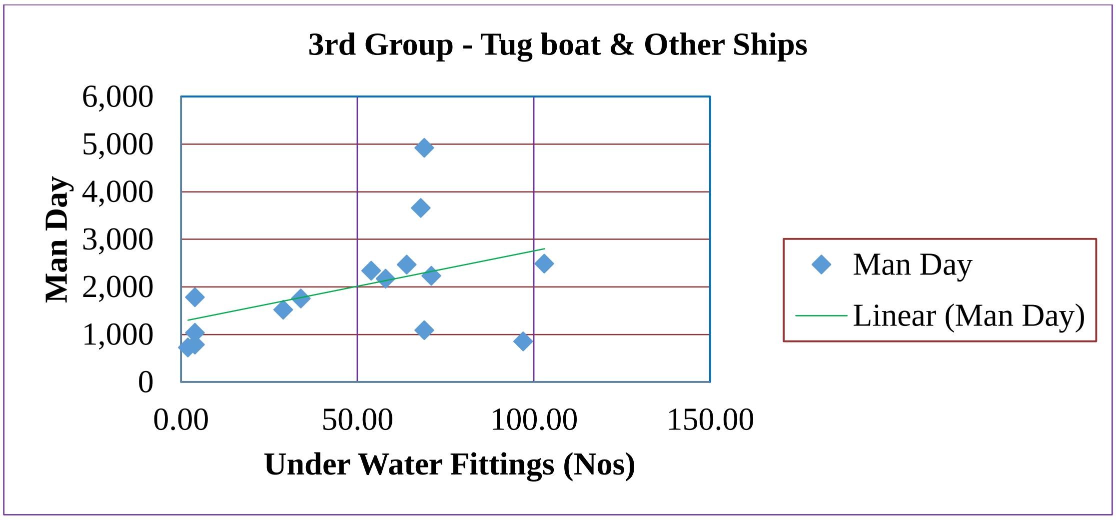


Figure – 59: Man Day vs Under Water Fittings (Nos)

86.67% of the samples is within 20 nos and figure 60 shows ship repairing labour (Man day) against above water fitting works with a positive and linear relationship as depicted in below:

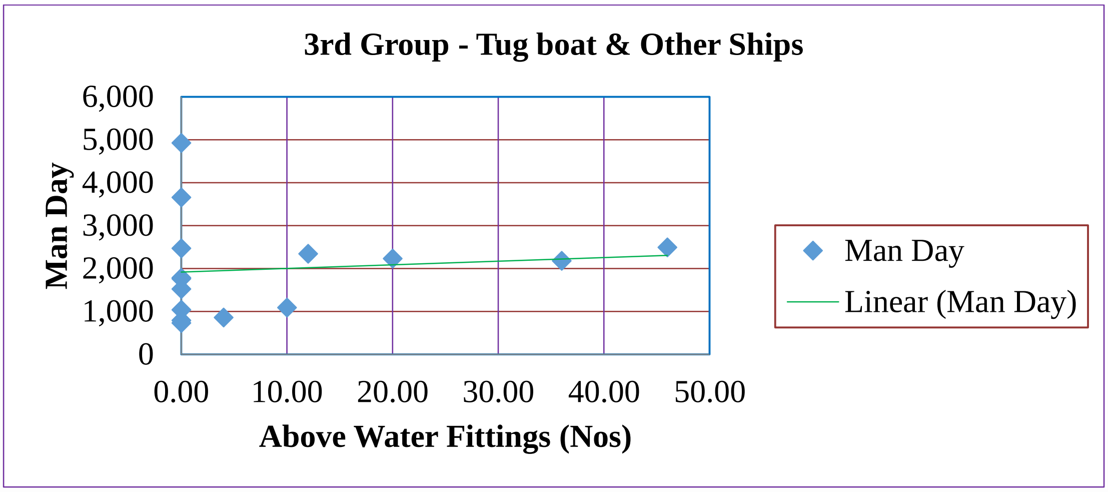


Figure – 60: Man Day vs Above Water Fittings (Nos)

13.33% of the samples forms data among out of 15 in number samples. That's why, less significant positive relationship exists between ship repairing labour (Man day) and machinery & equipment as shown in figure 61 below:

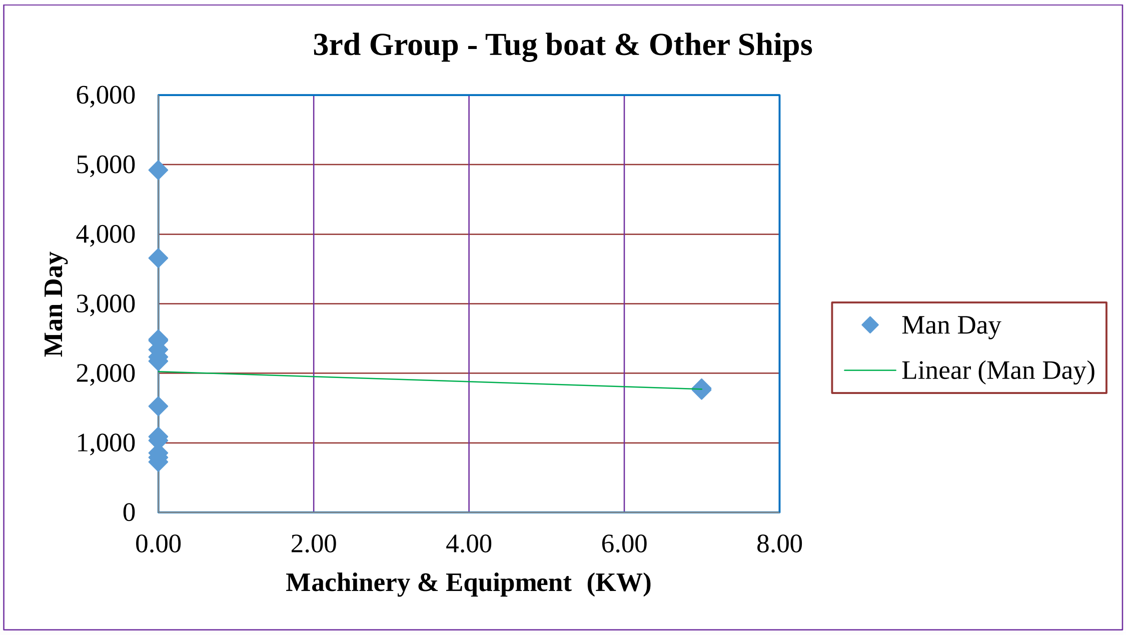


Figure – 61: Man Day vs Machinery & Equipment (KW)

6.7 Number of Graphs (Man-day vs Type of Ship) for "Cargo Ship, Fishing vessel, Oil Tanker, Dredger and Barge", 'Warships' and "Tug boat & Other Ships"

Values for Type of ships (T) like the fishing vessel, cargo vessel, oil tanker, barge, frigate, corvette, offshore patrol vessel, minesweeper, patrol craft, tug, and other vessel are found out as stated in Appendix D.

Figure 62 states ship repairing labour (Man day) against type of ships for cargo ship, fishing vessel, oil tanker, dredger and barge a linear relationship as shown below:

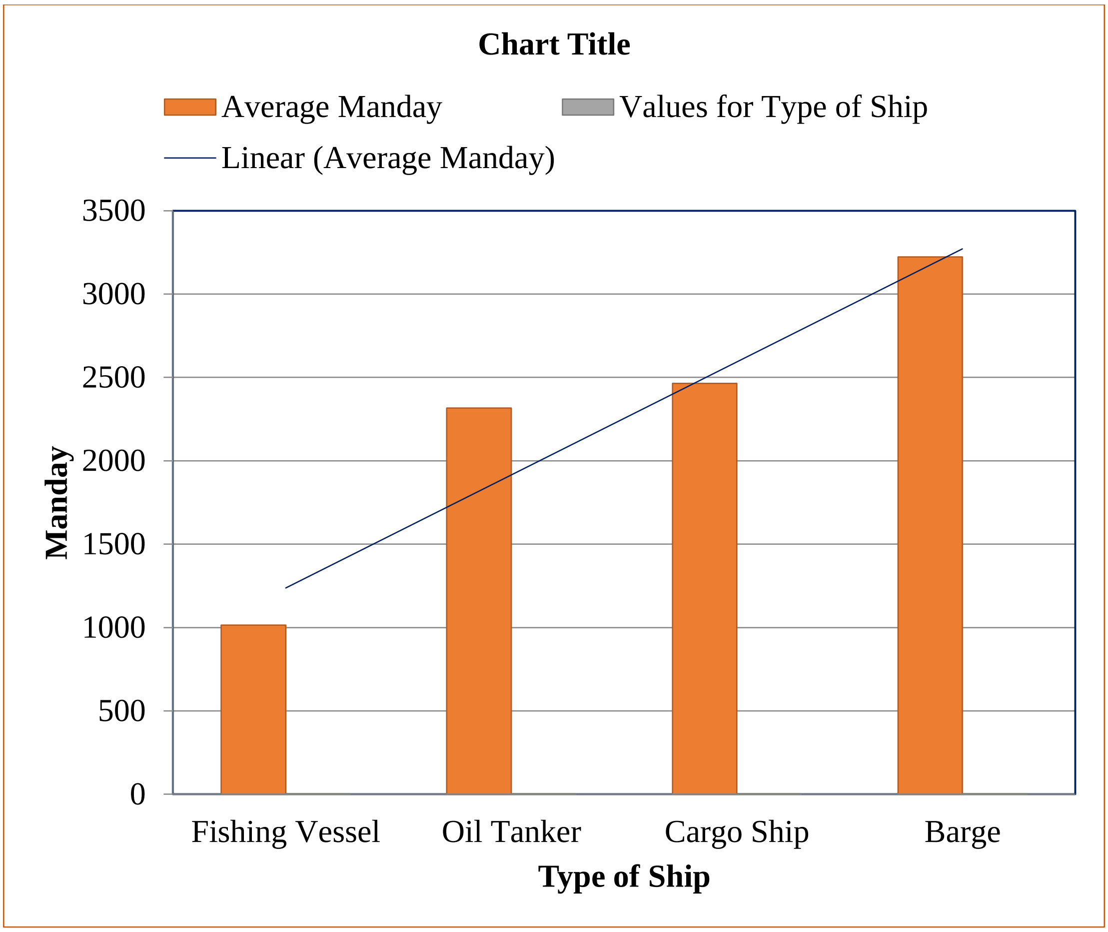


Figure – 62: Manday vs Type of Ship

Figure 63 indicates ship repairing labour (Man day) against type of ships for warships a linear relationship as shown below:

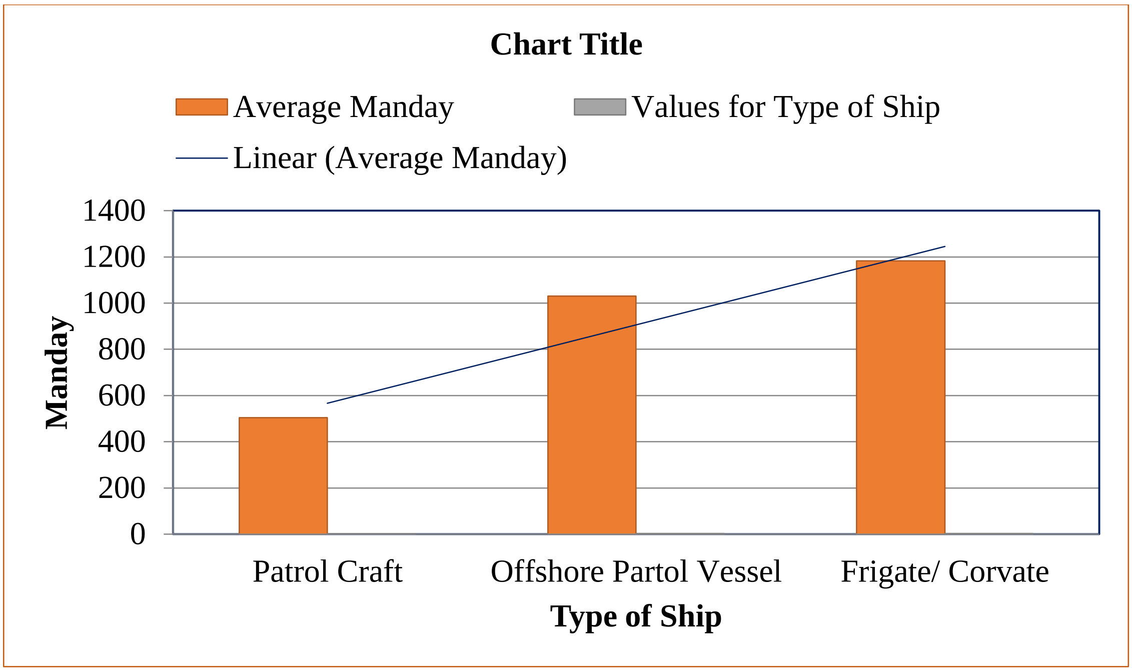


Figure – 63: Manday vs Type of Ship

Figure 64 shows ship repairing labour (Man day) against type of ships for tug boat & other ships a linear relationship as follows:

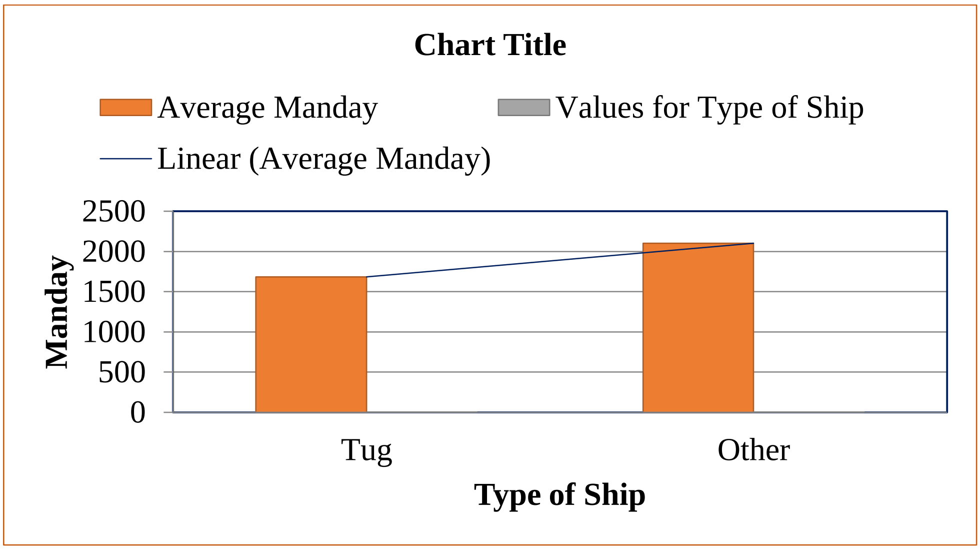


Figure – 64: Man day vs Type of Ship

CHAPTER VII

Analysis, Results and Discussion

7.1 Correlation Coefficient (r) and Coefficient of Multiple Determination (R^2)

Mathematically, correlation coefficient (r) and coefficient of multiple determination (R^2) are the ratios of the explained variation to the total variation in dependent variable accounted for the change in independent variables. Each one's value lie between -1 to +1. Plus sign and minus sign indicate the nature of the linear co-relationship in the form of positive slope and negative slope respectively. Values 0 and 1 indicate no linear relationship and perfect linear/ straight-line relationship respectively. Value other than 0 and 1 measures the degree of relationship of variables of the derived model. Values of the correlation coefficient for "Cargo ships, oil tankers, fishing vessel and dredgers", 'Warships', and "Tugboat and other ships" are enumerated in the following tables:

Table 2 – Correlation Coefficient - 1st Group - Cargo Ship + Oil Tanker + Fishing Vessel + Dredger

Ser	Variables	Correlation Coefficient (r)	Relationship
1.	Man day vs Full Load Displacement	0.424123641	Uphill (positive) linear relationship exists
2.	Man day vs Lightweight Displacement	0.339735537	Uphill (positive) linear relationship exists
3.	Man day vs Deadweight Tonnage	0.449541112	Uphill (positive) linear relationship exists
4.	Man day vs Age of Docking	0.202820912	Uphill (positive) linear relationship exists
5.	Man day vs General Services	0.756638038	Uphill (positive) linear relationship exists

6.	Man day vs Plate works	0.759369538	Uphill (positive) linear relationship exists
7.	Man day vs Hull Cleaning & Painting	0.681878037	Uphill (positive) linear relationship exists
8.	Man day vs Piping	0.530892397	Uphill (positive) linear relationship exists
9.	Man day vs Under Water Fittings	0.398389774	Uphill (positive) linear relationship exists
10.	Man day vs Above Water Fittings	0.036155368	Less significant uphill (positive) linear relationship exists
11.	Man day vs Machinery & Equipment	0.088048304	Less significant uphill (positive) linear relationship exists

Table 3 – Correlation Coefficient - 2^{nd} Group - Warship

Ser	Variables	Correlation Coefficient (r)	Relationship
1.	Man day vs Full Load Displacement	0.770639944	Uphill (positive) linear relationship exists
2.	Man day vs Lightweight Displacement	0.726934063	Uphill (positive) linear relationship exists
3.	Man day vs Age of Docking	0.420738176	Uphill (positive) linear relationship exists
4.	Man day vs General Services	0.896575621	Uphill (positive) linear relationship exists

5.	Man day vs Plate works	0.624373783	Uphill (positive) linear relationship exists
6.	Man day vs Hull Cleaning & Painting	0.907813108	Uphill (positive) linear relationship exists
7.	Man day vs Piping	0.509845692	Uphill (positive) linear relationship exists
8.	Man day vs Under Water Fittings	0.558432939	Uphill (positive) linear relationship exists
9.	Man day vs Above Water Fittings	0.000000000	No uphill (positive) linear relationship exists
10.	Man day vs Machinery & Equipment	0.039799242	Less significant uphill (positive) linear relationship exists

Table 4 – Correlation Coefficient - 3rd Group - Tug Boat & Other Ships

Ser	**Variables**	**Correlation Coefficient (r)**	**Relationship**
1.	Man day vs Full Load Displacement	0.130098227	Uphill (positive) linear relationship exists
2.	Man day vs Lightweight Displacement	0.223784823	Uphill (positive) linear relationship exists

3.	Man day vs Age of Docking	0.441198117	Uphill (positive) linear relationship exists
4.	Man day vs General Services	0.825535860	Uphill (positive) linear relationship exists
5.	Man day vs Plate works	0.605039256	Uphill (positive) linear relationship exists
6.	Man day vs Hull Cleaning & Painting	0.643314417	Uphill (positive) linear relationship exists
7.	Man day vs Piping	0.836366763	Uphill (positive) linear relationship exists
8.	Man day vs Under Water Fittings	0.439001140	Uphill (positive) linear relationship exists
9.	Man day vs Above Water Fittings	0.107195659	Uphill (positive) linear relationship exists
10.	Man day vs Machinery & Equipment	0.077465169	Less significant uphill (positive) linear relationship exists

Table 5 – Analysis of Correlation Coefficient

Ser	1st Group - Cargo Ship + Oil Tanker + Fishing Vessel + Dredger	2nd Group-Warship	3rd Group - Tug boat & Other Ships
1.	The values of r indicates that plate works and general services have the highest degree of co-relation (0.76) followed by hull cleaning & painting (0.68), piping (0.53), ships' age (0.48), deadweight tonnage (0.45), under water fittings (0.40) respectively.	The values of r indicates that hull cleaning & painting have the highest degree of co-relation (0.91) followed by general services (0.90), full load displacement (0.77), plate works (0.62), under water fittings (0.56), piping (0.51), and ships' age (0.42) respectively.	The values of r indicates that piping have the highest degree of co-relation (0.84) followed by general services (0.83), hull cleaning & painting (0.64), plate works (0.61), ships' age (0.44), under water fittings (0.44), full load displacement (0.13) respectively.
2.	The values of r^2 of above indicate that 58% of the variation in man-days is accounted for the difference in plate works and general services followed by 46%, 28%, 23%, 20% and 16% for hull cleaning & painting, piping, ships' age, deadweight tonnage and under water fittings respectively.	The values of r^2 of above indicate that 83% of the variation in man-days is accounted for the difference in hull cleaning & painting followed by 81%, 59%, 38%, 31%, 36% and 18% for general services, full load displacement, plate works, under water fittings, piping, and ships' age respectively.	The values of r^2 of above indicate that 71% of the variation in man-days is accounted for the difference in piping followed by 69%, 41%, 37%, 19%, 19% and 2% for general services, hull cleaning & painting, plate works, ships' age, under water fittings and full load

Ser	1st Group - Cargo Ship + Oil Tanker + Fishing Vessel + Dredger	2nd Group-Warship	3rd Group - Tug boat & Other Ships
			displacement respectively.

7.2 Regression Equations

7.2.1 Cargo Ships, Oil Tankers, Fishing Vessel and Dredgers

Symbolizing deadweight as S_D in regression multiple regression, final regression equation for the ship repairing labour (man-days) for cargo ships, oil tankers, fishing vessel and dredgers is as follows:

$$Y=(-256.99)+(-0.0008)*S_D+7.27*A+120.55*T+4.25*GS+16.14*PL+0.07*HCP+2.46*P +0.83*UWF+ 8.00*AWF+4.43*ME$$

In the regression equation, all the variables have the similar sign as assumed except the deadweight (S_D). Ships' age, type of ship, general service works, plate works, hull cleaning & painting works, piping works, above water fitting works, underwater fitting works and machinery & equipment works) have the positive and significant impact on the ship repairing labour (man-days). Positive values of the respective partial regression coefficients of these independent variables show that the bigger these parameters, the more the labour cost needed for these repair works. Expected change in labor cost is high for a small unit change in above water fitting works and machinery & equipment works. This is very likely, since above water fittings (for example, fishing gears, cranes, bollards, anchors and chain cables etc) and machinery & equipment of cargo ships, oil tankers, fishing vessel and dredgers are maintained on a daily basis by crews because of cargo handling/fishing. That is why above water fittings and machinery & equipment do not normally need repair in dry dock other than major repair of the same. And when major repair is done, it involves comparatively more labour cost than other type of repair works.

Co-efficient of deadweight tonnage becomes negative. This goes against the hypothesis. It appears that deadweight tonnage does not have positive impact on labour cost. Some reasons for the same are as follows, which is mainly incomprehensive inclusion of repair works reflecting disproportional/ unexpected volume of repair works vis-à-vis different deadweight tonnages:

i) Repair cost at CDDL is the highest compared to that of other shipyards in Bangladesh. This is so, because foreign vessels are repaired here for which repair bills are paid in foreign currency. Such condition dictate CDDL to set the "Tariff Chart" for repair of ships in line with the "Tariff Chart" of the foreign shipyards (Singapore, Malaysia etc). But strictly speaking, labour is very cheap in Bangladesh in comparison with that of other countries. Now most of the cargo ships, oil tankers, fishing vessels (except ships of Bangladesh Shipping Corporation) coming for repair at CDDL belong to private owners. Irrespective of high tariff for repair, still these private owners come to CDDL for ship repair because of the quality of works. With a view to keep the repair budget minimum, they try to carry out minimum repair works that is unavoidable due to Classification Society's mandatory requirements. Generally, these private owners limit their repair works only to underwater parts of their ships. So, repair works needed after certain period of time arising from the perspective of deadweight tonnage do not surface up accurately. As such, the data of the repaired ships do not reflect the real effect of deadweight tonnage. During repair of ships, private owners ensure repair of those parts of ship that will hamper watertight integrity if not repaired.

ii) Another factor is that the same ships are docked both at CDDL and at other shipyards at different times. That means, either consecutive or every repair of all these ships may not carried out at CDDL. Sometimes private owners carry out repair of their ships in other shipyards as suited to their available time and requirements of their business ventures at cheaper rates than that of CDDL. Repair data of the ships (docked at CDDL) are taken in our study, but the repair data of the same ships also docked at different times at other shipyards are missing in our analysis. This is another factor which is likely to contribute to the negative influence of deadweight tonnage on labour cost.

iii) Another thing, sometimes private owners even don't want to carry out repair of something to the full extent. For example, in a portion of MS plate, some pitting have developed. Rather than changing that portion of MS plate, they want that those pitting holes to filled up by welding with welding rods. In such case, less labour is involved them than of which would otherwise require to change the whole portion of the plate. This has negative impact on labour cost.

The above reasoning appears to be realistic. Because when regression analysis is carried out with only dependent variable (labour man-day) and independent variables (deadweight, age, type of ship), then deadweight doesn't become negative. When some repair works (independent variables like general service works, plate works and hull cleaning & painting works) are added in regression analysis, deadweight still remained positive. But then starts appearing from negative when other independent variables like piping, above water fittings, underwater fitting and machinery & equipment works are added. These are reflected in the chronological regression equations of cargo ships, oil tankers, fishing vessel and dredgers:

$Y=1350.56+0.10*S_D$

$Y=845.02+0.09*S_D+23.38*A$

$Y= (-324.08) +0.05*S_D+24.88*A+707.56*T$

$Y=(-1255.98)+0.03*S_D+12.03*A+409.19*T+7.87*GS$

$Y=(-280.93)+0.05*S_D+5.42*A+200.16*T+4.75*GS+25.27*PL$

$Y=(-188.72)+0.006*S_D+3.22*A+136.5*T+4.56*GS+20.9*PL+0.07*HCP$

$Y=(-266.62)+(-0.0003)*S_D+7.29*A+144.98*T+4.42*GS+15.42*PL+0.07*HCP +2.38*P$

$Y=(-256.84)+(-0.0015)*S_D+7.46*A+125.17*T+4.22*GS+16.12*PL+0.07*HCP +2.46*P+0.83*UWF$

$Y=(-254.13)+(-0.0009)*S_D+7.26*A+119.66*T+4.25*GS+16.14*PL+0.07*HCP +2.46*P+0.83* UWF+8*AWF$

$Y=(-256.99)+(-0.0008)*S_D+7.27*A+120.55*T+4.25*GS+16.14*PL+0.07*HCP +2.46*P+0.83*UWF + 8.00*AWF+4.43*ME$

To verify the correctness of the negative sign for deadweight derived from regression analysis of cargo ships, oil tankers, fishing vessel and dredgers, following procedure are carried out:

i) Firstly, deadweight is replaced at by full load displacement. Then multiple regression is done again for cargo ships, oil tankers, fishing vessel and dredgers.

ii) Secondly, deadweight is replaced at by lightweight displacement. Then multiple regression is done for cargo ships, oil tankers, fishing vessel and dredgers yet again.

In both the cases, full load displacement and lightweight displacement turn out to be negative as follows:

$Y=(-284.25)+(-0.008)*S_{FD}+7.53*A+145.23*T+4.24*GS+15.56*PL+0.07*HCP +2.49*P +0.88*UWF +6.91*AWF+2.41*ME$

$Y=(-296.21)+(-0.06)*S_{LD}+7.84*A+187*T+4.09*GS+15.56*PL+0.08*HCP+2.46*P +0.97*UWF +4.66*AWF+(-0.10)*ME$

So, it appears that the negative sign for deadweight derived from regression analysis of cargo ships, oil tankers, fishing vessel and dredgers is accurate.

7.2.2 Warships

Representing full load displacement as S_{FD} in regression multiple regression, final regression equation for the ship repairing labour (man-days) for warships is as follows:

$Y= (-116.09) +0.05*S_{FD}+ (-0.48)*A+ 172.73*T+ 2.65*GS+ 22.54*PL+ 0.12*HCP+ 1.88*P + 3.12*UWF+ 0.00*AWF+ (-1.66)*ME$

In the regression equation, all the variables have the positive sign as hypothesized except age (A) and machinery & equipment (ME). Co-efficients of age (A) and machinery & equipment (ME) become negative, which is contrary to the hypothesis.

Warship has different connotation than other types of ships. Above water fittings of warships mostly consist of weapons and armaments beside anchor and chain cables. Above water fittings of a warship are maintained on a daily basis at the highest order of excellence by naval crews as per standard norms and practices of defence service. This is evident in collected data of above water fittings of warships while under repair in dry dock, which is nil. As such, it does not contribute anything to labour cost.

The probable reason for the negative sign for machinery & equipment could be the less quantity of works. Because out of all machinery & equipment, most of the equipment are related to weapons and armaments system. As these equipment are maintained on a daily basis like weapons and armaments as stated above and hence don't need major repair at dock. Other maximum machinery & equipment are repaired with extreme care at dockyard of Bangladesh Navy. This is clearly visible in collected data of machinery & equipment for repair at CDDL.

Bangladesh Navy has its own floating dock and dockyard. Bangladesh Navy maintains "Refit and Docking Plan" for all of its warships and carries out docking and repair of the warships as per that plan in its own floating dock. When number of warships awaiting refit and docking at any point of time become more than that of which can be scheduled and accommodated at its own floating dock, then Bangladesh Navy plans to dock those extra unscheduled warships at Chittagong Dry Dock Ltd, Khulna Shipyard Ltd and Dockyard Engineering Works Ltd, Narayanganj. As a consequence of this factor, the data for some warships at CDDL taken in this study does reflect the chronological and comprehensive repair data of the particular warship. Moreover, most importantly, warships are expensive as most of the warships are purchased from foreign country. So, to economize purchase of warships from foreign country, old warships are renovated and repowered with new plates, machinery and equipment and fittings. As such, repair of such warships at later stage is less affected by age factor to a greater extent. Therefore, age factor in relation to other repair data for such warships did not produce the expected positive influence on the labour cost.

The above logics appear to be convincing. While regression analysis is carried out with only dependent variable (labour/ man-day) and independent variables (full load displacement and age), then age doesn't become negative. However when independent variables like type of ship and repair works (general service, plate, and hull cleaning & painting, piping, above water fittings, underwater fitting and machinery & equipment works) are added in regression analysis, then age starts to appear negative. That means, amount of these repair works are not enough. Age would otherwise act positively with the elapse of time and if increase of amount of repair works with time would be more. These are reflected in the chronological regression equations of warships:

$Y=383.47+0.52*S_{FD}$

$Y=342.51+0.50*S_{FD}+1.74*A$

$Y=600.59+0.611*S_{FD}+ (-0.47)*A+ (-174.74)*T$

$Y= (-137.66) +0.15*S_{FD}+ (-3.99)*A+155.45*T+3.73*GS$

$Y= (-183.1) +0.012*S_{FD}+ (-5.65)*A+262.75*T+3.67*GS+111.87*PL$

$Y= (-170.75) + (-0.04)*S_{FD}+ (-1.68)*A+260.07*T+2.68*GS+81.27*PL+0.17*HCP$

$Y= (-112.01) +0.0088*S_{FD}+ (-1.08)*A+207.51*T+2.5*GS+54.32*PL+0.17*HCP +2.22*P$

$Y = (-121.38) + 0.048*S_{FD}+ (-0.41)*A+175.83*T+2.65*GS+23.23*PL+ 0.13*HCP +1.87*P +3.06*UWF+0.00*AWF$

$Y= (-116.09) +0.05*S_{FD}+ (-0.48)*A+172.73*T+2.65*GS +22.54*PL+0.12*HCP +1.88*P +3.12*UWF +0.00*AWF + (-1.66)*ME$

To verify the correctness of the negative sign for age and machinery & equipment derived from regression analysis of warships, multiple regression is done by lightweight displacement. In this case also, age and machinery & equipment turn out to be negative as follows.

$$Y=(-136.46)+0.04*S_{LD}+(-0.30)*A+188.63*T+2.65*GS+28.64*PL+0.14*HCP+1.82*P+2.71*UWF+0.00*AWF+(-1.12)*ME$$

So, it appears that the negative sign for age and machinery & equipment derived from regression analysis of various repair data of warships at CDDL is accurate.

7.2.3 Tugboat and Other Ships

Denoting full load displacement as S_{FD} in regression multiple regression, final regression equation (enclosure 8) for the ship repairing labour (man-days) for tugboat and other ships is as follows:

$$Y= (-1054.87) + (0.01)*S_{FD} + (-3.5)*A + 1199.99*T + 2.2*GS+2.29*PL + 0.18*HCP + 2.69*P +1.41*UWF + (- 7.27)*AWF + 3.57*ME$$

Regression equation for tugboat and other ship shows positive sign for full load displacement, type, general service works, plate works, hull cleaning & painting works, piping works, underwater fitting works and machinery & equipment works as hypothesized. This indicates that these independent variables have the positively influenced ship repairing labour (man-days). Negative sign for age (A) and above water fittings (AWF) goes against the hypothesis.

Tug boats and other ship taken in this regression analysis are from Chittagong Port Authority. These tugs and other ship (pilot boat, anchor boat etc) are constantly engaged in port duties on a 24 hour basis. Above water fittings and machinery & equipment are heavy and of high power/capacity in a tug boat. These are maintained on a daily basis because of towing requirement for ships coming to and going from Chittagong Port daily and that is why the frequency of repair of the same is less at dock. Less quantity of above water fittings works and less frequency of repair of the same contribute to the negative sign for above water fittings in the regression equation. Besides, in most cases, the tugs, pilot and anchor boats are repowered by total replacement of propulsion machinery. Renovation is also done at same time. This is economic and contributes to life enhancement of the old tugs, pilot and anchor boats and leads to less frequency of repair. This factor leads to two outcome. Firstly, age factor doesn't appear much effective in influencing positively on labour cost. Secondly, expected change in labor cost is high for a small unit change in machinery & equipment works.

The aforesaid explanation appears to be sensible. Because when regression analysis is carried out with only dependent variable (labour man-day) and independent variables (full load displacement, type of ship, general service works, plate works, hull cleaning & painting works), then age doesn't become negative. The same is logical since these are jobs carried out at dock. But age starts affecting negatively on labour cost with elapse of time when plate works reduce after renovation, but piping and underwater fitting works added in less amount. Age continues to influence negatively on labour cost along with negative impact of above water fittings works, while other independent variables like piping and underwater fitting and machinery & equipment works in less amount are added. Age would otherwise act positively with the elapse of time and if increase of amount of repair works with time would be more. These are replicated in the chronological regression equations of tugboat and other ships:

$Y=1932.49+0.03*S_{FD}$

$Y=1041.63+0.0071*S_{FD}+32.58*A$

$Y=2.73+0.0034*S_{FD}+31.69*A+905.91*T$

$Y=(-2477.24)+0.04*S_{FD}+12.54*A+2069.59*T+3.8*GS$

$Y=(-2500.87)+0.044*S_{FD}+10.57*A+2152.75*T+3.31*GS+8.61*PL$

$Y=(-992.52)+0.002*S_{FD}+1.73*A+923.32*T+2.96*GS+7.27*PL+0.18*HCP$

$Y=(-827.77)+(-0.0002)*S_{FD}+(-3.72)*A+1077.58*T+1.9*GS+3.05*PL+0.181*HCP$
$+3.27*P$

$Y=(-938.73)+(-0.0013)*S_{FD}+(-2.77)*A+1129.16*T+1.92*GS+3.63*PL+0.17*HCP$
$+3.1*P +0.86*UWF$

$Y=(-990.07)+(0.01)*S_{FD}+(-3.44)*A+1148.59*T+2.19*GS+2.49*PL+0.18*HCP$
$+2.69*P+1.33*UWF+(-7.07)*AWF$
$Y=(-1054.87)+(0.01)*S_{FD}+(-3.5)*A+1199.99*T+2.2*GS+2.29*PL+0.18*HCP+2.69*P$
$+1.41*UWF+(-7.27)*AWF+3.57*ME$

7.2.4 Coefficient of Multiple Determination Considering All Independent Variables

Taking in to account all the independent variables, finishing regression equations for all groups of ships pass the F-statistic test. For "Cargo ships, oil tankers, fishing vessel and dredgers", 'Warships', and "Tugboat and other ships", the value of the coefficient of multiple correlations (shown in the table below) are 0.86490138, 0.962035515 and 0.995611654 respectively, which can be considered amply safe:

Table 6 - Coefficient of Multiple Determination (R^2)

Ser	1st Group - Cargo Ship + Oil Tanker + Fishing Vessel + Dredger	2nd Group-Warship	3rd Group - Tug boat & Other Ships
1.	The value R = 0.930000742 (R^2 = 0.86490138), indicates the degree of the relationship between the independent variables like ships' age, deadweight, type, general service works, plate works, hull cleaning & painting works, piping works, above water fitting works, underwater fitting works and machinery &	The value R = 0.980834092 (R^2 = 0.962035515), indicates the degree of the relationship between the independent variables like ships' age, full load displacement, type, general service works, plate works, hull cleaning & painting works, piping works, above water fitting	The value R = 0.997803414 (R^2 = 0.995611654), indicates the degree of the relationship between the independent variables like ships' age, deadweight, type, general service works, plate works, hull cleaning & painting works, piping works, above water fitting works, underwater fitting works and machinery & equipment

Ser	**<u>1st Group - Cargo Ship + Oil Tanker + Fishing Vessel + Dredger</u>**	**<u>2nd Group-Warship</u>**	**<u>3rd Group - Tug boat & Other Ships</u>**
	equipment works and the dependent variable, man-days in the multiple linear regression models assumed. On the other hand, R^2 = 0.86490138 indicates that about 86% of the variation in man-days is accounted for the changes in ships' age, deadweight, type, general service works, plate works, hull cleaning & painting works, piping works, above water fitting works, underwater fitting works and machinery & equipment works. Remaining 14% is the error of estimation.	works, underwater fitting works and machinery & equipment works and the dependent variable, man-days in the multiple linear regression models assumed. On the other hand, R^2 = 0.962035515 indicates that about 96% of the variation in man-days is accounted for the changes in ships' age, full load displacement, type, general service works, plate works, hull cleaning & painting works, piping works, above water fitting works, underwater fitting works and machinery & equipment works. Remaining 4% is the error of estimation.	works and the dependent variable, man-days in the multiple linear regression models assumed. On the other hand, R^2 = 0.995611654indicates that about 99.56% of the variation in man-days is accounted for the changes in ships' age, deadweight, type, general service works, plate works, hull cleaning & painting works, piping works, above water fitting works, underwater fitting works and machinery & equipment works. Remaining 0.44% is the error of estimation.

Ser	1st Group - Cargo Ship + Oil Tanker + Fishing Vessel + Dredger	2nd Group-Warship	3rd Group - Tug boat & Other Ships
Note: Unexplained errors occurred for many reasons. One of them is the absence of one or more independent variables that have a strong relationship with the dependent variable.			

It clarifies that for “Cargo ships, oil tankers, fishing vessel and dredgers”, ‘Warships’, and “Tugboat and other ships”, 86%, 96% and 99.56% of the explained variation in the dependent variable respectively are contributed to the change in the independent variables and remaining 14%, 4% and 0.44% respectively are called the error of estimation. Error of estimation is referred to statistically as error of the sum of squares (SSE) or unexplained variation, which also reflects the variation about the regression line. The variation behaves randomly or unpredictably (Murray, R.S. 1992). This error of estimation occurs owing to the absence of one or more important independent variables responsible for the change in the dependent variable. The coefficient of multiple determination and the error of estimation are inter-related. For the lower value of the coefficient of multiple determination, the error of estimation is more and vice versa.

7.2.5 Regression Coefficients and Other Statistical Parameters

The estimates of regression coefficients and other statistical parameters of the regression equation during the process of adding new variables are shown in the following three tables below. The primary measurement of the adequacy of the model is higher R^2 value. It can be seen from the tables that the successive inclusion of variables of the scope of works in the model contributed higher R^2 value.

Table 7 - Statistical Parameter

Cargo, Fishing, Tanker & Barge with Deadweight																
Mathematical Models	**Regression Coefficients**											**Statistical Parameter**				
	$\mathbf{b_0}$	$\mathbf{b_1}$	$\mathbf{b_2}$	$\mathbf{b_3}$	$\mathbf{b_4}$	$\mathbf{b_5}$	$\mathbf{b_6}$	$\mathbf{b_7}$	$\mathbf{b_8}$	$\mathbf{b_9}$	$\mathbf{b_{10}}$	**Multiple R**	$\mathbf{R^2}$	**Adjusted** $\mathbf{R^2}$	**F**	**Significance F**
$Y=f(S_D)$	1350.56	0.10	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4495	0.2021	0.1961	33.6849	$4.51x10^{-8}$
$Y=f(S_D,A)$	845.02	0.09	23.38	NA	NA	NA	NA	NA	NA	NA	NA	0.4732	0.2239	0.2121	19.0380	$5.44x10^{-8}$
$Y=f(S_D,A,T)$	-324.08	0.05	24.88	707.56	NA	NA	NA	NA	NA	NA	NA	0.5469	0.2991	0.2831	18.6343	$3.97x10^{-10}$
$Y=f(S_D,A,T,GS)$	-1255.98	0.03	12.03	409.19	7.87	NA	NA	NA	NA	NA	NA	0.8175	0.6682	0.6580	65.4650	$3.17x10^{-30}$
$Y=f(S_D,A,T,GS,PL)$	-280.93	0.05	5.42	200.16	4.75	25.27	NA	NA	NA	NA	NA	0.8960	0.8029	0.7952	105.0838	$9.40x10^{-44}$
$Y=f(S_D,A,T,GS,PL,HCP)$	-188.72	0.006	3.22	136.5	4.56	20.9	0.07	NA	NA	NA	NA	0.9133	0.8342	0.8264	107.3245	$1.71x10^{-47}$
$Y=f(S_D,A,T,GS,PL,HCP,P)$	-266.62	-0.0003	7.29	144.98	4.42	15.42	0.07	2.38	NA	NA	NA	0.9289	0.8628	0.8552	114.0602	$1.22x10^{-51}$
$Y=f(S_D,A,T,GS,PL,HCP,P,UWF)$	-256.84	-0.0015	7.46	125.17	4.22	16.12	0.07	2.46	0.83	NA	NA	0.9298	0.8645	0.8559	100.4749	$6.15x10^{-51}$
$Y=f(S_D,A,T,GS,PL,HCP,P,UWF,AWF)$	-254.13	-0.0009	7.26	119.66	4.25	16.14	0.07	2.46	0.83	8.00	NA	0.9300	0.8649	0.8552	88.9123	$5.29x10^{-50}$
$Y=f(S_D,A,T,GS,PL,HCP,P,UWF,AWF,ME)$	-256.99	-0.0008	7.27	120.55	4.25	16.14	0.07	2.46	0.83	8.00	4.43	0.9300	0.8649	0.8540	79.3848	$5.13x10^{-49}$

Table -8 Statistical Parameter

Warship with Full Load Displacement																
Mathematical Models	**Regression Coefficients**											**Statistical Parameter**				
	b_0	**b_1**	**b_2**	**b_3**	**b_4**	**b_5**	**b_6**	**b_7**	**b_8**	**b_9**	**b_{10}**	**Multiple R**	**R^2**	**Adjusted R^2**	**F**	**Significance F**
$Y=f(S_{FD})$	383.47	0.52	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.7706	0.5938	0.5831	55.5465	6.05×10^{-9}
$Y=f(S_{FD},A)$	342.51	0.50	1.74	NA	NA	NA	NA	NA	NA	NA	NA	0.7710	0.5944	0.5725	27.1167	5.61×10^{-8}
$Y=f(S_{FD},A,T)$	600.59	0.61	-0.47	-174.74	NA	NA	NA	NA	NA	NA	NA	0.7789	0.6067	0.5739	18.5101	1.96×10^{-7}
$Y=f(S_{FD},A,T,GS)$	-137.66	0.15	-3.99	155.45	3.73	NA	NA	NA	NA	NA	NA	0.9456	0.8942	0.8821	73.9508	1.41×10^{-16}
$Y=f(S_{FD},A,T,GS,PL)$	-183.10	0.01	-5.65	262.75	3.67	111.57	NA	NA	NA	NA	NA	0.9660	0.9332	0.9234	94.9849	5.59×10^{-19}
$Y=f(S_{FD},A,T,GS,PL,HCP)$	-170.75	-0.04	-1.68	260.70	2.68	81.27	0.17	NA	NA	NA	NA	0.9762	0.9529	0.9444	111.3376	1.86×10^{-20}
$Y=f(S_{FD},A,T,GS,PL,HCP,P)$	-112.01	0.01	-1.08	207.50	2.50	54.32	0.17	2.22	NA	NA	NA	0.9797	0.9598	0.9510	109.1117	1.69×10^{-20}
$Y=f(S_{FD},A,T,GS,PL,HCP,P,UWF)$	-121.38	0.05	-0.41	175.83	2.65	23.23	0.13	1.87	3.06	NA	NA	0.9808	0.9619	0.9521	97.8208	8.07×10^{-20}
$Y=f(S_{FD},A,T,GS,PL,HCP,P,UWF,AWF)$	-121.38	0.05	-0.41	175.83	2.65	23.23	0.13	1.87	3.06	0.0	NA	0.9808	0.9619	0.9198	97.8208	9.58×10^{-20}
$Y=f(S_{FD},A,T,GS,PL,HCP,P,UWF,AWF,ME)$	-116.09	0.05	-0.48	172.73	2.65	22.54	0.120	1.88	3.12	0.0	-1.66	0.9808	0.9620	0.9173	84.4680	1.09×10^{-18}

Table 9 - Statistical Parameter

Tug Boat & Other Ship with Full Load Displacement																
Mathematical Models	**Regression Coefficients**											**Statistical Parameter**				
	b_0	**b_1**	**b_2**	**b_3**	**b_4**	**b_5**	**b_6**	**b_7**	**b_8**	**b_9**	**b_{10}**	**Multiple R**	**R^2**	**Adjusted R^2**	**F**	**Significance F**
$Y=f(S_{FD})$	1932.49	0.03	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1301	0.0169	-0.0587	0.2238	6.44×10^{-1}
$Y=f(S_{FD},A)$	1041.63	0.0071	32.58	NA	NA	NA	NA	NA	NA	NA	NA	0.4423	0.1956	0.0615	1.4590	2.71×10^{-1}
$Y=f(S_{FD},A,T)$	2.73	0.0034	31.69	905.91	NA	NA	NA	NA	NA	NA	NA	0.4509	0.2033	-0.0140	0.9355	4.56×10^{-1}
$Y=f(S_{FD},A,T,GS)$	-2477.24	0.04	12.54	2069.59	3.8	NA	NA	NA	NA	NA	NA	0.9055	0.8199	0.7478	11.3779	9.67×10^{-4}
$Y=f(S_{FD},A,T,GS,PL)$	-2500.87	0.044	10.57	2152.75	3.31	8.61	NA	NA	NA	NA	NA	0.9198	0.8461	0.7606	9.8954	1.86×10^{-3}
$Y=f(S_{FD},A,T,GS,PL,HCP)$	-992.52	0.002	1.73	923.32	2.96	7.27	0.18	NA	NA	NA	NA	0.9797	0.9598	0.9296	31.8081	3.68×10^{-5}
$Y=f(S_{FD},A,T,GS,PL,HCP,P)$	-827.77	-0.0002	-3.72	1077.58	1.9	3.05	0.181	3.27	NA	NA	NA	0.9969	0.9939	0.9877	162.2517	3.31×10^{-7}
$Y=f(S_{FD},A,T,GS,PL,HCP,P,UWF)$	-938.73	-0.0013	-2.77	1129.16	1.92	3.63	0.17	3.1	0.86	NA	NA	0.9970	0.9940	0.9860	124.2897	4.26×10^{-6}
$Y=f(S_{FD},A,T,GS,PL,HCP,P,UWF,AWF)$	-990.07	-0.01	-3.44	1148.59	2.19	2.49	0.18	2.69	1.33	-7.07	NA	0.9978	0.9956	0.9877	125.5782	2.37×10^{-5}
$Y=f(S_{FD},A,T,GS,PL,HCP,P,UWF,AWF,ME)$	-1054.87	0.01	-3.5	1199.99	2.2	2.29	0.18	2.69	1.41	-7.27	3.57	0.9978	0.9956	0.9846	90.7505	2.86×10^{-4}

CHAPTER VIII

Validation and Deduction

8.1 Validation of the Model

With a view to verify the adequacy of fitness of the model to the system, validation of the mathematical model is carried out. Validation tests are performed on six ships repaired, whose data were not included to form the regression model equation. Table 9 below shows the estimated value and actual value of man-day for repairing these six ships and the error between those two values. It is seen that there is reasonably acceptable difference between the estimated and actual ship repair labour value for repairing these six ships indicating the prospective usefulness of the models.

Table 10 – Results of Verification of Mathematical Model Derived from Regression Analysis

Ser	Independent Variables													
	Name of Ships	DWT (Ton)/ Full Load Displacement	Age of Ship at the Time of Docking (Year)	Values for Type of Ship	GS (Days)	PL (Ton)	HCP (Sqm)	P (rm)	UWF (No.)	AWF (No.)	ME (kW)	Estimated Ship Repair Labour (Man day)	Actual Ship Repair Labour (Man day)	Error (%)
1.	MD KHANAK	4161	26	3.18	432	99.9	8875	0	245	0	0	4075.0362	3796.47	7.33750563
2.	CGS MANSUR ALI	1285	33	2.35	252	4.9	3733.8	100	137	0	0	2179.98	2117.22	2.96426446
3.	FV LONGFIN	248.7	17	1	192	11	1752	0	100	0	0	1696.131	1603.51	5.77614109
4.	MV ANSHU	5352	9	2.43	312	196.42	2256	2	45	0	0	4793.5037	4011.48	19.49464287
5.	M.T ENERGY	2529.41	24	2.28	372	136.58	9508	4.5	132	0	0	4761.912	5754.29	17.2458809
6.	SVITZER FOXTROT	1492.92	6	1	132	3.3	3275.23	7.39	24	0	0	1080.27	1241.26	12.96988544

8.2. Deduction

In repairing different group of ships, this article establishes a possible strong relationship between dependent (ship repair labour) and independent variables (deadweight/ full load displacement, age, type of ship and repair works namely general service, plate, hull cleaning & painting, piping, underwater fitting, above water fitting, machinery & equipment works etc) by verifying correlation coefficients and in the form of mathematical equations by using the multiple linear regression. Theses equations are also verified with statistical testing parameters to demonstrate the adequacy of the models for the system. Therefore, it is summarized that there is a considerable amount of variation in their response (the dependent variable) as a result of the differences in independent variables in the proposed model. Despite the limitations mentioned above in the discussion, the mathematical model can be useful to CDDL. The comparison between the actual and estimated value for man-hours of construction shows that the model has viable accuracy. This model can act as a guide for CDDL with a view to estimate the expected ship repairing labour (man day) against an expected scope of repairing works of a ship. Before docking of a vessel, CDDL can forecast estimated labour (in man day) from this mathematical model based on identified variables (deadweight, age, scope of repair works). The result of the estimated value of man-day for repairing a ship multiplied by wage rate will be the estimated labor cost for repair during the quotation stage.

CHAPTER IX

Conclusion and Recommendations

9.1. Conclusion

Docking of ships for repair and maintenance are highly technical task. Dry docking of ships are part of manufacturing and production processes incorporating hull inspection and cleaning, sandblasting, "plate cutting, fitting and welding", under and above water fitting works, painting, tank cleaning and machinery & equipment works etc. This also includes berth preparation for a ship coming for repair and essentially demands planning of manufacturing and production of various ship components with lead time. Ship repair work is labor intensive with strict time constraints. Labour cost significantly affects total repair cost. Both Labour hour and repair time determines labour cost. Proper estimation of labor cost will guide CDDL to stay competitive in not only mass ship repair market of Bangladesh but also in international arena. A flaw in estimation and planning not only cause financial losses to CDDL but also affect the ship owner as well in the same manner. This paper therefore, focuses on the estimation of the labour costs for different group of ships so that both parties benefit financially. This research paper also identifies and analyzes some important independent variables (deadweight/ full load displacement, age, repair works etc) that affect the outcome of labour (man-days). Forecast on ship repairing labour (man-days) by CDDL from the derived regression model herein can be translated into total number of workers, days and hence labour cost with a view control of labour cost and for budgetary purpose.

9.2 Recommendations

i) Shipyard management may verify the effect of delay in delivery of repair equipment/materials on derived labour cost estimation model of CDDL.

ii) Shipyard management may examine effect of introduction of the state of the art production machinery/equipment on labour hour and thus on derived labour cost estimation model of CDDL.

iii) Future study may relate skill of labour to various factors affecting labour cost as considered in derived labour cost estimation model of CDDL.

iv) Further study may cater for using larger sample data size in statistical analysis to address the reasons for the difference between actual value and model value of ship repairing labour.

v) Further investigation may be carried out taking in to account the influence of the ambient conditions (environmental factors) on labour hour and how the same affect derived labour cost estimation model of CDDL.

9.3 Limitations of the Study

i) Research has been based on available limited data.

ii) All the data have been collected and entire information have not been gathered due to confidentiality.

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Appendix A. Regression Analysis Equations & Statistical Parameters for Cargo Ship, Fishing vessel, Oil Tanker, Dredger and Barge

Regression Statistics	
Multiple R	0.449540998
R Square	0.202087109
Adjusted R Square	0.196087764
Standard Error	1386.52636
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	64757642.69	64757642.69	33.68486179	4.51411E-08
Residual	133	255686561.3	1922455.348		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1350.564776	167.2967865	8.072867411	3.60822E-13	1019.658217	1681.471335	1019.658217	1681.471335
Deadweight Tonnage	0.103153496	0.017773238	5.803866107	4.51411E-08	0.06799872	0.138308273	0.06799872	0.138308273

$\mathbf{Y=1350.56+0.10*S_D}$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.473156164
R Square	0.223876756
Adjusted R Square	0.212117312
Standard Error	1372.633488
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	71740008.71	35870004.35	19.03804063	5.43783E-08
Residual	132	248704195.2	1884122.691		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	845.0209186	310.474527	2.721707725	0.007371347	230.871625	1459.170212	230.871625	1459.170212
Deadweight Tonnage	0.09887212	0.017735151	5.574923925	1.34102E-07	0.063790238	0.133954002	0.063790238	0.133954002
Age of Ship at the Time of Docking	23.38897262	12.14966854	1.92507084	0.056371568	-0.644272308	47.42221754	-0.64427231	47.42221754

$Y=845.02+0.09*S_D+23.38*A$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.546901451
R Square	0.299101197
Adjusted R Square	0.28305008
Standard Error	1309.387593
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	95845245.03	31948415.01	18.63429103	3.97048E-10
Residual	131	224598958.9	1714495.87		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-324.0842008	430.0358493	-0.753621358	0.452428992	-1174.797679	526.6292776	-1174.79768	526.6292776
Deadweight Tonnage	0.056161046	0.020395286	2.753628761	0.0067317	0.015814306	0.096507786	0.015814306	0.096507786
Age of Ship at the Time of Docking	24.88409357	11.59671368	2.145788389	0.033733754	1.943027956	47.82515918	1.943027956	47.82515918
Values for type of ship	707.562837	188.7024503	3.749621883	0.000264739	334.2643826	1080.861291	334.2643826	1080.861291

$Y=(-324.08)+0.05*S_D+24.88*A+707.56*T$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.817464953
R Square	0.668248949
Adjusted R Square	0.658041225
Standard Error	904.2961624
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	214136502.6	53534125.64	65.46502503	3.16619E-30
Residual	130	106307701.4	817751.5492		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1255.980934	306.9343749	-4.092017826	7.45839E-05	-1863.213878	-648.7479888	-1863.21388	-648.7479888
Deadweight Tonnage	0.037266012	0.014172841	2.629396098	0.009585213	0.009226742	0.065305282	0.009226742	0.065305282

Age of Ship at the Time of Docking	12.03382411	8.079935811	1.489346499	0.138818213	-3.951362354	28.01901058	-3.95136235	28.01901058
Values for Type of Ship	409.1915567	132.6628697	3.084446747	0.0024916	146.7339385	671.649175	146.7339385	671.649175
General Services Works	7.870549857	0.654394194	12.02723056	7.33933E-23	6.575909223	9.165190491	6.575909223	9.165190491

$$\mathbf{Y=(-1255.98)+0.03*S_D+12.03*A+409.19*T+7.87*GS}$$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.896034939
R Square	0.802878612
Adjusted R Square	0.795238248
Standard Error	699.7585759
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	257277797.6	51455559.53	105.0838185	9.39595E-44

Residual	129	63166406.33	489662.0645
Total	134	320444204	

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-280.9338547	259.2337259	-1.083708741	0.280515306	-793.8341234	231.966414	-793.834123	231.966414
Deadweight Tonnage	0.052086926	0.011080249	4.700880348	6.55339E-06	0.030164382	0.074009471	0.030164382	0.074009471
Age of Ship at the Time of Docking	5.427674577	6.291868371	0.862649098	0.389931324	-7.020940923	17.87629008	-7.02094092	17.87629008
Values for Type of Ship	200.1681891	105.0441754	1.905562001	0.058932342	-7.66428183	408.00066	-7.66428183	408.00066
General Services Works	4.756216558	0.605398683	7.856337804	1.35296E-12	3.558420453	5.954012662	3.558420453	5.954012662
Plate Works	25.27315896	2.692533835	9.38638491	2.85E-16	19.94591489	30.60040302	19.94591489	30.60040302

$Y=(-280.93)+0.05*S_D+5.42*A+200.16*T+4.75*GS+25.27*PL$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.913337573
R Square	0.834185522
Adjusted R Square	0.826412968
Standard Error	644.291571
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	267309915.5	44551652.58	107.3245111	1.70783E-47
Residual	128	53134288.44	415111.6285		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-188.719402	239.4212723	-0.788231556	0.432018632	-662.4552879	285.0164839	-662.455288	285.0164839
Deadweight Tonnage	0.005935768	0.013864084	0.428139953	0.669268763	-0.021496691	0.033368228	-0.02149669	0.033368228
Age of Ship at the Time of Docking	3.221418313	5.810495279	0.554413722	0.580263129	-8.275639164	14.71847579	-8.27563916	14.71847579
Values for Type of Ship	136.4994176	97.58103939	1.398831356	0.164281957	-56.58133793	329.5801732	-56.5813379	329.5801732
General Services Works	4.559781767	0.558841565	8.15934614	2.71674E-13	3.454018268	5.665545267	3.454018268	5.665545267
Plate Works	20.89875747	2.633963556	7.934338128	9.20299E-13	15.68701064	26.11050431	15.68701064	26.11050431
Hull Cleaning & Painting Works	0.065288733	0.013280804	4.916022519	2.65286E-06	0.039010393	0.091567073	0.039010393	0.091567073

$$\mathbf{Y=(-188.72)+0.006*S_D+3.22*A+136.5*T+4.56*GS+20.9*PL+0.07*HCP}$$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.928851583
R Square	0.862765263
Adjusted R Square	0.855201144
Standard Error	588.4456773
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	276468127.9	39495446.85	114.0602392	1.21954E-51
Residual	127	43976076.02	346268.3151		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-266.6163169	219.1926887	-1.216355885	0.226105227	-700.3590854	167.1264516	-700.359085	167.1264516

Deadweight Tonnage	-0.000293756	0.01272018	-0.023093669	0.981611801	-0.025464696	0.024877185	-0.0254647	0.024877185
Age of Ship at the Time of Docking	7.289356064	5.365479407	1.358565659	0.176692465	-3.327959257	17.90667139	-3.32795926	17.90667139
Values for Type of Ship	144.9798001	89.13816548	1.626461565	0.106330283	-31.40854069	321.3681409	-31.4085407	321.3681409
General Services Works	4.425271878	0.51107201	8.658803052	1.83654E-14	3.413952615	5.436591141	3.413952615	5.436591141
Plate Works	15.42106405	2.630906086	5.861503051	3.71853E-08	10.21497576	20.62715234	10.21497576	20.62715234
Hull Cleaning & Painting Works	0.069552741	0.012157955	5.7207597	7.21439E-08	0.045494342	0.09361114	0.045494342	0.09361114
Piping Works	2.376172149	0.462039305	5.142792235	9.97716E-07	1.461879759	3.290464539	1.461879759	3.290464539

$Y=(-266.62)+(-0.0003)*S_D+7.29*A+144.98*T+4.42*GS+15.42*PL+0.07*HCP+2.38*P$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting (Sqm)

P= Piping Works (Rm)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.929777855
R Square	0.86448686

Adjusted R Square	0.855882851
Standard Error	587.0588531
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	277019803.7	34627475.47	100.4748917	6.14872E-51
Residual	126	43424400.22	344638.097		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-256.8406582	218.8125643	-1.173793009	0.242691874	-689.8642847	176.1829682	-689.864285	176.1829682
Deadweight Tonnage	-0.001546156	0.01272875	-0.12146959	0.903512606	-0.026735978	0.023643666	-0.02673598	0.023643666
Age of Ship at the Time of Docking	7.457804348	5.354489778	1.392813257	0.166128991	-3.138573372	18.05418207	-3.13857337	18.05418207
Values for Type of Ship	125.1676937	90.29626958	1.386188978	0.168137373	-53.52596696	303.8613543	-53.525967	303.8613543
General Services Works	4.221051782	0.534807459	7.892656894	1.23912E-12	3.162683556	5.279420008	3.162683556	5.279420008
Plate Works	16.11960075	2.682146521	6.009962776	1.85997E-08	10.8117117	21.42748979	10.8117117	21.42748979
Hull Cleaning & Painting Works	0.06518859	0.012610238	5.169497172	8.95118E-07	0.0402333	0.09014388	0.0402333	0.09014388
Piping Works	2.459786786	0.465663906	5.282322198	5.42383E-07	1.538251618	3.381321954	1.538251618	3.381321954
Under Water Fittings Works	0.827065872	0.653701943	1.265203325	0.208133252	-0.466591039	2.120722783	-0.46659104	2.120722783

$Y=(-256.84)+(-0.0015)*S_D+7.46*A+125.17*T+4.22*GS+16.12*PL+0.07*HCP+2.46*P+0.83*UWF$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)
A= Age of Ship at the Time of Docking (Year)
T= Values for Type of Ship
GS= General Service Works
(Days)
PW= Plate Works (Ton)
HCP= Hull Cleaning & Painting Works (Sqm)
P= Piping Works (Rm)
UWF= Under Water Fittings Works (Nos)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.929997674
R Square	0.864895674
Adjusted R Square	0.855168163
Standard Error	588.5126884
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	9	277150805.9	30794533.99	88.91232665	5.2902E-50
Residual	125	43293398.04	346347.1844		
Total	134	320444204			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-254.1313538	219.3986788	-1.158308496	0.248946408	-688.3485631	180.0858554	-688.348563	180.0858554
Deadweight Tonnage	-0.000909396	0.012802208	-0.071034271	0.943484004	-0.026246554	0.024427763	-0.02624655	0.024427763
Age of Ship at the Time of Docking	7.255009985	5.377868465	1.349049355	0.179759809	-3.388459013	17.89847898	-3.38845901	17.89847898
Values for Type of Ship	119.662344	90.96142686	1.315528441	0.190740193	-60.36160656	299.6862946	-60.3616066	299.6862946
General Services Works	4.247796251	0.537892602	7.897108523	1.25554E-12	3.183240048	5.312352454	3.183240048	5.312352454
Plate Works	16.14216118	2.689039003	6.002947954	1.95367E-08	10.82021933	21.46410303	10.82021933	21.46410303
Hull Cleaning & Painting Works	0.065029599	0.01264411	5.14307447	1.01499E-06	0.040005337	0.090053862	0.040005337	0.090053862
Piping Works	2.455984594	0.466858046	5.260666742	6.03426E-07	1.532014592	3.379954596	1.532014592	3.379954596
Under Water Fittings Works	0.830547743	0.655345273	1.26734376	0.207388344	-0.466461871	2.127557356	-0.46646187	2.127557356
Above Water Fittings Works	7.996209503	13.00171794	0.615011765	0.539664944	-17.73580361	33.72822261	-17.7358036	33.72822261

$Y=(-254.13)+(-0.0009)*S_D+7.26*A+119.66*T+4.25*GS+16.14*PL+0.07*HCP+2.46*P+0.83*UWF+8*AWF$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

P= Piping Works (Rm)

UWF= Under Water Fittings Works (Nos)

AWF= Above Water Fittings Works (Nos)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.930000742
R Square	0.86490138
Adjusted R Square	0.85400633
Standard Error	590.8684806
Observations	135

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	10	277152634.3	27715263.43	79.38480163	5.13224E-49
Residual	124	43291569.61	349125.5614		
Total	134	320444204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-256.9920291	223.7956484	-1.14833345	0.253041387	-699.9463005	185.9622423	-699.9463	185.9622423
Deadweight Tonnage	-0.00087402	0.012862747	-0.067949733	0.945935095	-0.026332998	0.024584958	-0.026333	0.024584958
Age of Ship at the Time of Docking	7.270225401	5.403487801	1.345469013	0.18092903	-3.424790427	17.96524123	-3.42479043	17.96524123
Values for Type of Ship	120.5484356	92.14268574	1.30828003	0.193198246	-61.82774781	302.9246191	-61.8277478	302.9246191
General Services Works	4.249843629	0.54078629	7.858637896	1.60023E-12	3.179476092	5.320211166	3.179476092	5.320211166
Plate Works	16.13746924	2.700581481	5.975553543	2.26155E-08	10.79226208	21.4826764	10.79226208	21.4826764
Hull Cleaning & Painting Works	0.065007212	0.012698493	5.119285693	1.13712E-06	0.039873338	0.090141085	0.039873338	0.090141085

Piping Works	2.455892721	0.468728579	5.239477243	6.69708E-07	1.528147577	3.383637865	1.528147577	3.383637865
Under Water Fittings Works	0.828664643	0.658482926	1.258445148	0.210595111	-0.474657503	2.131986789	-0.4746575	2.131986789
Above Water Fittings Works	8.004622668	13.05428095	0.613179899	0.540880466	-17.83345572	33.84270106	-17.8334557	33.84270106
Machinery & Equipment Works	4.431635633	61.23717607	0.072368387	0.942425342	-116.7738878	125.6371591	-116.773888	125.6371591

$Y=(-256.99)+(-0.0008)*S_D+7.27*A+120.55*T+4.25*GS+16.14*PL+0.07*HCP+2.46*P+0.83*UWF+8.00*AWF+4.43*ME$

Where

Y= Labor Cost (Man Day)

S_D= Deadweight Tonnage (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works
(Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

P= Piping Works (Rm)

UWF= Under Water Fittings Works (Nos)

AWF= Above Water Fittings Works (Nos)

ME= Machinery & Equipment Works (kW)

Appendix B. Regression Analysis Equations & Statistical Parameters for Warships

Regression Statistics	
Multiple R	0.770574497
R Square	0.593785055
Adjusted R Square	0.583095188
Standard Error	387.1401853
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	8325176.883	8325176.883	55.54653368	6.0477E-09
Residual	38	5695345.876	149877.5231		
Total	39	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	383.4721829	84.91908246	4.515736296	5.94922E-05	211.5624894	555.3818764	211.5624894	555.3818764
Full Load Displacement (Ton)	0.515225073	0.069130311	7.452954695	6.0477E-09	0.375278077	0.655172069	0.375278077	0.655172069

$Y=383.47+0.52*S_{FD}$

Where

Y= Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.771003939
R Square	0.594447073
Adjusted R Square	0.572525293
Standard Error	392.0170997
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	8334458.719	4167229.36	27.11673404	5.60892E-08
Residual	37	5686064.04	153677.4065		
Total	39	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	342.5076458	187.5577661	1.826144835	0.075906496	-37.52048327	722.535775	-37.52048327	722.535775
Full Load Displacement (Ton)	0.504821977	0.081804716	6.171062026	3.68456E-07	0.339069879	0.670574075	0.339069879	0.670574075
Age of Ship at the Time of Docking	1.743547253	7.094499734	0.245760423	0.807225884	-12.63127453	16.11836903	-12.63127453	16.11836903

$Y=342.51+0.50*S_{FD}+1.74*A$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.77890174
R Square	0.60668792
Adjusted R Square	0.573911914
Standard Error	391.3807809
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	8506081.796	2835360.599	18.51012319	1.96319E-07
Residual	36	5514440.962	153178.9156		
Total	39	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	600.5882242	307.4269932	1.95359626	0.058553865	-22.90261214	1224.079061	-22.90261214	1224.079061
Full Load Displacement (Ton)	0.610649954	0.129097868	4.730131988	3.41705E-05	0.348827345	0.872472564	0.348827345	0.872472564
Age of Docking Ship at the Time of Docking	-0.466023609	7.384184464	-0.063111046	0.950027201	-15.44184372	14.5097965	-15.44184372	14.5097965
Values for Type of Ship	-174.7404467	165.0840423	-1.05849387	0.296881292	-509.5464003	160.0655068	-509.5464003	160.0655068

$Y=600.59+0.611*S_{FD}+(-0.47)*A+(-174.74)*T$

Where
Y= Labor Cost (Man Day)
S_{FD}= Full Load Displacement (Ton)
A= Age of Ship at the Time of Docking
T= Values for Type of Ship

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.945619877
R Square	0.894196951
Adjusted R Square	0.882105174
Standard Error	205.8719472
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	12537108.71	3134277.177	73.95083054	1.41284E-16
Residual	35	1483414.052	42383.25863		
Total	39	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-137.6593047	178.5520394	-0.770975819	0.445895025	-500.1392132	224.8206038	-500.1392132	224.8206038
Full Load Displacement (Ton)	0.147860674	0.08284496	1.78478781	0.08296592	-0.020323534	0.316044882	-0.020323534	0.316044882

Age of Ship at the Time of Docking	-3.986494364	3.900926195	-1.021935347	0.313823505	-11.90579551	3.932806782	-11.90579551	3.932806782
Values for Type of Ship	155.445839	93.20348466	1.667811451	0.104277418	-33.76729299	344.6589709	-33.76729299	344.6589709
General Services Works (Days)	3.727533854	0.38221781	9.752381379	1.6272E-11	2.951590452	4.503477256	2.951590452	4.503477256

$Y=(-137.66)+0.15*S_{FD}+(-3.99)*A+155.45*T+3.73*GS$

Where

Y= Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking

T= Values for Type of Ship

GS= General Service Works (Days)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.966018871
R Square	0.933192459
Adjusted R Square	0.923367821
Standard Error	165.9798575
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	13083846.11	2616769.223	94.98491719	5.59415E-19
Residual	34	936676.6451	27549.31309		

Total	39	14020522.76

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-183.0955419	144.3146265	-1.268724774	0.213156959	-476.3781475	110.1870638	-476.3781475	110.1870638
Full Load Displacement (Ton)	0.011998322	0.073425265	0.163408635	0.87116417	-0.137219769	0.161216414	-0.137219769	0.161216414
Age of Ship at the Time of Docking	-5.653987664	3.167234359	-1.785149763	0.083161344	-12.09058226	0.782606935	-12.09058226	0.782606935
Values for type of ship	262.7492332	78.90939762	3.329758446	0.002100694	102.3860441	423.1124223	102.3860441	423.1124223
General Services Works	3.671410956	0.308412354	11.90422791	1.12313E-13	3.044641646	4.298180266	3.044641646	4.298180266
Plate Works	111.8652434	25.11083561	4.454859453	8.64116E-05	60.83388587	162.8966009	60.83388587	162.8966009

$Y=(-183.1)+0.012*S_{FD}+(-5.65)*A+262.75*T+3.67*GS+111.87*PL$

Where

Y= Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.976179344
R Square	0.952926111

Adjusted R Square	0.944367222
Standard Error	141.4214129
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	13360522.23	2226753.705	111.3375961	1.86475E-20
Residual	33	660000.5286	20000.01602		
Total	39	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-170.753814	123.0065422	-1.388168556	0.174386695	-421.0125046	79.50487651	-421.0125046	79.50487651
Full Load Displacement	-0.042388372	0.064247381	-0.659768102	0.513981307	-0.173100651	0.088323906	-0.173100651	0.088323906
Age of Ship at the Time of Docking	-1.676532943	2.902770759	-0.577562985	0.567479354	-7.582264428	4.229198541	-7.582264428	4.229198541
Values for Type of Ship	260.0693547	67.23779292	3.867904394	0.000488737	123.2730371	396.8656722	123.2730371	396.8656722
General Services	2.681174482	0.374079105	7.167399742	3.25624E-08	1.920104824	3.44224414	1.920104824	3.44224414
Plate Works	81.27132707	22.92212431	3.545540805	0.001196784	34.63591475	127.9067394	34.63591475	127.9067394
Hull Cleaning & Painting	0.173824048	0.046734672	3.719380963	0.000740551	0.078741644	0.268906452	0.078741644	0.268906452

$Y=(-170.75)+(-0.04)*S_{FD}+(-1.68)*A+260.07*T+2.68*GS+81.27*PL+0.17*HCP$

Where

Y= Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)
PW= Plate Works (Ton)
HCP= Hull Cleaning & Painting Works (Sqm)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.979687687
R Square	0.959787964
Adjusted R Square	0.950991581
Standard Error	132.7349053
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	13456729	1922389.857	109.1116637	1.6923E-20
Residual	32	563793.7626	17618.55508		
Total	39	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-112.0069791	118.1566214	-0.947953469	0.350257446	-352.6841399	128.6701816	-352.6841399	128.6701816
Full Load Displacement	0.008797604	0.064156313	0.137127637	0.89178907	-0.121884529	0.139479736	-0.121884529	0.139479736
Age of Ship at the Time of Docking	-1.083235994	2.736279016	-0.395879217	0.694821372	-6.656853934	4.490381946	-6.656853934	4.490381946
Values for Type of Ship	207.506482	66.99678492	3.097260297	0.004045921	71.03849748	343.9744665	71.03849748	343.9744665
General Services	2.496244602	0.359910587	6.935735401	7.4553E-08	1.76313073	3.229358475	1.76313073	3.229358475

Plate Works	54.31997089	24.41071019	2.225251559	0.033236476	4.596981596	104.0429602	4.596981596	104.0429602
Hull Cleaning & Painting Works	0.167458374	0.043948602	3.810323113	0.000594877	0.077938002	0.256978747	0.077938002	0.256978747
Piping Works	2.216517358	0.948535246	2.336779121	0.025872047	0.284414297	4.14862042	0.284414297	4.14862042

$Y=(-112.01)+0.0088*S_{FD}+(-1.08)*A+207.51*T+2.5*GS+54.32*PL+0.17*HCP+2.22*P$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

G_S= General Service Works (Days)

P_W= Plate Works (Ton)

H_{CP}= Hull Cleaning & Painting (Sqm)

P= Piping Works (Rm)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980763048
R Square	0.961896156
Adjusted R Square	0.952062905
Standard Error	131.2760965
Observations	40

ANOVA

	df	SS	MS	F	Significance F
Regression	8	13486286.94	1685785.867	97.82077511	8.07373E-20
Residual	31	534235.8189	17233.41351		
Total	39	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-121.3812085	117.0770482	-1.036763485	0.30786601	-360.1614216	117.3990046	-360.1614216	117.3990046
Full Load Displacement	0.047865044	0.070113672	0.682677754	0.499880648	-0.095132732	0.190862819	-0.095132732	0.190862819
Age of Ship at the Time of Docking	-0.406495478	2.755099044	-0.147542964	0.883658929	-6.025557002	5.212566045	-6.025557002	5.212566045
Values for Type of Ship	175.8319307	70.53650203	2.49277928	0.018225125	31.97178692	319.6920745	31.97178692	319.6920745
General Services	2.648506575	0.374460909	7.072851961	6.05536E-08	1.884788519	3.412224631	1.884788519	3.412224631
Plate Works	23.22926475	33.85912383	0.686056286	0.497777025	-45.82687331	92.28540281	-45.82687331	92.28540281
Hull Cleaning & Painting Works	0.128269939	0.052769773	2.430746448	0.021047291	0.020645277	0.2358946	0.020645277	0.2358946
Piping Works	1.87338075	0.974012207	1.923364756	0.063660561	-0.113130235	3.859891734	-0.113130235	3.859891734
Under Water Fittings Works	3.056410886	2.333781985	1.309638563	0.199941472	-1.703368835	7.816190607	-1.703368835	7.816190607

$Y=(-121.38)+0.048*S_{FD}+(-0.41)*A+175.83*T+2.65*GS+23.23*PL+0.13*HCP+1.87*P+3.06*UWF$

Where

Y= Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

G_S= General Service Works (Days)

P_W= Plate Works (Ton)

H_{CP}= Hull Cleaning & Painting Works (Sqm)

P= Piping Works (Rm)

U_{WF}= Under Water Fittings Works (Nos)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980763048
R Square	0.961896156
Adjusted R Square	0.919804841
Standard Error	131.2760965
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	9	13486286.94	1498476.327	97.82077511	9.58194E-20
Residual	31	534235.8189	17233.41351		
Total	40	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-121.3812085	117.0770482	-1.036763485	0.30786601	-360.1614216	117.3990046	-360.1614216	117.3990046
Full Load Displacement	0.047865044	0.070113672	0.682677754	0.499880648	-0.095132732	0.190862819	-0.095132732	0.190862819
Age of Ship at the Time of Docking	-0.406495478	2.755099044	-0.147542964	0.883658929	-6.025557002	5.212566045	-6.025557002	5.212566045

Values for Type of Ship	175.8319307	70.53650203	2.49277928	0.018225125	31.97178692	319.6920745	31.97178692	319.6920745
General Services Works	2.648506575	0.374460909	7.072851961	6.05536E-08	1.884788519	3.412224631	1.884788519	3.412224631
Plate Works	23.22926475	33.85912383	0.686056286	0.497777025	-45.82687331	92.28540281	-45.82687331	92.28540281
Hull Cleaning & Painting	0.128269939	0.052769773	2.430746448	0.021047291	0.020645277	0.2358946	0.020645277	0.2358946
Piping Works	1.87338075	0.974012207	1.923364756	0.063660561	-0.113130235	3.859891734	-0.113130235	3.859891734
Under Water Fiffings Works	3.056410886	2.333781985	1.309638563	0.199941472	-1.703368835	7.816190607	-1.703368835	7.816190607
Above Water Fittings Works	0	0	65535	#NUM!	0	0	0	0

Y=(-121.38)+0.048*S_{FD}+(-0.41)*A+175.83*T+2.65*GS+23.23*PL+0.13*HCP+1.87*P+3.06*UWF+0.00*AWF

Where

Y= Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

P= Piping Works (Rm)

UWF= Under Water Fittings Works (Nos)

AWF= Above Water Fittings Works (Nos)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980834092

R Square	0.962035515
Adjusted R Square	0.917312836
Standard Error	133.2018421
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	10	13488240.84	1348824.084	84.4680251	1.09191E-18
Residual	30	532281.9224	17742.73075		
Total	40	14020522.76			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-116.0964634	119.8571818	-0.968623336	0.340477912	-360.8774837	128.684557	-360.8774837	128.684557
Full Load Displacement (Ton)	0.055716088	0.074972904	0.743149663	0.46317142	-0.097399008	0.208831185	-0.097399008	0.208831185
Age of Ship at the Time of Docking	-0.489353431	2.806643159	-0.174355414	0.862757464	-6.22128343	5.242576568	-6.22128343	5.242576568
Values for Type of Ship	172.7276496	72.17996911	2.393013626	0.02317241	25.31648731	320.1388119	25.31648731	320.1388119
General Services Works	2.646421233	0.380005999	6.964156456	9.77456E-08	1.87034545	3.422497015	1.87034545	3.422497015
Plate Works	22.53956731	34.41862505	0.654865419	0.517544403	-47.75264239	92.831777	-47.75264239	92.831777
Hull Cleaning & Painting Works	0.123714229	0.055275779	2.238127304	0.032787202	0.01082603	0.236602429	0.01082603	0.236602429
Piping Works	1.883264993	0.988749145	1.904694434	0.066447245	-0.136030145	3.90256013	-0.136030145	3.90256013
Under Water Fittings Works	3.121147081	2.376038884	1.313592594	0.198941125	-1.73137167	7.973665832	-1.73137167	7.973665832
Above Water Fittings Works	0	0	65535	#NUM!	0	0	0	0
Machinery & Equipment Works	-1.655045095	4.987343623	-0.33184902	0.742310606	-11.84055957	8.530469382	-11.84055957	8.530469382

$$\mathbf{Y=(-116.09)+0.05*S_{FD}+(-0.48)*A+172.73*T+2.65*GS+22.54*PL+0.12*HCP+1.88*P+3.12*UWF+0.00*AWF+(-1.66)*ME}$$

Where

Y= Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

P= Piping Works (Rm)

UWF= Under Water Fittings Works (Nos)

AWF= Above Water Fittings Works (Nos)

ME= Machinery & Equipment Works (Kw)

Appendix C. Regression Analysis Equations & Statistical Parameters for Tug boat & Other Ships

Regression Statistics	
Multiple R	0.13010538
R Square	0.01692741
Adjusted R Square	-0.05869356
Standard Error	1180.97918
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	312199.9101	312199.9101	0.22384546	0.643970992
Residual	13	18131253.69	1394711.822		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1932.48635	329.8410802	5.858840712	5.60304E-05	1219.908018	2645.06468	1219.908018	2645.06468
Full Load Displacement	0.03003324	0.06347871	0.473123092	0.643970992	-0.107104171	0.167170658	-0.107104171	0.167170658

$Y=1932.49+0.03*S_{FD}$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

SUMMARY OUTPUT

Regression Statistics

Multiple R	0.44226822
R Square	0.19560118
Adjusted R Square	0.0615347
Standard Error	1111.90124
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3607561.201	1803780.601	1.458986533	0.270912201
Residual	12	14835892.4	1236324.367		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1041.6319	627.8407226	1.6590703	0.122989394	-326.3155257	2409.579317	-326.3155257	2409.579317
Full Load Displacement	0.00714458	0.061388016	0.116383883	0.909273376	-0.126608422	0.140897574	-0.126608422	0.140897574
Age of Ship at the Time of Docking	32.5823065	19.95705806	1.632620719	0.128494501	-10.90038767	76.06500061	-10.90038767	76.06500061

$Y=1041.63+0.0071*S_{FD}+32.58*A$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.45085768
R Square	0.20327265
Adjusted R Square	-0.01401663
Standard Error	1155.7919
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	3749049.64	1249683.213	0.935493225	0.456257246
Residual	11	14694403.96	1335854.905		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.7269707	3258.264518	0.00083694	0.999347204	-7168.66488	7174.118822	-7168.66488	7174.118822
Full Load Displacement	0.00345071	0.06481278	0.05324124	0.958494315	-0.139201254	0.146102679	-0.139201254	0.146102679
Age of Ship at the Time of Docking	31.6855376	20.92703675	1.514095761	0.158192911	-14.3745597	77.74563494	-14.3745597	77.74563494
Values for Type of Ship	905.906913	2783.573809	0.325447419	0.750948977	-5220.697734	7032.511559	-5220.697734	7032.511559

$Y=2.73+0.0034*S_{FD}+31.69*A+905.91*T$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.90545962
R Square	0.81985712
Adjusted R Square	0.74779996
Standard Error	576.407572
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	15120996.7	3780249.176	11.37787275	0.000967375
Residual	10	3322456.895	332245.6895		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2477.24298	1679.317019	-1.475149095	0.170948386	-6218.994476	1264.508514	-6218.994476	1264.508514
Full Load Displacement	0.03906666	0.032891219	1.187753367	0.262376015	-0.034219547	0.112352859	-0.034219547	0.112352859
Age of Ship at the Time of Docking	12.5446465	10.93736944	1.146952798	0.278102507	-11.82533131	36.91462428	-11.82533131	36.91462428
Values for Type of Ship	2069.5902	1402.379836	1.475770081	0.170784812	-1055.106794	5194.287201	-1055.106794	5194.287201
General Services Works	3.79768564	0.649129394	5.850429322	0.000161515	2.351335216	5.24403606	2.351335216	5.24403606

$Y=(-2477.24)+0.04*S_{FD}+12.54*A+2069.59*T+3.8*GS$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement
(Ton)
A= Age of Ship at the Time of Docking (Year)
T= Values for Type of Ship
GS= General Service Works
(Days)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.91983298
R Square	0.84609271
Adjusted R Square	0.76058867
Standard Error	561.603053
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	15604871.7	3120974.34	9.895352691	0.001861849
Residual	9	2838581.902	315397.9891		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2500.873	1636.296463	-1.528374021	0.160770354	-6202.432767	1200.68676	-6202.432767	1200.68676
Full Load Displacement	0.04391773	0.032284877	1.360319017	0.206821701	-0.029115734	0.116951199	-0.029115734	0.116951199
Age of Ship at the Time of Docking	10.5674633	10.77534703	0.980707467	0.352362808	-13.80806517	34.94299178	-13.80806517	34.94299178
Values for Type of Ship	2152.74781	1368.009385	1.573635262	0.150023138	-941.904422	5247.400036	-941.904422	5247.400036

General Services Works	3.30945471	0.745235015	4.440820205	0.00162157	1.623615985	4.99529344	1.623615985	4.99529344
Plate Works Works	8.60743273	6.949227151	1.238617265	0.246818646	-7.112811245	24.3276767	-7.112811245	24.3276767

Y=(-2500.87)+0.044*S_{FD}+10.57*A+2152.75*T+3.31*GS+8.61*PL

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97967767
R Square	0.95976833
Adjusted R Square	0.92959458
Standard Error	304.55108
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	17701442.72	2950240.453	31.80805598	3.68102E-05
Residual	8	742010.8807	92751.36008		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-992.516095	942.3550054	-1.053229504	0.323004703	-3165.590634	1180.558445	-3165.590634	1180.558445
Full Load Displacement	0.00200334	0.019602075	0.102200342	0.921112919	-0.043199128	0.047205806	-0.043199128	0.047205806
Age of Ship at the Time of Docking	1.72675783	6.132081623	0.281594071	0.785401527	-12.41384775	15.86736341	-12.41384775	15.86736341
Values for Type of Ship	923.320113	785.6325118	1.175257005	0.273682586	-888.3517081	2734.991934	-888.3517081	2734.991934
General Services Works	2.95958996	0.410777743	7.204844976	9.20141E-05	2.012334783	3.90684513	2.012334783	3.90684513
Plate Works	7.27319667	3.778923126	1.924674418	0.090460947	-1.441015688	15.98740902	-1.441015688	15.98740902
Hull Cleaning & Painting Works	0.1791573	0.037682514	4.754388272	0.001437122	0.092261268	0.266053333	0.092261268	0.266053333

$Y=(-992.52)+0.002*S_{FD}+1.73*A+923.32*T+2.96*GS+7.27*PL+0.18*HCP$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99693254
R Square	0.99387449

Adjusted R Square	0.98774898
Standard Error	127.040816
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	18330478.02	2618639.717	162.251679	3.31075E-07
Residual	7	112975.583	16139.36899		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-827.747951	393.9801363	-2.100989046	0.073763393	-1759.362936	103.8670342	-1759.362936	103.8670342
Full Load Displacement	-0.00020113	0.008184455	-0.024574184	0.981080475	-0.019554287	0.019152034	-0.019554287	0.019152034
Age of Ship at the Time of Docking	-3.71612652	2.702439008	-1.375100977	0.211495018	-10.10637934	2.674126295	-10.10637934	2.674126295
Values for Type of Ship	1077.58337	328.6499485	3.278818015	0.01350905	300.4497331	1854.71701	300.4497331	1854.71701
General Services Works	1.89924721	0.241265106	7.872034381	0.00010102	1.328745888	2.469748528	1.328745888	2.469748528
Plate Works	3.05166158	1.715258333	1.779126513	0.118446083	-1.004279875	7.107603031	-1.004279875	7.107603031
Hull Cleaning & Painting Works	0.18071739	0.015720917	11.49534699	8.47894E-06	0.143543333	0.217891455	0.143543333	0.217891455
Piping Works	3.26742857	0.523373669	6.243012904	0.000427032	2.029846498	4.505010638	2.029846498	4.505010638

$Y=(-827.77)+(-0.0002)*S_{FD}+(-3.72)*A+1077.58*T+1.9*GS+3.05*PL+0.181*HCP+3.27*P$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works
(Days)
PW= Plate Works (Ton)
HCP= Hull Cleaning & Painting Works (Sqm)
P= Piping Works (Rm)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99699644
R Square	0.9940019
Adjusted R Square	0.98600444
Standard Error	135.785125
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	18332828	2291603.5	124.2896837	4.25792E-06
Residual	6	110625.6014	18437.60023		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-938.727772	523.4091518	-1.793487501	0.123057212	-2219.463828	342.0082849	-2219.463828	342.0082849
Full Load Displacement	-0.00134494	0.009316048	-0.144368086	0.889936966	-0.024140488	0.021450608	-0.024140488	0.021450608

Age of Ship at the Time of Docking	-2.76557026	3.928398571	-0.703994315	0.50782393	-12.37801528	6.846874757	-12.37801528	6.846874757
Values for Type of Ship	1129.16441	379.8238037	2.972863743	0.024865168	199.7690481	2058.559781	199.7690481	2058.559781
General Services Works	1.91872049	0.263577225	7.27953827	0.000342164	1.273770259	2.563670729	1.273770259	2.563670729
Plate Works	3.62915372	2.444919936	1.484365059	0.188246106	-2.353349842	9.611657291	-2.353349842	9.611657291
Hull Cleaning & Painting Works	0.17309796	0.027163166	6.372525139	0.000701554	0.106632086	0.239563833	0.106632086	0.239563833
Piping Works	3.10035936	0.72932862	4.25097723	0.005374352	1.315756513	4.8849622	1.315756513	4.8849622
Under Water Fittings Works	0.85600069	2.397695784	0.357009714	0.733305093	-5.010949542	6.722950915	-5.010949542	6.722950915

$Y=(-938.73)+(-0.0013)*S_{FD}+(-2.77)*A+1129.16*T+1.92*GS+3.63*PL+0.17*HCP+3.1*P+0.86*UWF$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PW= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

P= Piping Works (Rm)

UWF= Under Water Fittings Works (Nos)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99779532
R Square	0.99559551
Adjusted R Square	0.98766742

Standard Error	127.463007
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	9	18362219.51	2040246.612	125.5782264	2.37172E-05
Residual	5	81234.09092	16246.81818		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-990.068267	492.8104952	-2.009024315	0.100771729	-2256.877975	276.74144	-2256.877975	276.74144
Full Load Displacement	0.01111384	0.012738853	0.872436361	0.422879957	-0.021632425	0.043860102	-0.021632425	0.043860102
Age of Ship at the Time of Docking	-3.44197771	3.72176489	-0.924824059	0.39749753	-13.00907893	6.125123512	-13.00907893	6.125123512
Values for Type of Ship	1148.59063	356.8372444	3.218808161	0.023496828	231.3112958	2065.869973	231.3112958	2065.869973
General Services Works	2.1909964	0.31968329	6.853646936	0.0010102	1.369224341	3.012768455	1.369224341	3.012768455
Plate Works	2.49147815	2.445980194	1.018601113	0.355120739	-3.796114109	8.779070407	-3.796114109	8.779070407
Hull Cleaning & Painting Works	0.1782363	0.025782965	6.912948181	0.000971036	0.11195908	0.244513523	0.11195908	0.244513523
Piping Works	2.68624692	0.750673813	3.578447619	0.015900938	0.75657845	4.615915387	0.75657845	4.615915387
Under Water Fittings Works	1.32735721	2.277863145	0.582720352	0.58537094	-4.528076413	7.182790838	-4.528076413	7.182790838
Above Water Fittings Works	-7.07265995	5.258428653	-1.345013962	0.236403251	-20.58988113	6.444561225	-20.58988113	6.444561225

$Y=(-990.07)+(0.01)*S_{FD}+(-3.44)*A+1148.59*T+2.19*GS+2.49*PL+0.18*HCP+2.69*P+1.33*UWF+(-7.07)*AWF$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship
GS= General Service Works
(Days)
PW= Plate Works (Ton)
HCP= Hull Cleaning & Painting Works (Sqm)
P= Piping Works (Rm)
UWF= Under Water Fittings Works (Nos)
AWF= Above Water Fittings Works (Nos)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99780341
R Square	0.99561165
Adjusted R Square	0.98464079
Standard Error	142.246491
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	10	18362517.34	1836251.734	90.75051397	0.0002855
Residual	4	80936.25717	20234.06429		
Total	14	18443453.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1054.87271	766.6654336	-1.375923142	0.240858937	-3183.477202	1073.731779	-3183.477202	1073.731779
Full Load Displacement	0.01117641	0.01422569	0.78564993	0.475999321	-0.028320435	0.05067326	-0.028320435	0.05067326

Age of Ship at the Time of Docking	-3.49891589	4.179854859	-0.837090284	0.449639589	-15.10405345	8.106221674	-15.10405345	8.106221674
Values for Type of Ship	1199.99434	581.4605316	2.063758887	0.107991268	-414.3989075	2814.387586	-414.3989075	2814.387586
General Services Works	2.19753831	0.360812809	6.090521878	0.003674944	1.195761351	3.199315269	1.195761351	3.199315269
Plate Works	2.29440038	3.176440023	0.722318182	0.510070746	-6.524810973	11.11361174	-6.524810973	11.11361174
Hull Cleaning & Painting Works	0.17837653	0.028796544	6.194372791	0.003453311	0.098424505	0.258328553	0.098424505	0.258328553
Piping Works	2.6925473	0.839346879	3.20790768	0.03265389	0.362146765	5.022947832	0.362146765	5.022947832
Under Water Fittings Works	1.41278355	2.637769985	0.535597703	0.620629866	-5.910840019	8.736407109	-5.910840019	8.736407109
Above Water Fittings Works	-7.27297846	6.096168992	-1.193040821	0.298780453	-24.19865702	9.652700098	-24.19865702	9.652700098
Machinery & Equipment Works	3.57132485	29.4363502	0.12132363	0.909285237	-78.15708559	85.29973529	-78.15708559	85.29973529

$Y=(-1054.87)+(0.01)*S_{FD}+(-3.5)*A+1199.99*T+2.2*GS+2.29*PL+0.18*HCP+2.69*P+1.41*UWF+(-7.27)*AWF+3.57*ME$

Where

Y=Labor Cost (Man Day)

S_{FD}= Full Load Displacement (Ton)

A= Age of Ship at the Time of Docking (Year)

T= Values for Type of Ship

GS= General Service Works (Days)

PL= Plate Works (Ton)

HCP= Hull Cleaning & Painting Works (Sqm)

P= Piping Works (Rm)

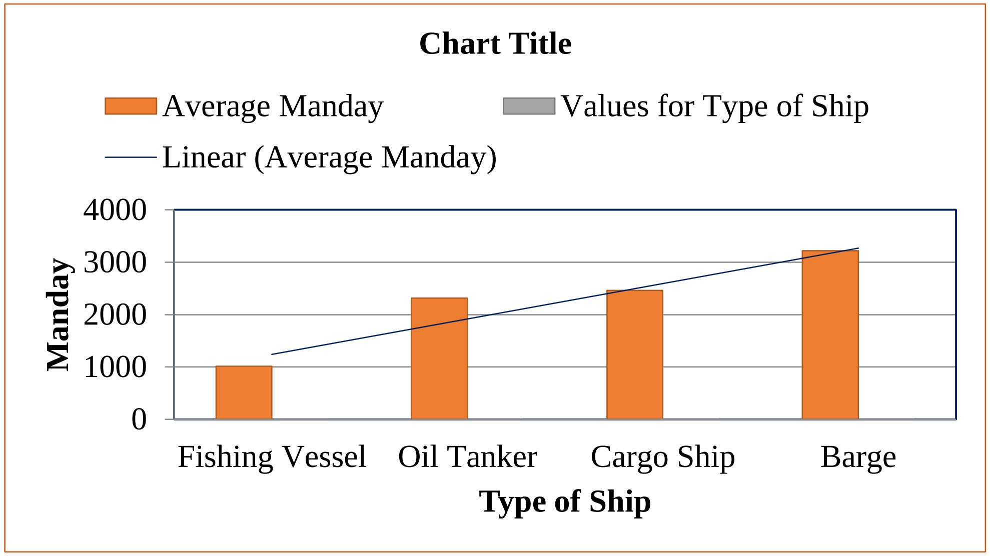
UWF= Under Water Fittings Works (Nos)

AWF= Above Water Fittings Works (Nos)

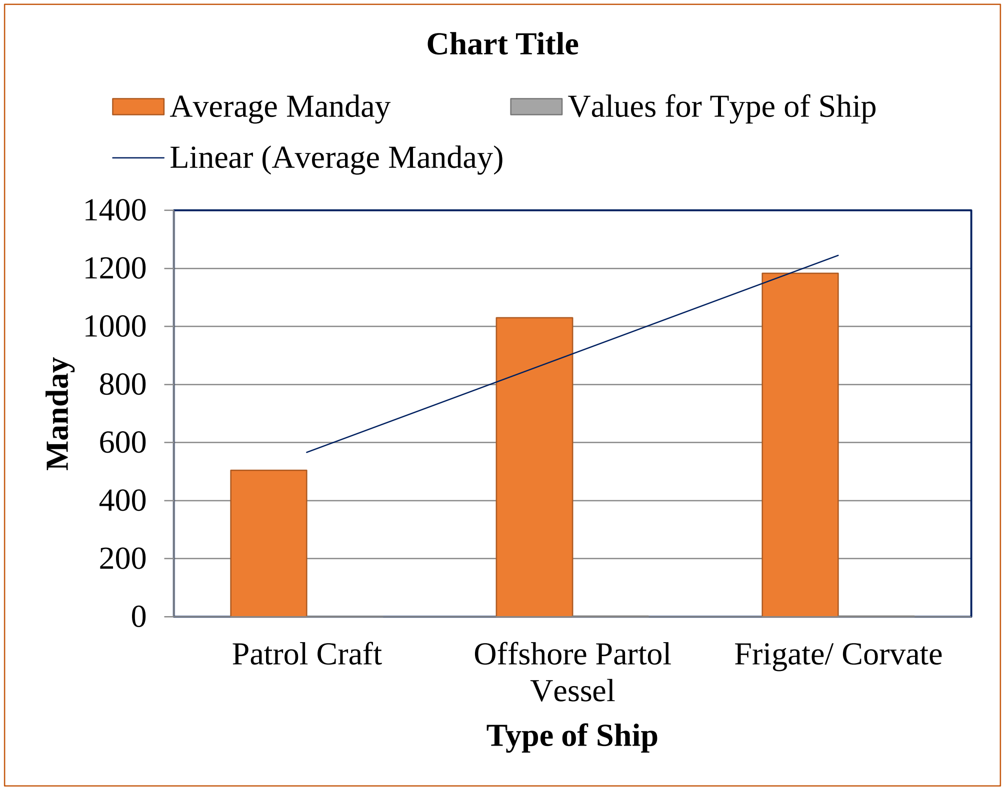
ME= Machinery & Equipment Works (kW)

Appendix D. Values of Type of Ship

Ser	Type of Ship	Average Man day	Values for Type of Ship
1.	Fishing Vessel	1013.92814	1.00
2.	Oil Tanker	2316.362	2.28
3.	Cargo Ship	2463.88686	2.43
4.	Barge	3222.45454	3.18



Ser	Type of Ship	Average Man day	Values for Type of Ship
1	Patrol Craft	503.95	1.00
2	Offshore Partol Vessel	1029.98	2.04
3	Frigate/ Corvate	1182.81	2.35



Ser	Type of Ship	Average Man day	Values for Type of Ship
1.	Tug	1686.065	1.00
2.	Other	2103.22727	1.25