2013

A study of the size of nuclear fuel carriers, the most required ships for safety : how large can ship's tonnage be?

Azusa Fukasawa
World Maritime University

WORLD MARITIME UNIVERSITY
Malmö, Sweden

A STUDY OF THE SIZE OF NUCLEAR FUEL CARRIERS, THE MOST REQUIRED SHIP FOR SAFETY

How large can ship's tonnage be?

By

AZUSA FUKASAWA
Japan

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE
In
MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENTAL ADMINISTRATION)

2013

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): ....

(Date): ......14 October 2013......

Supervised by:	**Raphaël Baumler, PhD** **Associate Professor,** **World Maritime University, Malmö**
Assessor:	**Aykut I. Ölçer, PhD** **Associate Professor,** **World Maritime University, Malmö**
Co-assessor:	**Dimitris Konovessis, PhD** **Senior Lecturer,** **Nanyang Technological University, Singapore**

ACKNOWLEDGEMENTS

First of all, I would like to express my sincere gratitude to Dr. Yohei Sasakawa, the Chairman of the Nippon Foundation, and staff of Ocean and Policy Research Foundation for giving me this valuable opportunity and full scholarship without which my studies at World Maritime University would not be possible.

I would also like to extend my deepest appreciation to my esteemed and illustrious dissertation supervisor, Dr. Raphaël Baumler who has been continuously inspiring and passionately guiding me, providing me with useful advice, suggestions and recommendations all through to accomplish this research.

I wish to thank Captain Trevor Dixon and Mr. Yoshiyuki Fujita, both Specialist Advisors of World Nuclear Transport Institute, for providing me with supportive information related to the INF ships, and Mr. Göran Helmertz not only as my host father, but also as a private advisor, giving me advice on approaching questions; you and your family cheered me up.

I would like to extend my gratefulness to Mr. Jan-Åke Jönsson, Swedish Naval Academy, former professor of World Maritime University, and Mr. Aji Vasudevan, Deputy Chief Ship Surveyor-cum-Senior Dy.Director General of Shipping (Tech) of India, alumni of WMU, for sharing knowledgeable material with me.

I appreciate Mr. Kazuya Kamiya, of the Maritime Bureau, the Ministry of Land, Infrastructure, Transport and Tourism, for giving me effective advice and reliable regulations on the National Act of INF ships

I further wish to thank Ms. Inger Battista, English Lecturer of World Maritime University, who helped me with precise comments on my language in this dissertation, and my dearest friends not only the MSEA class of 2013, but also beyond the specializations and classes; your continuous reinforcement kept me going on.

I am grateful to Dr. Takeshi Nakazawa and Dr. Momoko Kitada of World Maritime University, and Mr. Erich and Mrs. Yoko Siebert, who kindly supported my studies and life in Malmö.

Last but not least, my warmest appreciation to Minagi, Hayase, and helpful brother Hirosuke Itoh who shared their happiness and stayed with me in Malmö; further, my parents, my husband and lovely Honoka for emotional support to me and patience during my absence.

The people I cited here are not definite. My apology to anyone I have not mentioned who has directly or indirectly contributed to the assistance of this dissertation. Tack så mycket.

ABSTRACT

Title of Dissertation **:** A study of the size of nuclear fuel carriers, the most required ship for safety: How large can ship's tonnage be?

Degree **:** Master of Science in Maritime Affairs (Maritime Safety and Environmental Administration)

The Tonnage Measurement Convention is the only existing international standards for tonnage measurement of ships. During the last four decades, ship design and operation systems have been changed drastically. Even new type of ships appeared gaining the economic advantage by exploiting a kind of loophole of the Convention and drove rival ships away from the fleet.

Most merchant ships are likely to have incentives to reduce gross tonnage (GT) to achieve the economic benefits that are most prominent. Yet there are ships which are not limited by the restriction of the GT based threshold.

This dissertation is a study to examine the distribution of general merchant ships looking for a trend comparing the ship's purpose and cargo types. The samples chosen are ships with a length of 100 metres from the world fleet register database.

The study focuses on the exceptional trend of GT appearance of the Irradiated Nuclear Fuel (INF) carrier with its abnormal characteristics of the cargo or the purpose and what factor makes the figures outstanding.

The idea of ‘a safe ship tends to be large’ was supported by the result of this study. Further, it might give a little push to shipping industries’ opinion which requests the amendments of the Tonnage Measurement Convention as it was never amended since its entry into force in 1982.

The question remains whether there is a direct link between changing the Convention and the ship becoming safer and crews’ well-being; however, the current measurement theory stands on the common sense of shipbuilding over a century ago; therefore, the Convention is too old to fit the reality of the shipbuilding and the operation system today.

In the end, the critique and recommendations of the author are reiterated in relation to the amendment of the Convention which has been emphasized in order to introduce the tacit amendment procedure.

Keywords: Tonnage Measurement Convention, Gross Tonnage, Net Tonnage, Deadweight, Maritime Real Estate, Irradiated Nuclear Fuel (INF) carrier

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AIS	Automatic Identification System
B	Breadth
CGT	Compensated Gross Tonnage
d	draft, summer draft
DMLC	Declaration of Maritime Labour Compliance
DNV	Det Norske Veritas
DWT	Deadweight Tonnage
GRT	Gross Register Tonnage, in tons
GT	Gross Tonnage, as per ITC-69
IAEA	International Atomic Energy Agency
IBC Code	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
ICFTU	International Confederation of Free Trade Unions
ILO	International Labour Organization
IMDG Code	International Maritime Dangerous Goods Code
IMCO	Intergovernmental Maritime Consultative Organization
IMO	International Maritime Organization
INF	Irradiated Nuclear Fuel

INF Code	International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships
ISO	International Organization for Standardization
ITC-69	International Convention on Tonnage Measurement of Ships, 1969
LL-66	International Convention on Load Lines, 1966
Loa	Length overall
MARPOL-73/78	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978
MLC-2006	Maritime Labour Convention, 2006
MOX	Mixed-Oxide
MRE	Maritime Real Estate
MSC	Maritime Safety Committee
N/A	Not applicable
NDA	Nuclear Decommissioning Authority
NFT	Nuclear Fuel Transport, as company's name
NRT	Net Register Tonnage, in tons
NT	Net Tonnage, as per ITC-69
OWS	Oily Water Separator
PCC	Pure Car Carrier

PGS	Petroleum Gas Services ASA, as company's name
PNTL	Pacific Nuclear Transport Ltd., as company's name
PC/UMS-NT	Panama Canal Universal Measurement System Net Tonnage
Ro-Ro ship	Roll-on Roll-off ship
RPS	Redundant Propulsion Separate
SBT	Segregated Ballast Tank
SKB	Svensk Käränbranslehantering, as company's name
SLF	Sub-committee on Stability and Loadlines and Fishing Vessels Safety
SOLAS	International Convention on Safety of Life at sea, 1974, as amended
SPS Code	Code of Safety for Special Purpose Ships, 2008
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended
TEU	Twenty-foot Equivalent Unit
UK	United Kingdom
ULCC	Ultra-large Crude Carrier
VLCC	Very Large Crude Carrier

Chapter 1 Introduction

1.1. Back ground

Over 40 years the International Convention on Tonnage Measurement of Ships (hereinafter the ITC-69 Convention) has never been amended since adopted in 1969. Its entry into force was in 1982, with an interim period until 1994. There were only circulars with interpretation. Further, the idea of the Convention was based on the common sense of shipbuilding which was available hundred years ago. Technology of shipbuilding and ship operation has been innovated, and shipping style has changed; however, still the measurement theory remains as before.

Tonnage is used for many purposes, e.g. charging dues and basis of regulatory limitations. It determines ship's size by total volume of enclosed spaces. It is believed to be fair to compare ship's tonnages in order to deal with several restrictions. Different types of ships' size could be compared with this tool.

However, because of economic competition, similar sized ships are attempted to be built as close as possible to the threshold and the figure of ship size never goes beyond. If the ship's size is larger than a particular figure, the ship would be useless, for example it will simply cost higher port fees and taxes and/or safety regulations may require more advanced equipment.

Naval architects have complained about the limitation of the tonnage measurement system, which restricts the freedom of ship design; consequently, ship might miss the chance of protecting itself because there is not enough space of volume to add for safety.

Even if new technology has been developed, the tonnage calculation method is the same as in the past, and the tonnage limitation on the regulation is the same as well. Therefore, the Convention should be revised to adjust the gap between the text and the reality.

It is time to think about renewing or amending the Convention; this strong pressure by the shipping industries has pushed International Maritime Organization (IMO).

1.2. Purpose

This dissertation compares the difference between the size of special ships and general merchant ships, and investigates the aspects influencing those disparities. There is an argument by ship designers saying that if the ship needs to be safer; through volume enhancement the tonnage becomes bigger. In this regards, the ship which has abnormal aspects such as carrying dangerous cargo stands as a special ship; further, the hypothesis is that if the ship becomes larger when it is safer, Irradiated Nuclear Fuel (INF) carriers might show quite a difference against the ships with the same length.

1.3. Methodology

It was a remarkable feeling to have a look at the photo of INF ship, *Pacific Heron* (see Figure 11), with its relatively high freeboard and top-heavy impression, perhaps because of the large structure of the accommodation. It was interesting what cargo the ship was carrying. The ship's design contains the finalized optimization of the shipowner's will, ship designer's innovation and shipbuilder's technique.

In this research, the hypotheses were built by the difference between ship types. Looking through data, it was sorted by cargo types or operational styles.

The data of sample ships were found in the Clarksons World Fleet database, such as merchant cargo carriers in general trade compared with INF ships. Quantitative analyses were made. Data sets of gross tonnage (GT), net tonnage (NT), deadweight tonnage (DWT), length overall (Loa), breadth (B) and summer draft (d) were classified from this database.

Actual GT distribution is observed from the overview of the ship around 100 metres in length. Ships are sorted by 12 categories in accordance with the data base description.

The frequency and distribution of the ratio of GT/DWT, GT/NT were observed, when the distribution shows they are concentrated in less tendencies, which means close to constant.

Further, relationship between GT and DWT, GT and NT, and GT and the volume of L x B x d were examined. The figure L x B x d were led by the ideas were taken from Maritime Real Estate (MRE) which are used as the basis of port fees in particular countries. The tendencies may appear on the trend line on the chart and are supposed to be close to the constant ratios mentioned above.

1.4. Structure

In this regard, Chapter 2 explains Tonnage and the Tonnage Measurement Convention today. Chapter 3 focuses on the use and importance of tonnage on ship design. Chapter 4 analyses the ship's size compared to nuclear fuel carriers and describes the trends of the ship's size by type. Chapter 5 investigates if there is any intention other than getting small tonnage with examples of how INF ships are designed to comply with safety requirements and how strong it appears as an impact to ships' tonnage. Chapter 6 discusses the basic concerns of when the Convention is going to be amended.

Finally, conclusions and recommendations are given in Chapter 7.

Chapter 2 Tonnage Measurement Convention

The concept of tonnage is to assess the ship's size by calculating the internal volume of a ship. It is related to the earning capacity indicated by various interpretations.

2.1. Before the Convention

How did the tonnage measurement begin?

2.1.1. Origin of Tonnage

In the Ancient Europe, unit of ship's size was compered by 'how many barrels of wine the ship could carry'. The idea started from 'the amount of wine', i.e. 'volume', so the three dimension factor turned into a dimensionless unit 'number' which meant of 'how many' casks. It made the figure easier to handle.

The sound of clapping wooden casks, 'tun(s)', is well-known as the origin of 'tonnage'. However, there was already the word 'tuns' used for charging when the wine cask was earthenware (jar) in a round shape. It was a heavy and less effective shape while the tonnage was based on the number of the containers instead of real weight of cargo. Subsequently, wooden wine casks were introduced and this reduced the weight of the package. Because of the same displacement ships could carry more, so wooden cask development resulted in a new relationship between cargo weight and cargo spaces on ships.

As wine was one of the major cargoes, it was initially levied by how many tuns the ship could carry. Later, it became a yardstick for all cargoes other than wine. Cargo carrying volume was the standard to indicate individual ship's size among various shapes and hull designs.

Consequently, calculation of vessel's volume required some sort of agreement, and many national rules appeared around the end of the 17th Century. For example, the first law of tonnage measurement was established in the leading maritime nation, the United Kingdom (UK), in 1694. Accordingly, in 1720, it was revised with regards to the relationship with tonnage and seaworthiness. In France, it began in 1681 to force the ship to carry a tonnage certificate. In the United States, they started using their independent method for measurement in 1789 (IMO, 2012).

In those days, the Builder's Old measurement rule calculated tonnage with the formula as follows:

Registered tonnage = {(L-3/5B) x B x B/2}/94 (Lane, 1964)

in which tonnage is influenced by the square of breadth. Here the depth was assumed as B/2 in constant. It led the trend of the hull form with long, narrow and deep shape which had lower tonnage. However, at the same time, there was less stability, so the ships could capsize easily. The incentive of getting small GT even ignoring the ships' safety could be seen. It turned into using actual depth for the calculation instead of half breadth when a British new rule was established in 1694.

The measurement systems started with a private agreement and followed by establishing the domestic rules of volume based calculation; however, there was still no unified system among other nations.

2.1.2. Moorsom's system

George Moorsom's measurement system appeared in the 19th century. It calculates the ship's total internal capacity with deductions and exemptions of some volumes which meet the conditions. The Moorsom's system was introduced in the British Merchant Shipping Act, 1854. Consequently, tonnage measurement became an important requirement during the registration process. The system is required to distinguish ships' ownership, measurement of size and registry to the administration.

Later, other countries followed implementing the Moorsom's system; for instance, Japan adopted Moorsom's principle in 1884. The British system became an informal international standard. The UK revised it several times, adding the item of exemption and deduction, expecting to solve baleful effects of the system and to get better working and living conditions on board.

The amendments of the system were to retrieve safe design and enhance crew's living conditions. There was a way to reduce tonnage, named tonnage openings, which has large hole(s) on construction deck, and caused loosing weather-tightness of the deck.

Some countries adjusted their systems according to their own policies, so Moorsom's system became dissecting out. It became a stake in shipping competition.

Consequently, the Suez Canal Authority switched to refer GT for charging instead NT. British shipowners' objection requested a specific rule for the Suez Canal Tonnage. In 1871, an independent computing theory was introduced at the European Danube Commission, and the Danube Rule was born to calculate the Suez Canal Tonnage, which is still alive today. Further, the Suez Canal Authority continued with its separate methods for tonnage measurement to collect canal fees.

Although today the Panama Canal Authority refers to the Gross Tonnage as a part of the calculation; it also adds individual factors to figure out their tonnage, in these cases Net Tonnage, the so called Panama Canal Universal Measurement System Net Tonnage (PC/UMS-NT), for charging canal fees.

After more than one century of experience, Moorsom's system became too complicated to handle over the multinational organization among worldwide trade.

In the 20th Century, there was a strong desire for a harmonized measurement system boiled up by maritime nations. Consequently, after the World War II, the United Nations was established and was required to develop an adequate system able to develop a uniform yardstick. In 1969, the conference was organized and led to the International Tonnage Convention which is still in use today.

2.2. Variability of Tonnage Measurement

Tonnage is a concept to indicate the magnitude of the ship. It is used to charge and to regulate ships in the shipping world. Many obligations are based on tonnage, e.g. tonnage tax, port dues, and several regulations on safety and pollution prevention at sea.

The magnitude can also be expressed in terms of weight, volume and others. In addition, it exist several tonnages and other scales exist. Some of them show how large the ship is, or how much it carries, without mentioning the word 'tonnage' but expressing ships' size. Here, it determines a concept of various interpretations which came into existence recently.

Further, seemingly GRT, NRT and GT, NT are similar names. However, there are significant differences between them. The former pair is for national registration, the latter is for international coordination. Until the Convention appeared, there were only registered tonnages which each country had determined on their own, though Moorsom's system had much influence in the maritime field.

The Convention was developed through a long period, and finally the requests of uniformalization had created a simple and harmonized method to measure, calculate and present ship's size. Historical challenges and changes were mentioned before in Chapter 2.1.

2.2.1. **Gross Register Tonnage and Net Register Tonnage**

Before ITC-69, in the Moorsom's system, GRT was calculated by the total enclosed space of the ship's inner liners, with subtracted special places named Exempted spaces. The navigational spaces, galleys, stairways and light and air spaces are deducted from Under-deck, Tweendeck, Superstructures, Deckhouses and Other erections. Total capacity was transformed into tons where one ton was equivalent to 100 cubic feet (Lane, 1964; Moorsom, 1855), or one cubic metre was equivalent to 0.353 tons.

Gross Register Tonnage (GRT) and Net Register Tonnage (NRT), both registered tonnage, were officially recorded by the flag States and indicated on the registration documents. Although there was no unified measurement system for these, they were likely measured by Moorsom's system before ITC-69 appears.

NRT showed the earning capacity for cargo and passengers, and was calculated by deducting certain spaces which did not generate money directly, such as the space for propulsion of machinery and crew accommodations from GRT.

These register tonnages were determined by each country's national regulation. In the case of Japan, it referred to the Figure calculated in the same way described in ITC-69 if the ship has been built or repaired drastically after 1982. If the Figure, K_1V, which is explained later in GT, is less than 4,000, and/or if the ship applies a special condition, the ship's GRT will be changed from GT (K_1V) with additional adjustment.

This adjustment was set for smoothing the gap between the conventional ships' and existing ships' tonnages, while the implementation of ITC-69 was requested. Those existing ships were applied to Moorsom's system in a Japanese version which had NRT in the past; however, even to the existing ships there is no NRT anymore. The Japanese Maritime Administration only refers to ships' GT in case that the ship holds the International Tonnage Certificate, and GRT.

2.2.2. **Gross Tonnage and Net Tonnage**

GT and NT are regulated under the International Convention on Tonnage Measurement of ships, 1969 (ITC-69). GT is a dimensionless number where the total enclosed spaces in moulded volume are transformed by a standard formula in the Regulation-3 of ITC-69. It includes all covered spaces when necessary, such as navigational space or light and air spaces which were exempted from GRT.

NT is calculated by Regulation-4 of ITC-69; it reflects the total volume of cargo spaces, passenger number, depth, draft, and the GT of the ship. Both GT and NT are rounded down without decimals to get the final Figure on the calculation.

The figure of tonnage is used for charging taxes, and to fuel statistics in maritime trade. While NT shows the size of cargo space, GT respects its total enclosed volume. GT, being the largest figure on the International Tonnage Certificate, is used as a representative number to measure shipping or cargo capacity.

2.2.3. **Deadweight and Twenty-foot Equivalent Unit**

Both DWT and Twenty-foot Equivalent Unit (TEU) are used to evaluate particular type of ships' cargo carrying ability. DWT represents for bulk carriers, both dry and liquid, TEU is used for containers.

DWT is the water weight displaced because of the cargo, and describes the ship's carrying capacity in weight where the different displacements between fully loaded and the lightweight of the ship are calculated. It includes, as far as the ship is not over-loaded, the total weight of the cargo and passengers, fuel, ballast, food, water, store, crew and luggage. Displacement of a particular draft is calculated from the beginning of the design period, and not only to find DWT but also to be sure of the stability calculation. Further, full load displacement tonnage is used to estimate construction of battle ships, as for war ships do not apply to ITC-69.

TEU stands for Twenty-foot Equivalent Unit, and indicates container ships' carrying capacity where one TEU is equivalent to one twenty-foot shipping container. The size of this container is standardized by the International Organization for Standardization (ISO), and approximately, L x B x H = 6.1 m x 2.44 m x 2.6 m with 39 m^3 in volume.

Both DWT and TEU are one of the useful numbers which represent ship's capacity, especially, comparing in the same category of ships such as tankers, as liquid bulkers, and container carriers.

In July 2013, Maersk Group in Denmark started operating the Triple E-class container named after its three principles, "Economy of scale", "Energy efficiency" and

"Environmentally improved" (“Building the world’s,” 2013). *Maersk Mc-Kinney Moller*, the ship’s length is 399.90 metres, and it has a capacity of 18,270 TEU (clarksons.net, 2013) which shows the largest container ship in the world at the moment.

On the contrary, the TI-class supertankers, where the ‘TI’ refers to the operator’s name, Tankers International L.L.C., represent the Ultra-large crude carriers (ULCCs). It includes *TI Europe* of 380 m in length overall and 442,470 DWT.

Although it is possible to calculate *M. Mc-Kinney’*s DWT which is 194,849, it does not conclude that the tanker carry twice as much as the container. Just for the record, GT of these ships are *M. Mc-Kinney*: 194,849GT and *TI Europe*: 234,006 GT.

It is meaningless to compare container carriers and tankers by DWT because these ships compete in different categories, i.e. different types of cargo markets.

2.2.4. Compensated Gross Tonnage

Compensated Gross Tonnage (CGT) is used in shipbuilding industries, and is important for economic evaluation. It shows commercial shipbuilding output and productivity, but does not indicate ship size.

Even if GT or DWT are the same, there are different works for different types of ships. It determines the workload for the particular ship which reflects the work contents and complexity. CGT includes two factors depending on type and size of ship; further, cost per CGT could express efficiency of the shipyard.

2.2.5. Maritime Real Estate

Maritime Real Estate (MRE) is a concept as a third tonnage after GT and NT for charging ships, proposed by Australia in 2005, and it introduced an argument at the SLF subcommittee at IMO (IMO, 2005a; IMO, 2005b). At the end of ninety-second session of MSC in 2013, the third tonnage concept was rejected. Still the universal idea of ship's magnitude is determined by GT and NT. However, MRE is used, in several ports for charging port dues.

MRE is produced by the contribution of length, breadth and draft, with a certain scale factor. Here draft has many meanings, for example, maximum draft, minimum draft, actual draft, i.e. draft for each condition at port, and summer draft. It depends on the situation when MRE is used, i.e. present condition or getting a certificate. In case of assessing a certificate, summer draft will be used as a representative figure.

This item is used to analyze ships' data in this research later.

To sum up, tonnage leads to an idea of the magnitude of the ship. There are many factors which describe ships' size and capacity. However, our focus is on GT and NT which are determined by the so called 'Tonnage Measurement Convention', and constitute the internationally recognized yardstick.

2.3. Present Tonnage Measurement Convention

The International Convention on Tonnage Measurement of Ships, (ITC-69) was established by the Intergovernmental Maritime Consultative Organization (IMCO) on 23rd June 1969, and came into force on 18th July 1982. There was a phase-in period for the existing ships up to 18th July 1994 expecting a smooth implementation. The Convention applies to all ship built (keel laid) on or after 18 July 1982, while the ships built before the entry day could retain their existing tonnage for 12 years which means until 18th July 1994.

2.3.1. Principle of the Convention

According to the first part of the Convention, it was agreed by the Member States' desire "to establish uniform principles and rules with respect to the determination of tonnage of ships engaged on international voyages" (ICMO, 1969).

After the Convention came into force, shipbuilders needed to consider the ships' tonnage with this Convention so ship design applied for new ship has been changed.

As of 31st July 2013, 152 States amounting to 99.06 % of world fleet have ratified the Convention (IMO, 1977; IMO, 1982; www.imo.org.) It became the first, sound and practical basis for universal tonnage measurement system. Until then, there were several national rules to calculate registered tonnages. Moorsom's System was one of them and required an internal measurement which took the distance from the top of the floor or from the inside of the frames; therefore, it was necessary to wait for all the structures to be completed. Now, tonnage should be surveyed on paper by the authority before ship's register.

ITC-69 applies to the ships in length of 24 metres, i.e. 79 feet and over, engaged on international voyages. War ships and the ships navigating in special areas which are mentioned in Article 4 are excluded from ITC-69.

2.3.2. Gross Tonnage and Net tonnage

GT and NT are indicated by dimensionless numbers; calculation is based on the total volume of enclosed and moulded spaces, and volume of cargo spaces (IMO, 1982). The total volume is considered with excluded spaces and whether it has enough opening to fulfill the Regulation 2(5) *Excluded Spaces*. The stipulations are not only the opening shape and size but also the condition whether it allows to secure cargos and/or stores or be able to close the opening; it means useful space could not be excluded from the total volume.

Calculation of the GT is determined by the following formula in Annex 1, Regulation 3 of ITC-69:

$$GT = K_1V$$

where: V = Total volume of all enclosed spaces of the ship in cubic metres,

$K_1 = 0.2 + 0.02 \log_{10}V$ (or as tabulated in Appendix 2)

(IMO, 1983; IMO, 1994).

For instance, when the total volume V is 100,000 m^3, $\log_{10}V$ is 5; therefore, GT is 30,000 ton. When V is 1,000,000 m^3, GT is 320,000 ton. The relationship between V and GT shows a liner tendency that GT is approximately 30 % of the total volume in cubic metres. Although the process to calculate total volume is complicated, the formula gives the designing simulation easier than before.

NT is determined in Annex 1; Regulation 4 of ITC-69 by the formula follows:

$$NT = K_2Vc(4d / 3D)^2 + K_3(N_1+N_2/10),$$

in which formula:

(a) the factor $(4d / 3D)^2$ shall not be taken as greater than unity;

(b) the term $K_2Vc(4d / 3D)^2$ shall not be taken as less than 0.25 GT; and

(c) NT shall not be taken as less than 0.30 GT,

and in which:

Vc = total volume of cargo spaces in cubic metres,

$K_2 = 0.2 + 0.02 \log_{10} Vc$ (or as tabulated in Appendix 2),

$K_3 = 1.25\,(GT + 10{,}000) / 10{,}000$,

D = moulded depth amidships in metres as defined in Regulation 2(2),

d = moulded draught amidships in metres as defined in paragraph (2) of this Regulation,

N_1 = number of passengers in cabins with not more than 8 berths,

N_2 = number of passengers,

$N_1 + N_2$ = total number of passengers the ship is permitted to carry as indicated in the ship's passengers certificate; when $N_1 + N_2$ is less than 13, N_1 and N_2 shall be taken as zero,

GT = gross tonnage of the ship as determined in accordance with the provisions of Regulation 3 (IMO, 1983; IMO, 1994).

Even if there is no place for cargo, i.e. $Vc = 0\ m^3$, NT does not appear as zero. As the regulation mentioned above, at least 30 % of the GT will be signed as NT on the Certificate.

2.3.3. Amendment Procedure

One of the reasons ITC-69 has never been amended since the Convention's entry into force, is the inflexible amendment procedure.

According to Article 18 in the Convention, the amendment to ITC-69 is possible upon the proposal of a Member State by one of the three following methods:

(i) Amendment by unanimous acceptance,

(ii) Amendment after consideration in the Organization, and

(iii) Amendment by a conference.

If every Member State agreed on the proposal, within 12 months the amendment will enter into force (ICMO, 1969).

As the Convention has never been amended, it still follows the 1960's amendment procedure in which positive acceptance is required by the Member States. Nevertheless, the requirement was too difficult to carry out to get enough acceptances to achieve entry into force. On the other hand, while the major maritime conventions such as SOLAS, MARPOL-73/78, STCW and LL-66, have introduced the tacit amendment procedure to amend the technical provisions. The ITC-69 does not have this simple amendment procedure.

Although it is difficult to change some rules on the Convention, there is a way to grant exemptions from tonnage survey. According to Regulation 1(3) of ITC-69, when the ship is regarded as 'novel type(s) craft' (IMCO, 1969) by the proposal from the Flag State to IMO, the tonnage is acknowledged to be measured and calculated as well as the circulation to the Contracting Governments. Therefore, the basics have never changed; however, it was circulated to confirm the exception of the normal interpretation.

2.3.4. **Implementation and Interpretation**

The appearance of the Convention affected ships' design strongly. After the adoption of ITC-69, there were several reports which claimed difficulties to fit the interpretation to the expression. For example, segregated ballast tanks (SBT) for tankers and open-top-containers for container ships were introduced to the circular. Both aspects were given to avoid the disadvantage of the ships influenced by using GT as a common threshold.

Tankers should fit SBT for pollution prevention issues, which are required in Regulation 13(F) (later by 2013, in Regulation18) of Annex 1 to MARPOL-73/78. To avoid unfair competition between these new characters and other conventional ships, SBT and the open-top containers were circulated to be endorsed on the Remarks column of the Certificate. The calculated special tonnage should be used as charging tonnage-based fees, while the conventional GT is put on the front page of the Certificate (IMO, 1993b; IMO, 2006).

In conclusion, ITC-69 was developed to harmonize tonnage and create a common yardstick. GT and NT were expected to be used in other treaties, conventions and arrangements, and so they did. Currently, many rules and regulations refer GT as a ruler for separating the table, such as port fees, safety limitations, manning level and so on. The simple method of measurement allows figuring out ship's tonnage easier than before. Unfortunately, it affects ship design and to limit freedom by constituting a serious construction.

2.4. Approach to Today's Tonnage Measurement

In reality, the appearance of figures sometimes does not match the size of a ship. Several approaches to cope with the target GT were attempted by naval architects, and ships' form was stuck into the limit. The idea of tonnage measurement as a ruler (yardstick) makes the rule itself unchangeable. It caused stakeholders to complain.

For example, ITC-69 does not consider deckload cargo for tonnage calculation. The container carrier is one of the developments of deckload ships after the Convention appeared. It has a huge pile of containers on deck; however, deck load containers are not included in GT; therefore it creates a large advantage to other dry cargo ships. In this regard, the Panama Canal Authority requires the consideration of the number of containers in the calculation of the PC/UMS-NT.

There are various arguments at IMO meetings to amend the TM Convention. The UK warned that the requirement of reserve buoyancy in the load line rules leads high draft, and accordingly larger GT, which generates demands of additional port dues (IMO, 2002). Further, the circular of the open-top containerships reflects an argument. It showed that if there were unfairness between the ship which concerns more safety and/or environmental friendly but receives disadvantages, the board will consider the proposal of ‘novel type(s) craft’ as an exemption and smooth the relation (IMO, 1992).

Australia suggests introducing the third tonnage scheme. According to the IMO and Vasudevan (2010), a new parameter, Toll Tonnage, is suggested for charging a multiplied Figure of length, breadth and draft with standard factors.

The Maritime Labour Convention (MLC-2006) has a requirement of seafarers’ accommodation. A suggestion of describing the Certificate of the tonnage which excludes the volume of crew’s accommodation has been rejected (IMO, 2013). The size of the crew’s room will be listed on the supplement of Maritime Labour Certificate, i.e. Declaration of Maritime Labour Compliance (DMLC) part II.

In any cases of complaining about ITC-69, tonnage should be equity; further, tonnage measurement rules should avoid including private purposes. It could not be changed by the intention of serving other social purposes, such as progress of seafarers’ right is not available. When the rule makers are thinking of someone’s circumstance, the fairness will disappear. Moreover, the tonnage measurement rule should be clear; no doubtful and no secret loopholes should exist.

However, the International Confederation of Free Trade Union (ICFTU) indicated the inadequate methods for reducing GT by dangerous practices, e.g. small freeboard, removing forecastle, less crew space, especially, low height of the accommodation (IMO, 2006; IMO, 2007).

From the point of view of the measurer, the problem of falling behind in time is not a business of the rule but of the user. Further, GT is used in such a wide area that it affects everywhere when even a small change is proposed to the Convention, so the consequences are not ignorable.

According to Vasudevan (2010, p.3), “From the medieval times, the ship-designers, shipbuilders and ship-owners made every effort to get the lowest possible tonnages for a given deadweight, even by compromising the safety or crew welfare aspects. This continued even under ITC-69”.

In next chapter, assumption of tonnage reduction with intention is investigated.

2.5. Summary

In this chapter, Tonnage Measurement was described as an old system where the rules were consolidated in length by Moorsom.

It is based on volume calculation. Several tonnage types exist, such as national rules, PC/UMS-NT by the Panama Canal Authority and Suez Net Tonnage by the Suez Canal Authority; further it is used in the shipbuilding industry, i.e. CGT.

There is a single international tonnage used in shipping stated by the International Convention on Tonnage Measurement of Ships, 1969. ITC-69 proposes a unified method to determine tonnage on paper. Shipbuilders can estimate tonnage in advance of ship construction. Although the calculation methods are simple and acceptable, soon after the Convention's entry into force, there were some issues regarding the interpretation of the explanation.

However, despite its established drawbacks, the Convention has never been changed since its adoption in1969 and entry into force in 1982.

Chapter 3 Influences of Tonnage Measurement

In this chapter, the practical use and the consequences of the Convention will be described.

Many regulations refer to GT, and thresholds are set according to GT. Therefore, it is extremely important to build a ship below the threshold if it is necessary to avoid higher standard of regulation to apply on the ship.

3.1. Use of Gross Tonnage to set Thresholds

The Figure of tonnage is used to compare national and regional fleets, to build political decision on maritime trade and the shipping industry, to allow shipbuilding and dismantling, to regulate application and manning scale, and to charge dues and survey fees form ships. Further, in case the ship is a pollutant, insurance premiums and limitation of liability are based on GT. It includes every part of the ship; therefore, it seems fair to use the figure to be representative to the ship scale.

It is said that shipowners favor small tonnage for their ships because it affects the expenses directly. As a representative figure of ship's size, daily port dues and taxes are based on GT. Further, many regulations in the maritime field also refer to GT.

Some examples of thresholds based on tonnage exist. Shipowners are likely to get the ship with maximum tonnage just below the border line to avoid being required by the extra regulations.

For instance, the ships of 100 GT and above need to put the IMO number on the hull according to SOLAS Chapter XI-1/3 in terms of maritime security. The ship with 300 GT or more needs to be equipped with the automatic identification system (AIS) on board and transmits its detail information on radio wave.

One of the most severe thresholds is 500 GT; basically SOLAS applies to ships which of 500 GT and above, and requires various safety instruments, survey and certification. Further, STCW also applies to the ship with 500 GT and above. There is an interim scheme described in Resolution A.494(XII) (IMO, 1981), later revised in Resolution A.758(18) (IMO, 1993) for the existing ship, i.e. keel laid before 1982 or 1994. To avoid to be applied by SOLAS, and to continue the vested rights on safety issues, some of the old ships held a safety certificate with the message of ‘the ship is surveyed with GRT of 499’ endorsed.

Even if the ship does not apply SOLAS, tankers of 150 GT or above and all ships of 400 GT and above are requested to have survey and certificate in terms of pollution prevention by MARPOL-73/78.

Moreover, 1,000 GT is a threshold for fire-fighting systems (SOLAS Chapter II-2). 1,600 GT divides ship structure (SOLAS Chapter II-1) and fire mains such as water pipes, 2,000 GT and over require fixed fire extinguishers (SOLAS Chapter II-2, Regulation10.5.6). Further, 3,000 GT is a threshold for having VDR onboard and MLC 2006 requirements of accommodation, recreation, food and catering in the Regulation-3.

Because the compliance of the regulations is compulsory, the ship cannot exist without having planned tonnage. Shipbuilders are fearing that the ship's GT is passing over the threshold accidentally and fail to comply with the regulations until the ship's design is completed.

3.2. What makes Tonnage larger?

There are several factors involved when building bigger ships. According to the formula which calculates GT, every enclosed space influences GT regardless whether the space earns or not.

GT and NT are respectively dependent on the total volume of enclosed spaces and cargo spaces. The enclosed spaces used in the calculation for GT include cargo hold and non-earning spaces such as crew accommodation and superstructure like forecastle.

Naturally, safer ships require more volume for buoyancy, more space for additional safety equipment, and storage of expendable items, even for spare parts. Further, the idea of extra fire stations seems effective to achieve a safer environment.

Perhaps it increases accommodation for safer manning. The case of inviting training personnel or security guard on board for fighting against piracy might affect in the same way.

When the ship is supposed to sail certain hours, it is necessary to provide places for staying on board. According to the International Labour Organization (ILO), the Convention concerning Crew Accommodation on Board Ship, 1946 (C075) (revised version in 1949: C092), Article 10.12 says that “members of the crew shall be provided with individual berths” (ILO, 1946). It is the difference between ground service and seafarer’s working environment. For seamen, the ship is a working place as well as living place. Because of the harsh working environment, seafarers tend to be tired throughout the voyage. The decision of adding more crews onboard is one of the solutions to safer manning. However, additional crew means the additional space which cannot carry cargo. Moreover, to achieve seafarers’ wellbeing and better living conditions, their cabins need to be of a certain volume reflected by the floor area and especially by the clearance of height. (MLC 2006, requirements)

Crew’s accommodation is regulated in ILO rules; however, the issues were very complicated to be complied with, in order to protect the seafarers’ wellbeing. Finally, MLC 2006 entered into force in 2013, and the standards are expected to be followed; it may require additional volume on board, and adjustment with existing ship design seems to be very difficult to cope with, because the total volume and requested cargo capacity have already been given at the beginning.

Forecastle is used for storage space and mooring equipment at the bow end of the ship; further, it is required for safety issues, seaworthiness and extra buoyancy.

Freeboard is the height between the ship's deck and water level; each ship has a freeboard mark that indicates the maximum level of the water, and normally when the Figure is larger, the ship is safer. Usually, merchant ships try to get low freeboard, as a strategy to maximize the ratio of cargo space in the total volume.

In addition, if the ship's deck is high enough from the water level, it is difficult for pirates who are coming from the outside of the ship in small boats. However, low draft mark determines the limitation of the ship's cargo carrying weight, and if there is still space, i.e. volume for cargo above the freeboard, it declines ship's earning capacity

One of the measures that looked for a safer and more pollution preventing situation, but caused more volume onboard with resulted in a disadvantage of getting larger tonnage, has a special treatment as the circular of the open-top container. The open-top container has improved a higher safety rate and environmental protection. It is defined as

> a ship which is designed for the carriage of containers and which is constructed like an open U, with not less than 66.7 % of the total cargo hatchway clear

> opening area in an open-top configuration, with a double bottom and above this, high-sided erections without hatch covers on the upper deck and without a complete deck above the moulded draught (refer to the Figure), and needs to be regarded as a ship of a novel type as referred to in regulation 1(3) of the Convention (IMO, 2006). (IMO, 1993; IMO, 1994; IMO, 2007)

Because of its high protection wall around the containers which concerns safety, there is less fear of boxes dropping from the deck into the sea, which might also cause pollution to the sea. Personally, the author is doubtful whether the missing deck on container carriers could really exist with enough seaworthiness; however, if there is enough logical consideration, the board will consider the fairness. In the circular GT_R for the open-top container is calculated as 90 % of GT, and endorsed in the remark column of the Certificate.

The findings of the capsizing of the container carrier, M.V. Dongedijk, in 2000, alerted shipping industry that the ship was designed as a small GT as possible with the container arrangement of two tiers in hold and four tiers on deck and minimum crew members onboard. She was sailing with three fewer seafarers compared to the same TEU container ship. When the ship accepts a safer design with one tier carried below the deck, i.e. three in hold, three on deck, the GT would have been increased from her tonnage 2,926 to 3,800 (“Fresh Dongedijk capsize,” 2001)

When shipbuilders search a safer and more comfortable ship, the volume onboard usually increases; in reality, there are shipbuilders whose efforts to reduce GT resulted in less space for crew, elimination of forecastle and minimum freeboard.

3.3. Why is there an incentive to reduce tonnage?

Although it is obvious safer ships are preferred; shipowners seem to favor smaller ships. Why do many ships need to be small? It is because of economic reasons.

To compete with others, generally most merchant ship builders try to reduce GT on the owner's request; they reduce volume for non-cargo space while keeping an expected cargo capacity. For same cargo capacity, when the ship is large, firstly it influences initial cost in shipbuilding; further, there are costs for maintenance and operation on a daily basis. Because of the uselessness for earning, those spaces which make ships even larger, non-cargo space for stability and extra buoyancy are disliked by shipowners.

Usually, to those ships, safety is considered a minimum requirement; if it is enough, they do not put on extra safety. Then, are all ships built in the same way in order to reduce GT? It seems mostly yes; however, completely, no. Not all ships need to decline GT as it depends on the shipowner's priority.

In comparison of the DWT among ships in the world fleet, bulkers and tankers, dry and liquid bulk carriers lead the sea trade, and general cargo ships mainly container ships follow after. Approximately, the percentage consists of 38 % for dry bulkers, 36 % for tankers, and 21 % for containers in DWT (Stopford, 2009). The former two bulk carriers carry large amounts of cargo in one voyage because it is earned by their cargo capacity. The latter, general cargo ships carry lighter cargo in specific gravity than bulkers. Moreover, the cargo value is rather high; therefore, it is earned by ship's speed and punctuality instead of cargo volume.

Passenger ships and pure car carriers (PCC) have relatively large volumes upon the water level. Therefore, the spaces should be covered up with walls and ceilings as both passengers and cars need certain height to stay in the ship. Further, both people and cars are lighter in weight compared to the cargo of tankers or bulkers, when it is considered by the occupancy of the volume in the ships volume. Therefore, it is unnecessary to worry about the freeboard so much; however, problematically large space is needed for earning. Roll-on Roll-off (RO-RO) ships are using automobiles for containing cargo in the ship, and they also have similar characteristics.

Then, does the incentive of making tonnage into particular Figure appear in practice?

3.4. Summary

Ships are not forced to reduce tonnage by the regulation; however, most merchant ships are competing, and small GT provides an advantage. Non-earning volume reduction is important for shipowners to cut cost on tonnage based taxes and keep the ship size below the thresholds. However, maximizing the tonnage to the limit seems more important than seafarers' welfare or ship safety.

Shipowners are always looking for saving on cost of tonnage-based charges; therefore, they try to find effective ways to reduce GT. This requirement is directly demanded of naval architects and affects the ship's design. It reduces design freedom by establishing strict constraints.

The complaints about Tonnage Measurement from shipping or shipbuilding industries are about crew and safety impacts as well as the restriction of new design; even if technology has been innovated, the Convention still follows the previous centuries' legacy.

The next chapter will analyze the practical ships' data and verify whether the ship will be intentionally calculated in a particular size.

Chapter 4 Quantitative Analysis: Gross Tonnage versus other factors

4.1. Introduction to Chapter 4

In the previous section, it was supposed that many shipbuilders intent to build ship to reach certain target size. Basically, they please the shipowners in their quest to reduce operational cost through reducing GT. Most of them follow this trend (GT reduction incentive) for competition purpose and to avoid passing regulatory threshold.

However, there may be other ship categories which do not follow this common trend, i.e. GT is not the main target for the shipowners.

In this chapter, it is expected to find out whether all shipowners follow the same incentive and build ships with reduced GT. In order to establish the trends, quantitative analyses are made.

The quantitative analysis in this chapter aims to verify the GT reduction incentive through comparison with other volume or weight factors.

4.2. Quantitative Analysis Principles

A detailed analysis of several types of ships and issues concerning the influence of ITC-69 are covered here. In this section, several types of ships around 100 metres in length focusing on GT, NT and DWT are studied. Further, the multiplied Figure of length, breadth and draft which lead to the idea of MRE is also a parameter which analyzed.

Why this Panel of Ships?

During the investigation, it was found that focusing on the INF ships is an interesting approach to compare with other types of ship because of its unusual GT and NT figures compared to their length and carrying capacity.

Hereby, it was discovered that most INF ships were concentrated in the range of 100 metres in length. This category was targeted because of its specific character, which involves dangerous cargo and has additional safety requirements.

Sources of Data

The study is made by using the database from the Clarksons World Fleet. More than 4,700 ships of approximately 100 metres are recorded and classified in the database. Totally 2,620 ships out of 4,717 ships were found to have been built after 1995. Because of the phase-in period of the ITC-69 ended in 1994. The study focuses on the ships build after 1995. Some of the columns were blank or missing information, and totally 2,233 ships have enough data sets available, i.e.GT, NT, DWT, length overall (Loa), Breadth (B), and summer draft (d).

4.3. Gross Tonnage Distribution among 100 metres in Length

Firstly, the distribution of GT in the group of 100 metres long ship will be examined. Further, the analysis will distinguish ship-types.

Justification of GT Analysis

The reason of analyzing GT distribution is to understand how the panel is constructed and organized as well as to identify areas out of the norms.

Description of Data

4.3.1. Figure 1: Outcome of GT distribution

Figure 1 shows the distribution of the GT of 100 metres long ships. The figure uses a sample from 90 m to 105 m in length. The X axis notches GT by 100 from 1,000 to 7,000. The number which represents the column means 'less than', for example, the column 2,500 stands for 2,400 to 2,499 GT.

In each GT section, three histograms describe frequency of the ship depending on its built year. The longest line shows the total distribution of the sample, and the second longest line is from same sample with sorting by the old ships' distribution those built before 1995. The shortest line shows the part of old ships which were built before 1982.

The reason for comparing with the year of built is based on the expectation to find out whether there were some differences that appeared before and after the Convention. The gap between ‘all’ and ‘old’ in each section shows the ship built after 1995, i.e. ‘new ship’ named in the Convention.

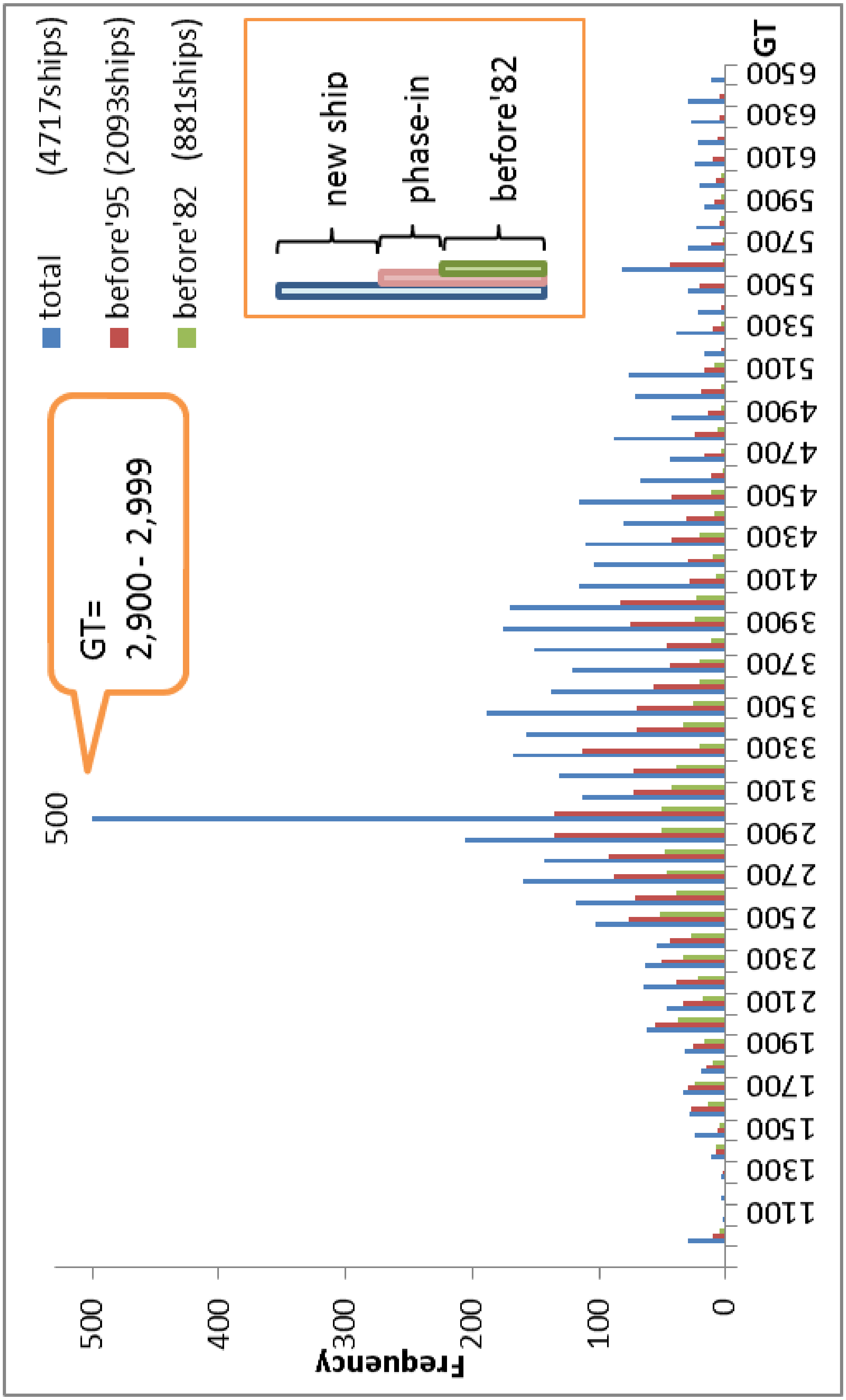


Figure 1 Distribution of GT of ships (Loa: 90-105m)

* The ships of which GT is 6,500 and more represent 3.82 % are not on this chart to improve visibility of the rest of 96 %.

FIGURE 1 DISTRIBUTION OF GT OF SHIPS (LOA: 90-105M)

According to Figure 1, ships from 2,900 to 2,999 GT account for the highest frequency. The new ships' GT also has high frequency between 2,900 and 2,999. Compared to the existing ships when the Convention entered into force, although the highest point is both at the same place, the significant silhouette of the 'peak at just below 3,000 GT' is a consequence of the entry into force of the Convention and the consequences of the Convention on ship design. It shows that after the Convention came into force, the incentive to avoid passing over the threshold of particular GT, i.e. 3,000 GT, appears clearly.

It seems that shipbuilders design ships to please shipowners and offer them the possibility to reduce GT in order to avoid thresholds passing and related expenses consequences. As shipowners being the customers, this is not a surprise that shipbuilders try to attract them with reduced GT ships.

Moreover, the simple calculation method proposed by the ITC-69 Convention makes possible to evaluate the GT on paper before the ship being build. Therefore, the builder can modify the ship design to reach the expected GT before starting the construction.

In short, the present Convention allows ship designer to calculate the GT from the drawing plan before starting the construction. If the trial computation is over the threshold, it is possible to modify and adjust the plan until it gets the exact targeted GT which meets the shipowners' expectations.

4.3.2. Figure 12: Outcome of Frequency by Types

Figure 12 (Appendix A) shows the percentages of distribution by types of ships. The group of ship type is taken from the Clarksons World Fleet database. The sample is used to focus on ships built after the ITC-69 entry into force. This ship distribution by type details and clarifies the data available for all ships.

According to Figure 12 (Appendix: A), the two big categories are 'dry cargo ships' without bulk carriers and 'oil tankers' which represent respectively 32 % and 30 % of the panel.

In accordance with the database, miscellaneous cargo category, which represents 0.5 %, includes cement carriers, mini bulk, livestock carriers and INF carriers. This latter ship type is the author's main focus. Later, the miscellaneous category will be split to highlight the specificities of INF ships. In short, INF vessels will form an independent category while the other miscellaneous cargo will be merged with bulk carriers.

In Figure 12 (Appendix: A), INF ships are in the category of miscellaneous cargo ships; however it represents very small proportion among total ships, but having relevant and rare characteristics.

4.3.3. Figure 2: Outcome of Distribution of GT by Ship Type

Figure 2 shows the distribution of GT of the ships which were built after 1995 distinguished by ship types. The figure numbers from Figure 2(a) to 2(l) distinguish the distribution of 12 groups of type.

In the major categories (dry ship/ tankers/ gas carriers/ containership/ bulk carriers) which have large population of ships, the peak of the distribution is at the same GT ‘closest to 3,000 (but not over)’.

The container ships present two peaks – one in the section of 3,900 to 3,999 and the other in section 2,900 to 2,999. Further, gas carriers represent the section of 2,900 to 2,999 and of 3,300 to 3,399. Moreover, though total number is few, and does not have significant influence; the bulk carrier has the highest frequency in the section of 3,300 to 3,399 and of 2,900 to 2,999 GT as gas carrier. However, the concentration at these sections is not sticking out like other types of ships

On the contrary, in the minor categories such as passenger ship, reefer, and miscellaneous cargo ships, it shows wide distribution without particular peaks. Further, non-cargo ships, such as offshore vessels, which include research vessels; and special purpose ships, mainly dredgers and tug boats, show similar appearances.

In Figure 13 (Appendix: B), the distribution of GT of the ships which were distinguished in color by ships’ types, and each of distribution is shown in Figure 2.

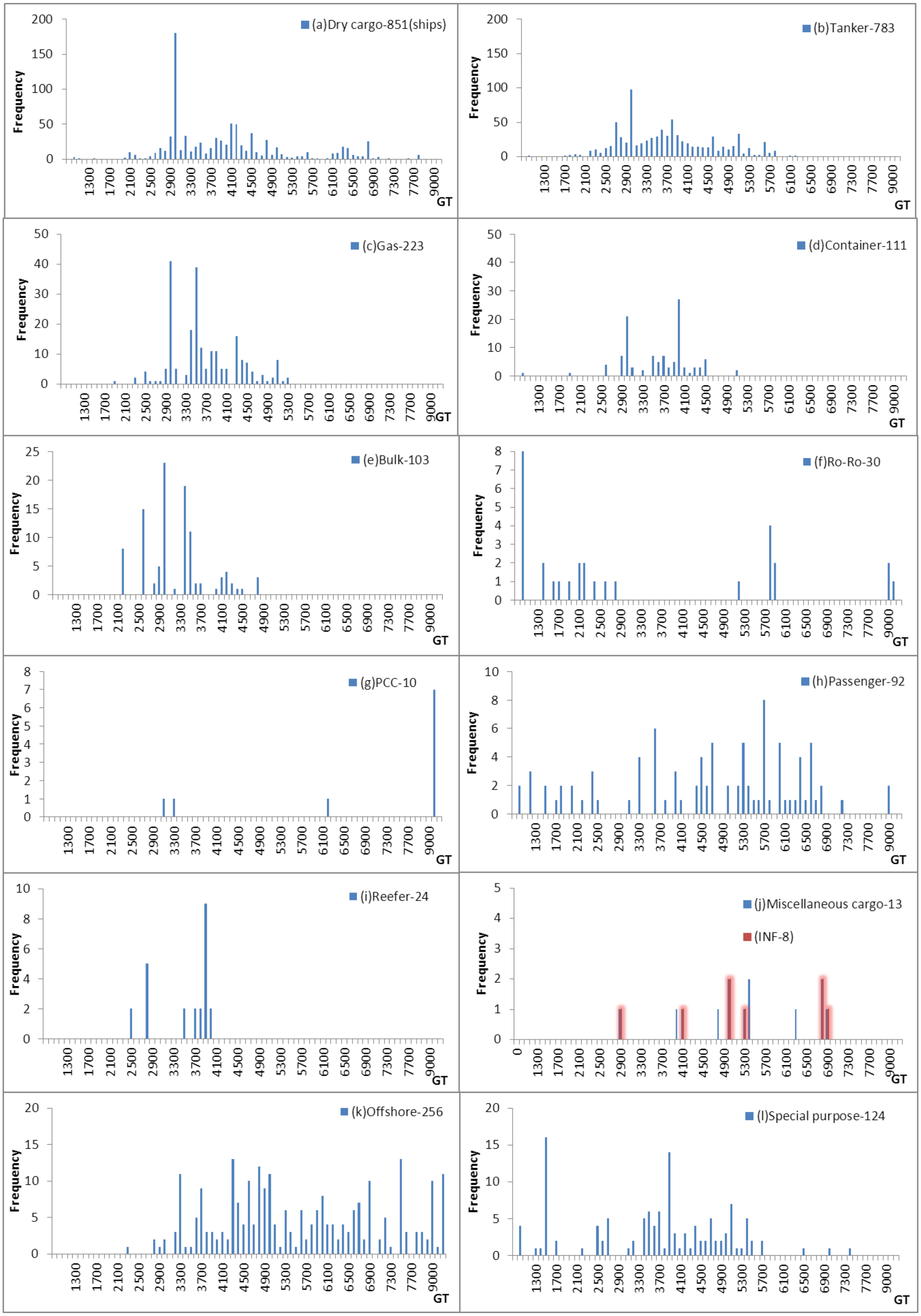


FIGURE 2 (A)-(L) DISTRIBUTION OF GT OF NEW SHIPS IN TYPES (LOA: 90-105M)

It is considered that the big categories show narrow distribution which probably indicates the optimal of ship design operating in the market segment. The particular GT ships are expected in the market and willing to be built.

On the other hand, small categories distribute in wide range; no optimal size of ship seems achieved. The ships may operate in niche market which does require specifically build ships and GT-related expenses are probably secondary.

In accordance with these trends, when certain types of ships are in competition among shippers on the same trade route, it seems this situation will limit the ship's GT.

4.4. Gross Tonnage versus Deadweight

Definition of DWT

DWT is the ship's cargo carrying capacity in weight. It is determined by the gap between the displacement of full-load and non-cargo (lightweight) condition.

The full-load condition is limited in accordance with maximum summer draft, in other words freeboard, determined by the safety regulation, i.e. International Convention on Load Lines, 1966 (LL-66).

Justification of Analysis

It seems to have a close relationship between GT and DWT of the merchant ships, as DWT is one of the factor of the earning capacity in weight. In short, large ship may carry large amount of cargo. It is expected the appearance of GT-DWT ratio showing the ships maximized DWT and minimum GT in a constant relation. When the distribution is not constant, or the GT is relatively high in the same DWT, there might be certain reasons not related to the efficiency of the carrying performance.

With the study of GT/DWT relationship, it is expected to establish that INF ships have large enclosed spaces (large freeboard) which means limited (small) DWT compared to GT. This relationship will be highlighted in comparison with other ship types in Figure 3.

Description of Data

The relationship between GT and DWT of conventional ships are shown in Figure 14 (Appendix: C) with 2,552 samples.

It shows that GT stands as from 50 % to 70 % of DWT, with tendency line of GT = 0.73 DWT, except for Pure Car Carriers (PCC) shown in Figure 15 (Appendix: D).

Selected by types, the results of tankers, dry cargo ships and PCC are given in Figure 16 (Appendix: E). Two major categories of ship types, tankers and dry cargo carriers, show close relation of GT as 70 % of DWT, correlation is estimated as $r^2>0.77$. Recalling to previous Figure 14 which total sample shows GT = 0.73 DWT, these majorities create the trend of the panel.

Figure 17 (Appendix: F) shows the frequency of GT/DWT and distribution with GT of (a) dry cargo ships, (b) tankers and (c) all samples, N=2,552. Concentration of the dots which presents the distribution of GT and GT/DWT ratio could be seen close to high frequency ranges. For example, oil tankers GT/DWT ratio is between: 0.600 to 0.799; that of dry cargo ships is 0.600 to 0.849. The similarity between tankers and dry cargo ships, two major categories among the samples of this research, is found the same as in Figure 17, GT = 0.70 DWT.

By comparing both frequencies of GT/DWT and tendencies of the drawn trend line by relationship between GT and DWT, it is found that the heavy cargo figure shows a rather small dispersion, i.e. trend line appears below the lighter cargo. Here it clarified tankers, dry cargo and bulk carriers as heavy cargo carriers. In the similar categories, gas carriers, container carriers are light cargoes.

Figure 18 (Appendix: G shows the distribution of tank ships' GT and DWT, i.e. oil tankers (GT=0.70 DWT) and gas carriers (GT=0.95 DWT). Here it called tank ships as tankers and gas carriers.

Although, there are slight differences between heavy and light cargo, compared to INF ships, these differences might be negligible.

In Figure 3, four types of ships' GT-DWT relationships are shown i.e. dry cargo ships, bulk carriers, container carriers and INF ships. The former three categories have similar tendency lines describing that GT is in between 63 % to 74 % of DWT. However, the INF category shows a different tendency than other ship types. The GT/DWT ratio is about twice as big as other ships.

Deduction and Analysis

The relationship between DWT and GT depends on cargo type and/or trading segment. Inside a particular category (e.g. tanker, dry bulk), whether the cargo is liquid or solid no much difference can be observed. Difference slightly appears whether cargo is heavy or light, as DWT is weight based factor. Usually shippers try to carry as much cargo as the ship can but respecting the safety requirements.

In Figure 16, PCC shows a different trend compared to dry cargo ships and tankers. Particularly, PCC, Ro-Ro ships and passenger ships show lack of stable tendencies in the GT and DWT relationship. These types of ships carry light cargo, including passengers with or without cars, which are extremely light compared to the space they use; further, these cargoes should be covered if possible. Therefore, the total enclosed volume could be relatively large, i.e. large GT compared to the weight the ship can carry.

As a result of the relationship between GT and DWT of the four types of ships, i.e. dry cargo ships, bulk carriers, container carriers and INF ships (see Figure 3), there is a close correlation between GT and DWT of each type, and similarities between types except the INF ships which are about twice the GT in the same DWT situation. Therefore, it is deducted that the enclosed volume accepted for INF vessel is larger than for other ship types which means this ship type accept high GT despite its operational consequences in term of cost if these ship were operating on a competitive environment.

Limitation of Analysis

One data of ship () which has 52,733 DWT with 1,498 GT is out from the Figure 14 so as to get closer view.

The relationship between GT and DWT of PCC and Ro-Ro ships are shown in Figure 15 (Appendix: D) with a distribution ratio of GT/DWT. PCC shows the relation of GT = 2.797 DWT with correlation coefficient of $r^2 = 0.54$. The exception of PCC appears from the small sample number of 10 ships; therefore, it seems to be disregarded.

Nevertheless, PCC and Ro-Ro ship have small population among the samples and this seems to be reliable. It appears GT is larger than that of other cargo ships, i.e. most of the Ro-Ro ships

To sum up, ordinary cargo ships have a DWT of twice the GT; however, INF ships have an opposite relation..

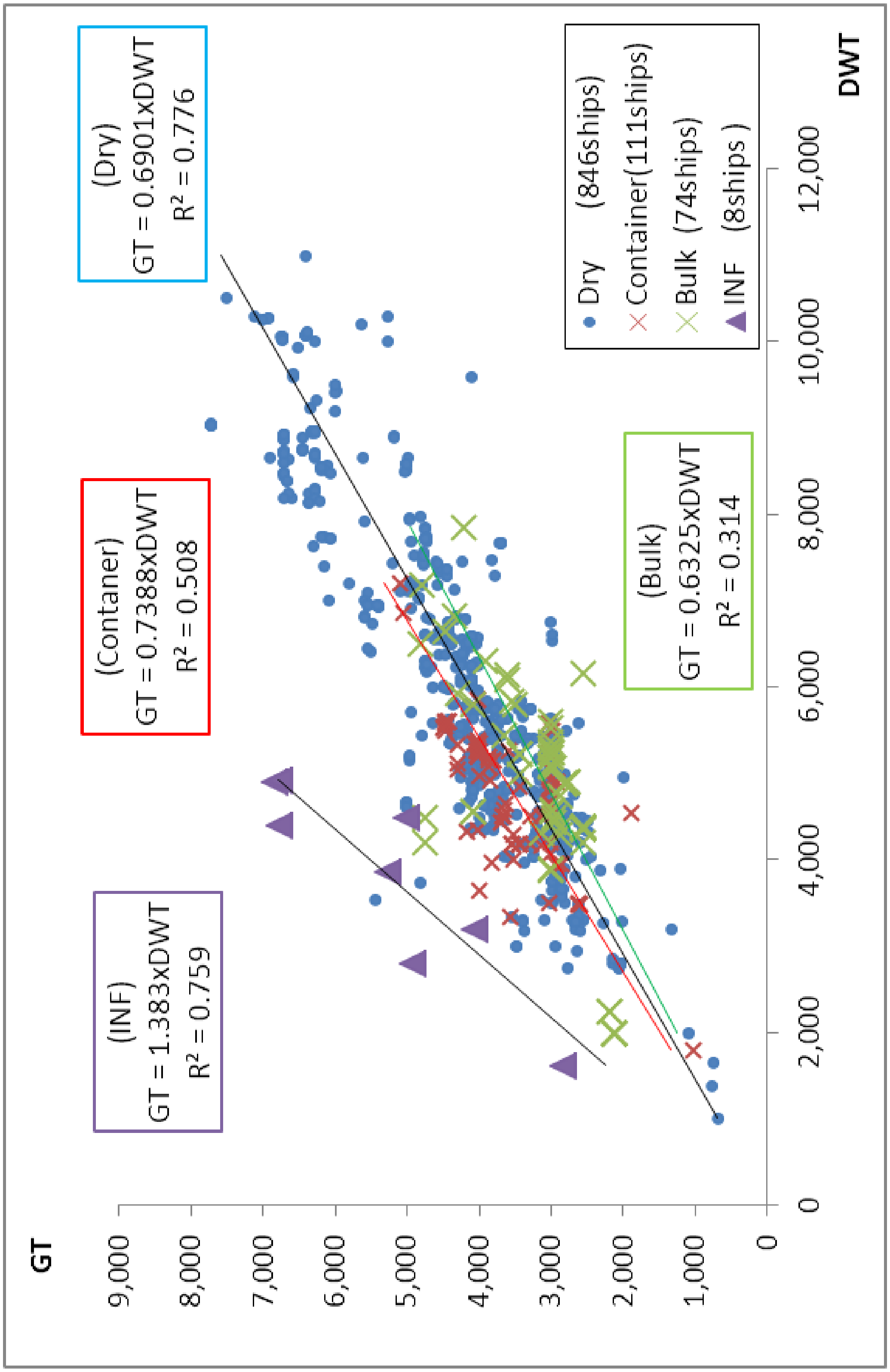


Figure 3 Relationship between GT and DWT (Dry cargo, Bulk, Container and INF ship)

FIGURE 3 RELATIONSHIPS BETWEEN GT AND DWT (DRY CARGO, BULK, CONTAINER AND INF SHIP)

4.5. Gross Tonnage versus Net Tonnage

Looking into GT/DWT of merchant cargo ships in the previous section, there was not such a significant difference between ship types; the ratio was about 0.5 to 0.7, except for INF ships and ships carrying light cargoes like cars (PCC) and with cars (RoRo).

Definition of NT

NT is determined by ship's cargo hold capacity (Vc), passenger number (N_1 and N_2) and moulded draft (d) as mentioned in the formula of the Regulation 4 of ITC-69:

> "$NT = K_2Vc(4d/3D)^2 + K_3(N_1+N_2/10)$
>
> where K_2 depends on Vc, and K_3 depends on GT" (IMCO, 1969).

While d is larger than 75 % of moulded depth (D), draft does not affect NT. It comes from the Regulation 4 which says: "the factor $(4d/3D)^2$ shall not be taken as greater than unity" (IMCO, 1969).

GT/NT is a Figure which shows, compared to NT, how large GT is.

Justification of Analysis

Here it is expected to see the comparison between cargo volume and total enclosed volume, i.e. NT and GT; further, how it is distributed according to the ship type.

It may show whether there are strong relationship between two volumes, i.e. basis of NT and GT. In the previous analysis, cargo weight (DWT) and the total volume (GT) were compared; here it is focused on the volume factor of cargo.

In addition, it may draw the different tendencies between certain categories of ships; more specified, if certain cargo types describe different trends, it might particularly highlight what appears in the INF ships.

Description of Data

The two figures, presented in Figure 18 (Appendix), are merged as one in Figure 4, where the ratio of GT/NT of the new ships is shown; the bar is the frequency for each ratio, and the dot is distribution of the ratio according to GT of the ship.

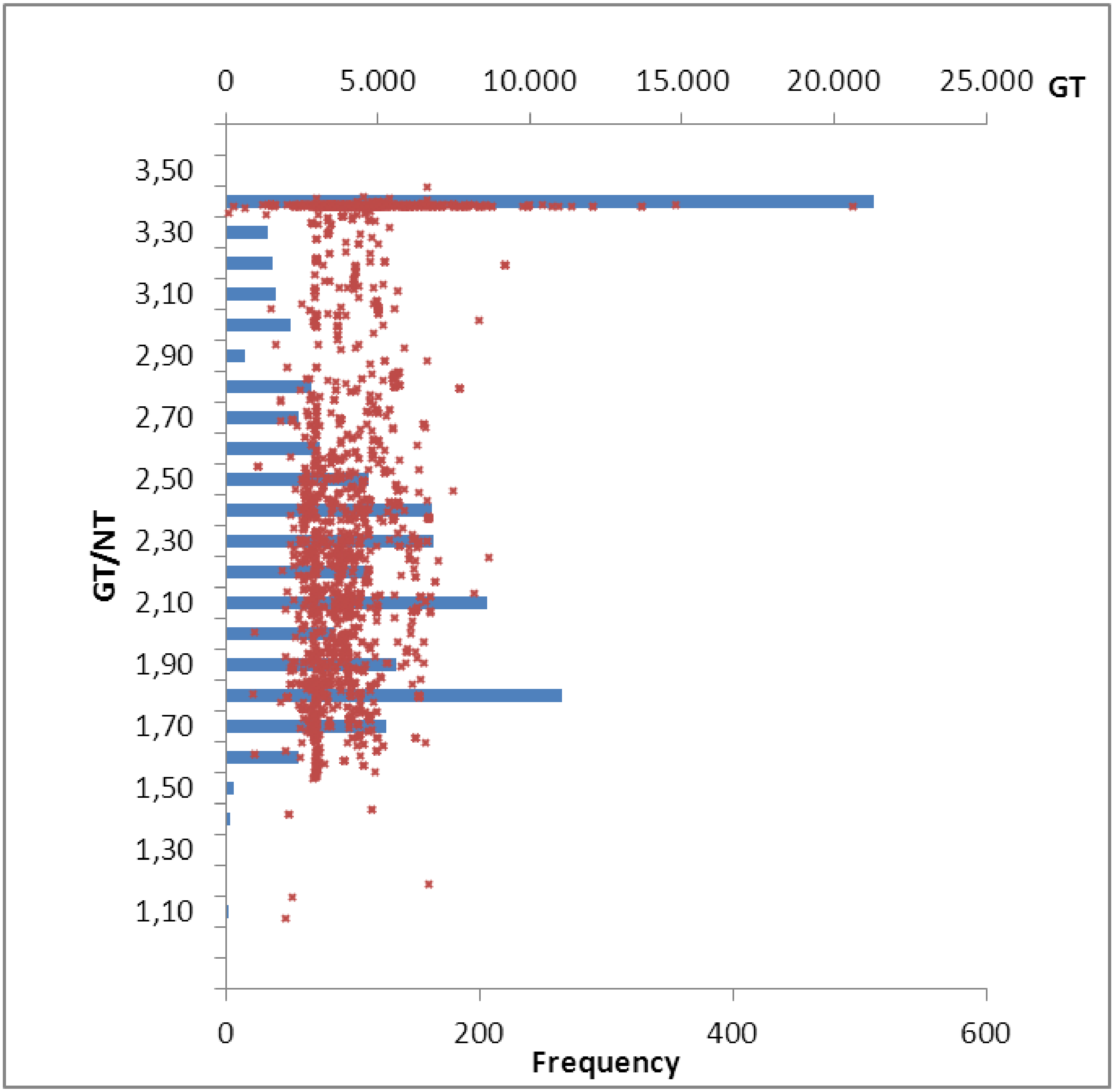


FIGURE 4 FREQUENCY AND DISTRIBUTION OF RATIO OF GT/NT (N = 2,328)

According to Figure 4, high frequency, about one-fifth of the total ship appears at the ratio of $3.\underline{3}$, which stands NT of these ship figures with 30 % of GT, and those ships are included in case the actual cargo capacity is not that large, even it is zero.

On the right side, all of the ships whose GT is more than 10.000 are at the same rate of $3.\underline{3}$, i.e. relatively small ratio of volume for cargo space per total volume.

Significant high frequency shown at the ratio of GT/NT = $3.\underline{3}$, these ships are ‘large GT but small NT, i.e. less cargo space’ or even it has enough volume of cargo spaces, the total volume is relatively large. Perhaps non-cargo ships or ships which have less cargo spaces included in computation are included here; however to confirm this point, it is necessary to analyze ships’ categories in detail.

The second peak of frequency appears at the ratio of 1.70 to 1.79 with both decreasing to the larger and the smaller ratios. Further, the distribution is concentrated at the range of 1.50 to 2.80.

The relationship between GT and NT is given in Figure 20 (Appendix: I). The first majority of 22 % is, as mentioned before, lined up on the trend line of $y = 3.\underline{3}\,x$, i.e. NT = 0.3 GT. Even the outstanding large GT ship is shown on this line.

Further, the trend line shows the average tendency of GT = 2.27 NT.

Deduction and Analysis

When the volume of cargo area and/or passenger number is large, NT's percentage of GT comes closer to 100. On the other hand, if the cargo space compared to the total volume is small, the ratio will decrease.

However, even if there is no cargo space, at least NT is 0.3 GT (IMCO, 1969); further, there is no cargo space, which is not included in the total volume, so it belongs to GT. Therefore, GT/NT ratio which explains 'how large GT is compared to NT' will be within 1.00 to 3.3.

Limitation of Analysis

Figure 4, Figure 19(Appendix) and Figure 20(Appendix) are the appearance of all new ships without categorized by types.

In the next part, it focuses on two major categories of shipping, transport by tanks or not carried in tank, i.e. dry cargoes.

4.5.1. **Tank Ships GT-NT Analysis**

Tank ships are used for carrying liquid cargo for a long distance, and are equipped with pumps for transferring cargo. Here it is called 'tank ships' as both categories of (oil) tankers and gas carriers.

Oil tankers carry huge amounts of product or sub-product of oil or chemicals. The earning capacity of these tankers is due to the large cargo tanks as the value of the cargo itself can be comparatively low.

(Particular ship in category)

Some of tankers are built for specified cargoes; such as asphalt, bitumen and sulphur products. Gas carriers transport gases formed in liquid; i.e. liquefied petroleum gas (LPG). To keep the gas in liquid form, it needs a covering structure around the tank which keeps the hold at low temperature.

(Justification of Analysis)

It is expected to find whether there are differences between the specified cargo types even in the similar transporting mode, i.e. by tanks.

(Description of Data)

The frequency and distribution of the ratio of GT/NT of these are shown in Figure 20(Appendix). There is an interesting difference between the type of tankers, which carry several types of oil and those built for a particular type of cargo. Specialized cargo tankers line up on the ratio point of GT/NT=3.33 with relatively high frequency.

The relationship between GT and NT of oil tankers and gas carriers is given in Figure 5. The tendencies are shown in trend lines which have same meaning of the ratio of GT/NT, i.e. how large GT compared to NT is.

According to Figure 5, the relationship between GT and NT of the oil tanker shows that GT is about 2.35 times larger than NT.

On the other hand, the ship for an exclusive cargo such as sulphur and LPG is lined up on the trend of GT as more than three times larger than NT. A certain percent of these exclusive ships are on the line of GT = 3.3 NT, which means it is not only that exact figure , but also probably the cargo space volume of these ships is less than 30 % of GT. It means, such ships working in specific segments are out of the norm.

Description of Data

It is shown that wide category of tank ship includes different trend of GT-NT distribution.

The assumption is that even if the ship is in the similar category, particular cargo types affect the ship's design and the ship's GT as well. .

In the next category, the comparison between general dry cargo, bulk carriers and container ships with INF ships is shown.

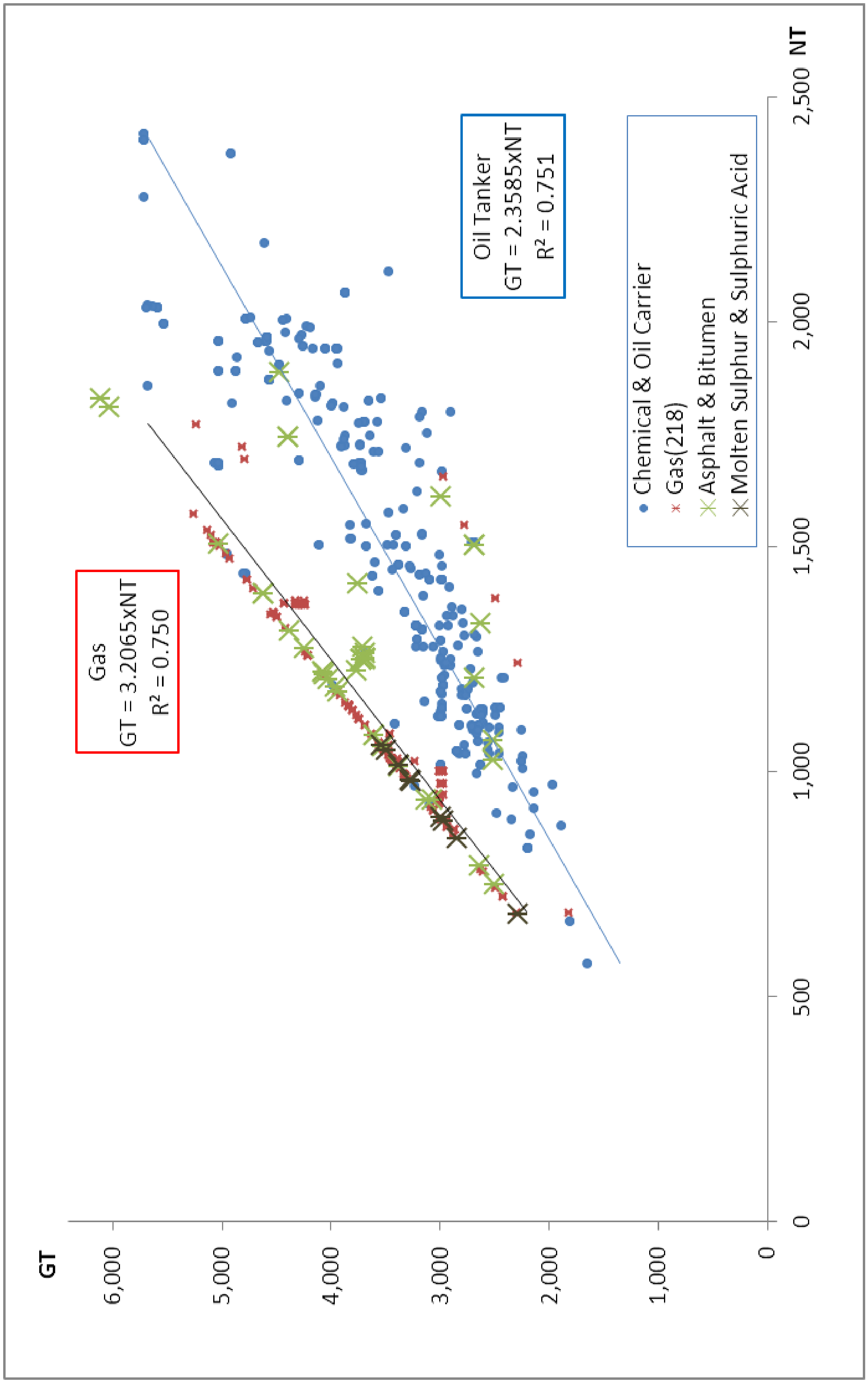


Figure 4 Relationship between GT and NT of Oil tanker and Gas carrier

FIGURE 5 RELATIONSHIPS BETWEEN GT AND NT OF OIL TANKERS AND GAS CARRIERS

4.5.2. **Dry Cargo Ship GT-NT Analysis**

Dry cargo ships, without bulk carriers, are one of the major ship types among the sample of ships built after 1995.

The ratio of GT/NT of dry cargo ships is given in Figure 22 (Appendix: K)(a), with bar for frequency of ratio and dot for distribution. Figure 22 (Appendix: K)(b) is the relationship between GT and NT.

About two-thirds of the dry cargo ships, in the light color bar, have a ratio of 1.60 to 2.09, and the peak appears at 1.70 to 1.79. Here the GT concentrates in the range of 2,000 to 5,000. Regarding the distribution of GT of dry cargo ships in Figure 2 (a), the majority of GT was in the section of 2,900 to 2,999.

Recalling to the frequency of GT/NT ratio in all ships (see Figure 20, 20 % for GT/NT = 3.3), the percentage of '3.3' class in dry cargo is very low, 20 ships out of 814 dry cargo ships in Figure 22 (a). As for the ratio of GT/NT, the ships in this category seem to carry relatively large amounts of cargo.

(Particular ships in category)

There are other ship types in a similar operation category of 'dry cargo, not in tanks', i.e. bulk carriers, container carriers and INF ships.

Figure 6 has overdrawn these three ship types in the previous Figure 22 (b) (Appendix: K). Further, the relationship between GT and NT of the same sample, dry cargo ships withdrawn from Figure 6 is given as Figure 7 to focus more clearly on the difference between three types of cargo. Dry cargo ships have a similar tendency as bulk and container carriers; therefore, a clearer difference between INF ships and others may be seen.

Description of Data

In Figure 6, it shows close relationship of dry cargo ships' GT is about twice as large as NT (GT = 1.93 NT), correlation factor of r^2=0.67; other two cargo types: bulk and container, are shown as similar relation to dry cargo.

On the other hand, almost all INF ships line up on the "GT=3.3 NT" line, though there are other dry cargo ships that also stay on the minimum NT, i.e. NT = 0.3 GT.

Deduction and Analysis

As mentioned in 4.3, dry cargo ships are one of the major ship types representing 32 % of the total sample ships. High population of competitors may create optimal ship design. However, it is seen that INF ships are special outstanding. There is no optimal size of this cargo type, as earning capacity is not based on the threshold and the operation in specific market environment.

(Limitation of Analysis)

In Figure 6, one data of the general cargo ship, *Adobia* (IMO 9169835), (NT, GT) = (5896, 6714), is missing from this figure so as to allow a closer view.

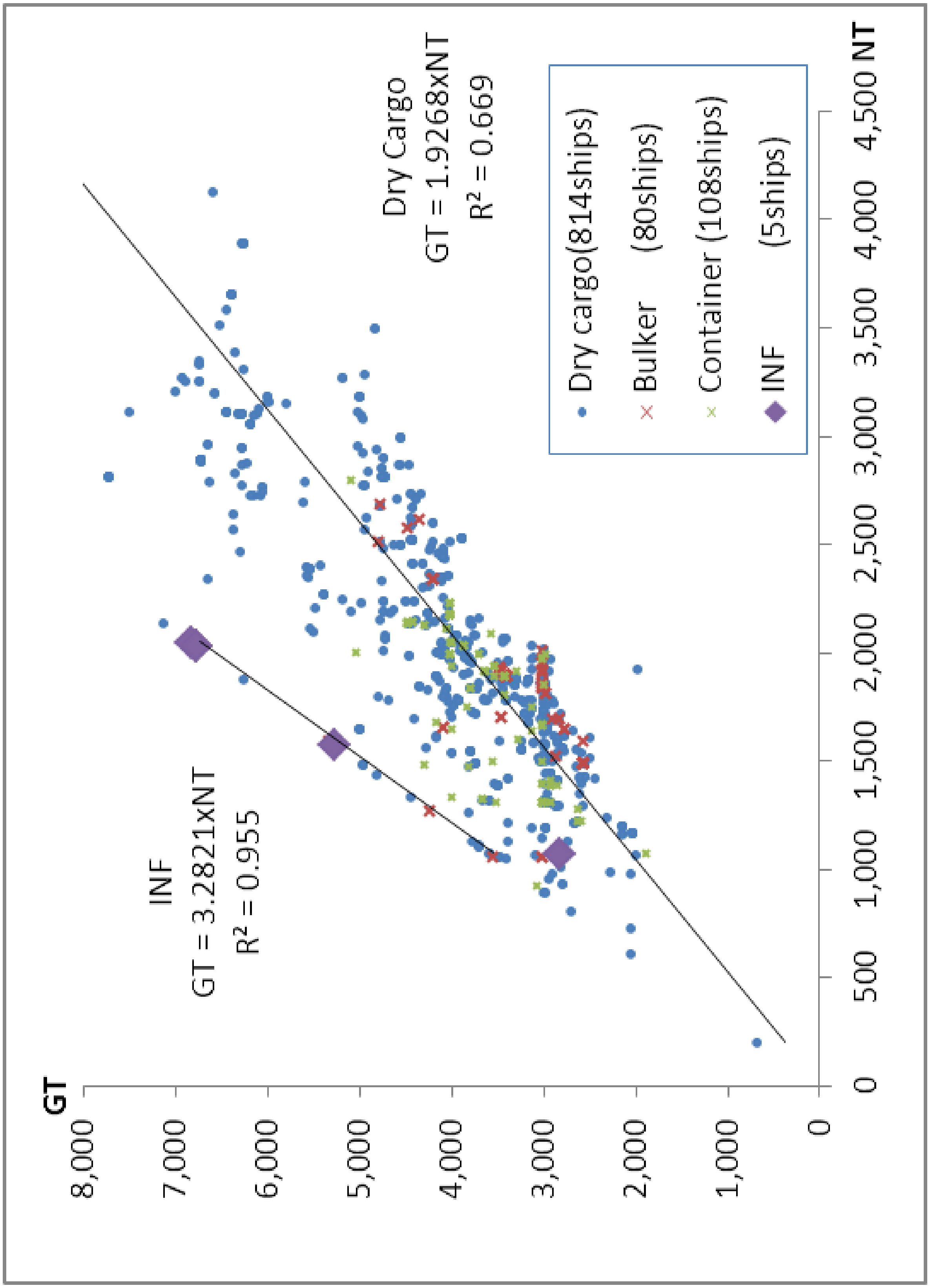


Figure 6 Relationship between GT and NT of Dry Cargo, Bulker, Container and INF ships

*One data of the ship which has 5,896NT with 6,714GT is out from the screen to improve visibility.

FIGURE 6 RELATIONSHIPS BETWEEN GT AND NT OF DRY CARGO SHIPS, BULKERS, CONTAINERS AND INF SHIPS

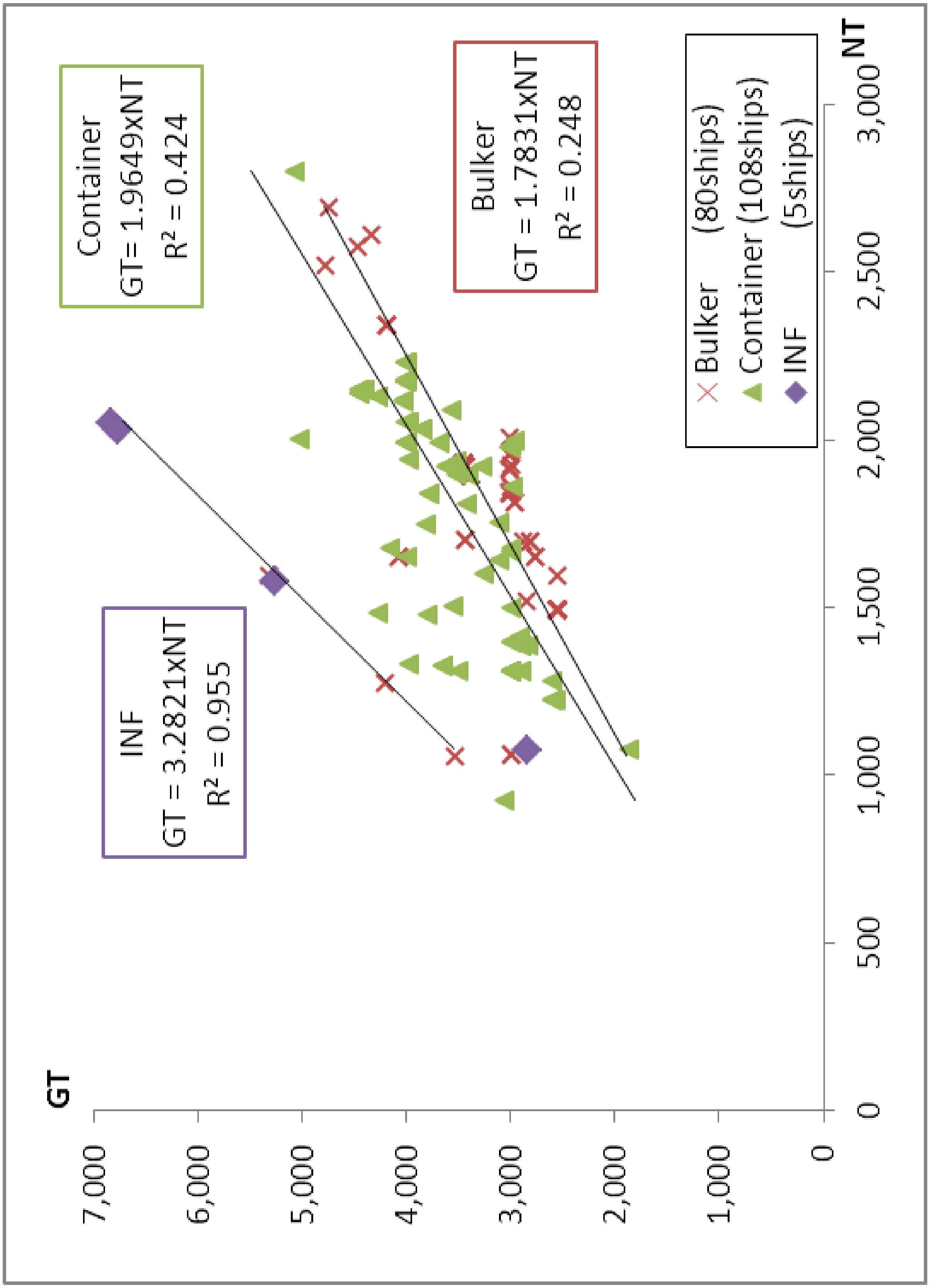


Figure 7 Relationship between GT and NT of Bulker, Container and INF ship

FIGURE 7 RELATIONSHIPS BETWEEN GT AND NT OF BULKERS, CONTAINERS AND INF SHIPS

4.6. Gross Tonage versus Maritime Real Estate

Definition of MRE

As mentioned in the previous sections (see 2.2.5), few ports are charging port fees by MRE. It is computed by the multiplied length overall, breadth and draft, and Australia supported at the IMO the generalization of this method of ship magnitude assessment.

The freeboard which fixes the upper point of the draft mark is determined with the consideration of seaworthiness by the regulations of LL-66.

MRE includes both under water volume factor of ship size and weight factor of cargo.

Justification of Analysis (reason of comparing)

Here it is analyzed by comparing the ship and cargo types with GT and MRE, i.e. L x B x d, where d stands for summer draft. Further, comparing with cargo type sharing similar category of transport mode is described, e.g. tank ships: oil tankers and gas carriers. Finally, it is highlighted on the GT-MRE comparison between dry cargo ships, container ships and INF ships.

It is interesting how container ships' figure which part of their earning spaces (deckload cargo) is without consideration on the tonnage calculation, appears in the comparison.

Description of Data

Figure 23 (Appendix: L) gives the relationship between GT and MRE of sample ships of this research. The average line of the sample shows that the trend of GT is about 39 % of the multiplied figure of L, B and d.

The comparison of the sample of tanker and gas carriers is shown in Figure 24 (Appendix: M). There are relatively high tendencies of GT given by 37 % MRE of tankers and 41 % MRE of gas carriers. In other words, when the factor of volume under the water is the same, at the fixed MRE, GT of gas carriers appears slightly larger than that of tankers.

Figure 8 shows the relationship between GT and MRE of dry cargo ships, container carriers and INF ships. The former two appear similar to the tanker trend mentioned before, i.e. GT is about 38 % MRE of dry cargo ships and36 % MRE of container carriers. On the contrary, GT of the INF ship is as large as 55 % of the figure of MRE.

Deduction and Analysis

While the length of the sample ship is fixed at 100 metres, breadth and draft are chosen by the reasonable proportion of the combination considering the effectiveness of hull design by the shipbuilders. Both DWT and MRE are affected by the factor of maximum summer draft (d), and it is determined by the safety consideration which shows how deep the ship's hull could be in the water.

Limitation of Analysis

There are relatively large ships seen as outsiders among the samples, namely the Research vessel, *Ramform Titan*: 20,637 GT and the multi-functional support ship, *Q4000*: 14,802 GT. These two ships are extraordinary large both in GT and in the figure of MRE; further, because of this reason, these are out of the figure to improve the visibility of other ships' distribution.

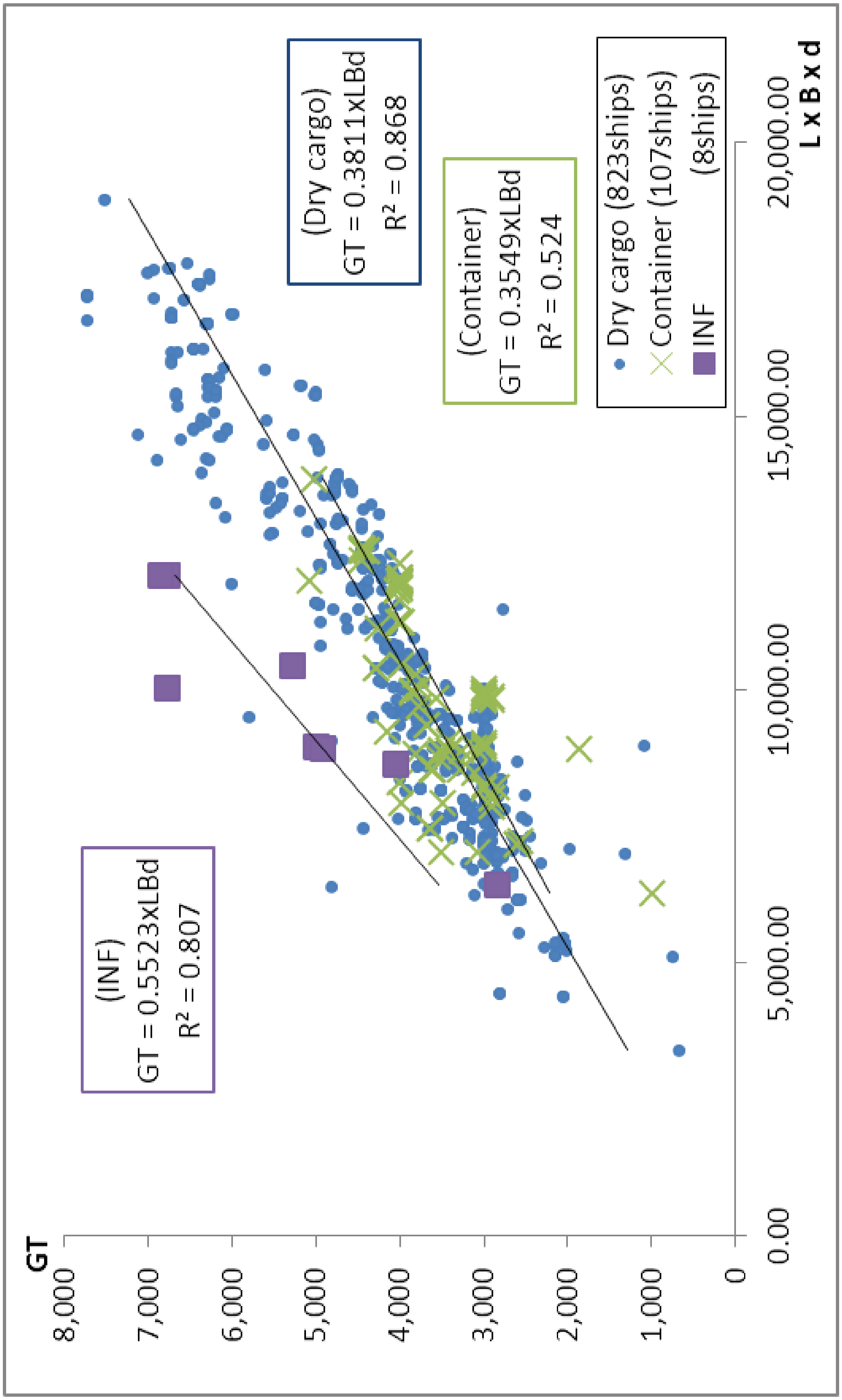


Figure 8 Relationship between GT and LxBxd of Dry Cargo, Container and INF ship

FIGURE 8 RELATIONSHIPS BETWEEN GT AND LBD OF DRY CARGO, CONTAINER AND INF SHIP

4.7. Limitations of the Analyses

Limitations of this research were concluded as:

- The data sets were transferred by the existing database, Clarksons World Fleet; therefore, some categories of data do not match the request of research exactly, e.g. year of built: the definition might be commonly the year of keel laid, launch or delivery; however, it depends on the data creator, i.e. the person who registered the ship and followed regulation of the nation's ship register. Further, data were classified by year level, not date level; therefore, some of the ships built from 18 July 1994 to 31 December 1994 are not included in the 'new' ships.
- Total number of the samples compared in the section 4.2 (N = 2,552), 4.3 (N = 2,328) and 4.4 (N = 2,539) differs because of lack of the data in sets. Some columns of the data were blank which meant unknown or not applicable (N/A). In the case of N/A, it is acceptable, e.g. Japanese ships do not have NT when the ship is limited to domestic voyage. On the other hand, if NT is smaller than 0.3GT or NT is larger than GT, it has nothing left except to question the believability of that particular data; therefore it is ignored. It was possible to use only full set samples completed; however, it will decrease the appearance of tendencies which have much meaning on the research.

- If the purpose of this research was to see the total trend of distribution, there was no need to care about the minorities' appearance. However, the hypothesis was expected to search the difference in the similar transportation mode; therefore, the abnormal data was followed up by cross matching before deleted.

4.8. Summary

To sum up the analysis in chapter 4, it is found that the figure which shows ships' size, especially GT, depends on the ship's purpose, often also related to cargo types. The majority of ships operating on the same segment seem to be built on optimal ship design considering the GT threshold; however, not all types of ships seem to have the incentive of reducing GT.

Comparisons were made between categories, i.e. ships or cargo type, and GT with several factors, i.e. DWT, NT and MRE. Further, particularly it was focused on INF ships because of their unusual GT and NT.

Firstly, GT distribution of the panel of this research was analyzed as significant concentration at the range of 2,900 to 2,999, just below 3,000 GT, which affects large categories: tankers and dry general cargo ships. On the contrary, a minority of ship types, e.g. special purpose and/or cargo ships, was distributed widely and in a rather larger range; it means their priority in ship design is not the consideration of GT but focus is on the ship's purpose.

Further, the GT and DWT relationship was assessed. Major cargo ships have a close relationship with GT at about 70 % of DWT. However, at the same time DWT, INF ships may be twice as large as general merchant ships in GT.

Thirdly, the GT-NT relationship was viewed, where NT represents ships' cargo space in volume. Although it shows a close relationship in each type of dry cargo groups and INF ships, the tendency lines differ as dry cargo ships' GT is less than twice NT; INF ships' GT is about three times larger than its NT.

According to GT and MRE distribution, INF ships' large freeboard seems to affect the GT-MRE relationship as larger GT at same L, B and d contribution.

In each comparison, INF ships stand outside of the merchant cargo ships norm because of the appearance of large GT. From another perspective, non-cargo ships, such as research vessels and offshore support vessels, are likely to show relatively large GT.

What makes their different trend? Compared to the major category showing an optimal size of ships, ship design in the minority category might be affected by different elements instead of size. In the next section, the ship categories showed as outstanding are analyzed for the reason why these ships are so differently built introducing three existing ships as examples.

Chapter 5 Investigation: What makes GT different?

The analysis in the previous section showed that there are some ships which have different priority rather than minimizing GT. What aspect makes these differences? In this chapter, the primary cause which affects ship design will be researched focusing on the characteristics of each ship type.

5.1. Design priority differed to GT

It is natural to imagine that shipowners are challenged to carry as much as they can while the ship's tonnage is in the allowed area of a certain level of standard. However, the priority of ship's design depends on the ship's type as well as the owners' interest and objectives.

While there is less restriction on tonnage, ship design can consider other aspects. Compared to the majority, the number of ships which has different characteristics is small; however, the previous section showed some outsiders that seem not to be so sensitive about the tonnage limitation.

The reasons why those ships are differently built are assumed as the five following factors.

- Firstly, the competition context is paramount. If there are few competitors, priority of reducing tonnage might be low. In other words, a monopolistic situation or governmental work does not need to care about beating others.
- Secondly, the reputation of the shipowner could be higher priority than saving costs. If the company is well known, and bases its strategy on safe operation of ships, safety expenses might not be considered as wasted but as necessary expenses to keep the company strategy.
- Thirdly, there is the marketing and communication strategy. When the market meets extra volume of space onboard as additional values, keeping GT in particular figure is no more high priority. For example, Stena V-max series is introduced later.
- Fourthly, the regulatory framework depends on the type of cargo. For instance, dangerous cargo ships have to comply with a higher level of safety standards; without following the rules, it cannot exist even as a ship to be marketable. As the additional standards simply raise the baseline, in this particular market, the additional volume will not be a disadvantage.
- Finally, there is a special type of ship which has high risk affecting all other businesses. Here the focus is on the INF ships. Although Very Large Crude Carrier (VLCC) always carries oil and risk of serious oil spill disasters, INF ships may not be compared to VLCC, for the difference of the risk level.

5.1.1. **Stena V-Max Series: Marketing Strategy**

According to the Concordia Maritime (in 2013, Stena bulk) in Sweden, Stena V-max series was a new VLCC concept, which responds to new market demands. It was announced that the ship covers "VLCC economy with Suezmax flexibility"; moreover all doubled and independent functions were to achieve "maximum safety at a minimum cost" (www.stenabulk.com). The shipbuilder, Hyundai Heavy Industries Shipyard in South Korea, adjusted ship's draft to 55 ft. (16.8 m) to compete with the Suezmax tanker, and downsized moulded depth to 25.6 m, while normal VLCC tankers have 30 m in depth. Still keeping the length with VLCC level and increased breadth a little to 70 m, Stena V-max series achieved optimized economy of scale with additionally 30 % cargo intake compared with the conventional VLCC and more than 70 % with the Suezmax (Jacobsen, 2001). It is equipped with "all doubled" propellers, rudders, pro-active Integrated Bridge Control System and engine rooms. The engine rooms are separated by fire proof watertight bulkheads independently, and it has got the Redundant Propulsion Separate (RPS) approval for the first large tanker certified by DNV.

In this case, to get the targeted GT for a certain threshold seems less priority than to encourage its strength. It has advantages of higher cost performance and belief of safety to compete with the recent tankers.

To sum up, there are ships built without considering GT as a main priority. GT affects costs directly, but when additional volume onboard makes ships more efficient, the owner's preference might differ while special circumstances exist. Therefore, those competing with others in a unique market and/or needing to secure their reputation as well as their ships are not focusing on GT so much.

5.2. Other Ships with Reduced or no Gross Tonnage Consideration

There might be some categories of ships which do not need to reduce GT. Now such ships will be investigated.

Some categories of ships are built without considering GT as a main priority with a combination of five factors mentioned before.

Four categories of ship are shown as follows:

(1) governmental ships

(2) non-cargo ships

(3) special purpose ships

(4) very dangerous cargo ships.

How different are these ships from typical merchant ships?

The following section will discuss in detail non-cargo ships which have special purpose and very dangerous cargo ships, i.e. INF ships. Before moving to the discussion, there is a brief description of the governmental ships.

Governmental ships

In contrast to merchant ships, governmental ships operate in niche markets. They work for the nation as far as the ship profits to society, saving costs for tonnage based taxes is not high priority.

In fact, many patrol craft owned by the water police or coast guard are registered as 21GT. Because of officers' perquisite (bonus for high grade skill), it needs to be just a little over the threshold of 20 GT, which divides the required level of seafarer’s certificate, though it is a very restricted case in domestic waters.

In the following section, non-cargo ships and INF ships are mentioned with examples.

5.3. Non-Cargo ships,

Basically, non-cargo ships are interested in the capacity and ability to complete their mission but not in the cargo carriage. For instance, research ships need useful spaces in the hull and on deck for the laboratory and sample storage. Further machinery space for specific purposes, such as maneuverability is necessary; they are expected to keep silence and have reduced vibration at the sampling point at sea. In those cases, electric propulsion is preferred.

Another example of non-cargo carriers is the cable placing/repairing ship; drilling ships also have similar characteristics. They need high power not only for navigating but also for machinery onboard; further, enough space for working on deck and their accommodation, not only seafarers but also additional workers are necessary.

Example of Non-Cargo Ships

Here are some examples of the outsiders: The research ship, *Ramform Titan*, the largest GT among the samples of a 100 metre ship with 20,000 GT; and the offshore drilling ship, *Q4000*, with the unreasonable proportion of 62 m width and 15 m draft.

It seems there are several reasons which create shipowners' priority to choose ships by size or other factors. Further, there are the special dangerous cargo vessels, INF carriers, which mainly focus on safety issues.

5.3.1. **Research Vessel – Ramform Titan**

A leading company in the marine oil and gas resource research field, the Norwegian company Petroleum Geo-Services ASA (PGS), received the seismic survey vessel, *Ramform Titan*, by Mitsubishi Heavy Industries, Ltd. on 10 May 2013. According to the company's information, the purpose of this vessel is "to collect maximum amounts of seismic data: quickly, safely and reliably" (www.pgs.com).

Ramform Titan is the fifth generation of PGS's seismic vessels which have recently the highest capacity to provide efficient three-dimensional (3D) seismic acquisition with 24 tow points of 12 km cable reel in length. To put on many cables at the stern, the ship has wide stern end which makes its hull design quite unique. The registered breadth is about 50 m in width, measured at the midship section and the ship's breadth is reported 70 m maximum at the stern end. This ship manages 24 cable lines at the end; which explains the size of its stern. On the other hand, as it is not necessary for cargo capacity and speed, the length is not so much requested.

Figure 9 shows *RamformTitan*, and Table 1 shows its principal characteristics.

TABLE 1: *RAMFORM TITAN*

L (Loa)	104.21m
B	70.00m
D	8.10m
D	6.42m
GT	20,637
NT	6,192
DWT	7,351
Transit Speed	abt. 16.5kt
Complement	80 p
Class	ABS

FIGURE 9 *RAMFORM TITAN*

(Source: http://www.pgs.com/Pressroom/Media_
Gallery/Media-Pictures/Ramform-Titan/)

Figure 9 recalls a giant squid or a huge jelly fish, with its triangular hull and 24 reels streaming behind. The appearance of the ship seems like a bow section of a tanker still being built in a shipyard or diverting the bow part from a VLCC; however, it is not waiting for the next joint to trail as a freight train. Further, it is interesting how she comes alongside the pier with this short parallel part of the hull.

In the respect of safety, the ship has large working and storage space for safer operations, stable capacity for over 6,000 tons of fuel and seismic equipment, automated back deck, two stern-launched workboats, triple redundancy in propulsion, fully separated engine rooms, and two lifeboats for 40 personnel each.

Because survey operations take all day long and sometimes continues for several months; there are 60 single berths and 10 double cabins; totally 80 persons are allowed to be onboard. Further, to stay long at sea, there are substantial facilities for seafarers not only accommodation but also recreation, such as a 225 square metre sports hall, a ball court, a gym, a pool, a sauna, theatres and TV/game rooms. Moreover, to avoid stoppage during the survey, there are one helicopter deck to relieve crews and to supply commodities and other equipment for onshore bunkering.

These large enclosed spaces are required because this ship earns with its high capacity of researching and accommodated equipment and researchers. Usually, cargo ships need to come to shore for unloading. Transporting commodities from port to port is the purpose of cargo ships; therefore, they ought to pay port fees. On the contrary, as a non-cargo ship, port fees may not be of much concern. The ship might stay for long at her mother port or at sea where the research will be carried out; further, calling port is not the daily purpose on her work as a cargo ship.

Putting on the latest technology as much as possible and improving crews' living condition seem to be higher priority than reducing GT.

5.3.2. **Offshore Drilling ship – Q4000**

Figure 10 shows an offshore drilling ship, *Q4000*, and Table 2 shows its principal characteristics.

TABLE 2: *Q4000*

L (Loa)	95.18m
B	62.79m
D	29.62m
d	15.25m
GT	14,802
NT	4,440
DWT	5,000
Speed	abt. 13.5kt
Year of built	2002
Complement	133p
Class	DNV

FIGURE 10 *Q4000*

(Source: http://static.subseaworldnews.com/wp-content/uploads/2012/02/Q4000-platform.jpg)

The length of the sample vessel is fixed around 100 metres. Normally, the pair of breadth and depth or draft creates reasonable proportion. However, this ship has an unusual figure in its large breadth and draft which resulted in large MRE, i.e. L x B x d.

Q4000 is an offshore oil field construction, and at the same time an oil well intervention vessel with an average transit speed of 12 knots.

These two examples were not included in merchant cargo ships; the special purpose of the ship affects its design. However, there are also ships transporting cargo but do not necessarily reduce GT.

5.4. INF ships – A Particular Type of Cargo Ship

The previous examples are mostly fit into non-cargo ships category; however, even among cargo ships, if there is no restriction on tonnage, the ship's size could be considered by other aspects more than cost saving competition.

Then what might be considered the safest type of cargo a ship carries? Nuclear materials are highly sensitive, so they have to be handled with care. Therefore, as INF carriers need to be extremely safe, focus during construction and design stages is not ship size, but on safety.

Depending on the dangerous characteristics of the nuclear cargo, the executive regulations, such as the INF Code determines the standards of structure, equipment, fittings, arrangements and materials onboard.

INF ships must consider safety as a priority to ensure cargo safety and industry reputation. There are no other competitors in the market, because it is a niche business. Further, because of the high quality requirements, it is necessary to comply with the regulations. Moreover, shippers may not wish to take risks for the most dangerous cargoes to save smaller costs on taxes. There is no objection to accommodating numerous seafarers onboard to avoid fatigue and enhance safety by proper human factor risks. In addition, extra personnel for security duty are welcomed. Naturally, the accommodation for those workers is available; additionally, it will be comfortable for the change of stressful work.

A list of INF ships was collected, and analyses of size characteristics were made.

INF-3 ships and details of each ship are shown in Table 3 (Appendix. N).

- There are three Pacific series which are owned by the Pacific Nuclear Transport Ltd. (PNTL); namely *P. Egret*, *P. Grebe* and *P. Heron*. The ISM Company which has responsibility for the safety management is Serco Marine Services.
- *Orient Pintail* is a UK flag ship and owned by the Nuclear Decommissioning. Management Company is the same as the Pacific series, i.e. Serco Marine Services.
- The Swedish ship *Sigrid* is going to be replaced after *Sigyn*; both ships are owned by Svensk Kärnbränslehantering AB (SKB) in Stockholm, Sweden. These ships are recognized as Ro-Ro ships on the database, although, they are found to be carrying nuclear fuel.
- The Russian ship *Serebryanka* is a nuclear fuel carrier, however, the year of built was 1974. As she is out of scope of ITC-69, there is no further research of the detailed profile

- Two Japanese ships, *Kaiei Maru* and *Rokuei Maru* owned by Nuclear Fuel Transport (NFT) are both INF-3 class ship; however, they are used only for domestic voyages to transfer INF; therefore, they do not have International Tonnage Certificate and NT. For Japanese ships, NT is only available to those operated in international voyages.

The characteristics of INF ships have close similarity between each ship, and are outstanding to other types of ship. The reasons for the differences appearing in these ships' profiles support the main hypothesis: ship's safety requires much space, i.e. large GT. What is the particular aspect which makes it different to others?

To present it, the study focuses on the *Pacific Heron* as an example of INF-3 ship in the next part.

5.4.1. **Pacific Heron**

One of the INF ships, the *Pacific Heron*, was built in 2008 and is owned by PNTL, in the UK. She was designed to carry mixed-oxide (MOX) fuel from Europe to Japan.

FIGURE 11 *PACIFIC HERON*

(Source: http://www.pntl.co.uk/our-fleet/pntl-ships/pacific-heron-2008/)

Figure 11 shows *Pacific Heron*.

MOX fuel is a conventional nuclear fuel manufactured with uranium and plutonium at reprocessing facilities. The Nuclear Decommissioning Authority (NDA) in the UK and AREVA in France, under the long-standing commercial contracts with the electric power companies in Japan transport MOX from Europe to Japan.

The MOX fuel assemblies are packaged in licensed casks designed to achieve safe transport. Japanese nuclear power plants need the transport for not only getting new fuel but also returning spent nuclear fuel to Europe and vitrified residues from France to Japan again (Transport of MOX, 2013).

According to PNTL, the INF cargo compartments are protected through double hull structures with additional strengthening surrounding the holds. To protect against collision, 20mm plate are used. Further, there are backup systems to provide high reliability and accident survivability. The ships are protected by duplication and separation of all the essential systems, and whether any system fails, there is always backup stand by to be brought into the operations. Steering gears and engines are independent; propellers and rudders are supplicated. Satellite navigation and communications system are built with the integrated bridge system, and twin radars are provided.

Not only the crews but also security personnel are specialists. Officers are holding a higher rank of the certificate of competency: For example, the Chief Officer has a Master’s license. Further, they have senior experiences dealing with dangerous goods. The INF transport information is guarded with confidentiality. The routes of the shipment were not available to the news broadcast before the ship’s arrival. The security measures are taken by the requirements of several regulations, guidelines, and agreements between the UK, France and Japan (PNTL, 2012).

Several precautions are taken on this special treatment of INF ship. In the next part, a view on what rules and standards are affecting INF ships is expressed.

5.4.2. **Rules and regulations**

How the requirements based on the international regulations fit to the category of ship is described in this section. Further, to pursue the safest ship completely, there should be other factors taken into account, for example manning, scantling, engine arrangement, navigational plan, security arrangement, and so on.

The International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships (INF Code) was adopted by the MSC.88(71) on 27 May 1999. It was followed after the Resolution A.748(18) which established the previous 'Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes in Flasks on Board Ships in 1993; A.790(19): 'Review of the A.748(18)' in 1995; A.853(20): 'Amendments to the A.748(18)'; and A.854(20): 'the Guidelines for Developing Shipboard Emergency Plans for ships Carrying Materials Subject to the INF Code' in 1997 (IMO, 1999).

The INF Code was adopted as a voluntary instrument in 1993, and became mandatory on 1st January 2001 when the Amendments came into force. The Code is set to the ships which require the shipments by the sea of packaged irradiated nuclear fuel, plutonium and high level radioactive wastes. It includes requirements for: "damage stability, fire protection, temperature control of cargo spaces, structural considerations, cargo securing arrangements, electrical supplies, radiological protection equipment, management, training and shipboard emergency plans" (PNTL, 2003).

Before 1993, there were no special requirements for ships transporting radioactive materials, and no limitation in variety or quantity. Proposals for special requirements for ships carrying irradiated nuclear fuel were made to IMO by the Italian delegation in 1985, and a working group was set. The International Atomic Energy Agency (IAEA) has the responsibility for formulating international regulations and standards for safety in all aspects of the civil nuclear industry's operations, including the transport of radioactive materials by package regardless of the mode of transport. The IMO drafted the IAEA standards into the International Maritime Dangerous Goods Code (IMDG Code), which allocates radioactive materials in the Class 7. The IAEA standards were concerned with the capability to protect people and the environment even in very severe accident conditions. Therefore, these ships need to be considered with this aim in mind. Tonnage is secondary.

The requirements for INF ships compared to merchant cargo ships are stated in an explicit control. Obviously, these ships follow the IMO regulations of SOLAS and MARPOL, and national regulations of both the UK and Japan, as well. The packages are designed and tested to match the requirements of international standards and are also set by the IAEA.

The Code divides INF ships into three classes; the highest required is Class INF3. The requirements of Class INF3 ships are, for example, damage stability leveled with the type 1 ship survival capability (Chapter 2 of the IBC Code), fire-extinguishing arrangement complied with category A (Regulation II-2/4 of SOLAS), adequate ventilation or cooling system with keeping temperature below 55 degrees Celsius. Further, double engines, double propellers and emergency generators are installed in case of black outs. The ships need to have stability even in the condition of full flooded compartments. There are sprinklers in holds to avoid overheating. The place for people, such as accommodation, services and control spaces are fitted either forward or after the cargo space. To avoid fatigue and respect human factor risks, extra manning and accommodation for large crew have been considered.

The Japanese national regulation, Kaisa No.520 is one of the control measures of INF ship’s safety standards and was at the origin of the INF Code which followed the previous regulation Hakusa No.610 designed for building *Hinoura Maru*.

The purpose of the ship is to deliver fuel for a particular power plant. Therefore, the number of the arrival places is limited. Port facilities are specially designed as well as the size of the port. Therefore, the total size, i.e. length of the ship, is automatically determined. The basis of the regulation was drawn in the field of a specific area, and that is why most of the INF-ships are built with approximately 100 metres in length.

5.5. Summary

There are some ships built without considering GT as a main priority.

Several factors may be considered as a condition against reducing GT incentive, such as competition context, reputation protection, marketing strategy and regulatory framework. Moreover, if the ship carries very high risk goods which influence all businesses working around the world, the ship design considers this particular shipping market instead of keeping ship's size below the threshold.

Few categories may match the combination of these factors, such as governmental ships, non-cargo ships, special purpose ships and very dangerous cargo ships, i.e. INF ships.

Three examples of ships were introduced: the research vessel *Ramform Titan*, the offshore drilling vessel *Q4000* and the INF carrier *Pacific Heron*.

It was found that:

- Because INF ships cannot accept any risk that may affect or release cargo, safety is top priority, even higher than cost saving.
- Duplication and separation of the equipment, increase manning level and invite extra security personnel and safer construction, e.g. double hull, large freeboard causes additional space included in the total volume, i.e. GT.

However, most merchant ships are struggling to maximize cargo volume without overrunning the thresholds, which regulate or charge ships and cause costs. When the safety issue has been incorporated in the ship's design, for instance, the INF ships' GT is about twice as large as other cargo ships' transporting in the same mode. The idea of the thresholds made by tonnage restricts the ships to have enough space for crews' well-being, when the space for safety is reduced.

In the next section, this dissertation is concluded; further, the principle of tonnage measurement itself and positive evolutions will be discussed.

Chapter 6 Conclusion and Recommendations

6.1. Conclusion

In conclusion, this dissertation concluded that the magnitude of ship (tonnage) is determined by several aspects which influence ship design, such as ship's purpose, cargo types, market requirement and owner's priority. Most merchant ships constitute the competition market; therefore, the majority of the ships seem to be built in a similar design, i.e. optimal design. However, not all ships are considered with this factor.

Firstly, tonnage measurement was described as an old system with volume based calculation, where the concept of tonnage started as the ship's cargo carrying capacity. Originally, tonnage was tun(s) which determined the number of wine casks the ship could carry. This resulted in several national regulations; the most famous one was the Moorsom's tonnage measurement system. By the passionate desire of internationally agreed uniformed system, the International Convention on Tonnage Measurement of Ships, 1969, was established. Although this system was easy to calculate tonnage at the design stage, and helped shipbuilders to deliver ships within particular tonnage requested by the owner, it sometime created rather unsafe and strict environment for seafarers. Further, because of too complicated and deliberate amendment procedures, the Convention has never been changed since it started.

Secondly, looking into the influences of tonnage measurement, there is an incentive of reducing tonnage because most merchant ships are competing, and small GT provides an advantage to save taxes and avoid passing thresholds. The technique is based on reducing volume of non-earning spaces, and consequently, it affects ship safety, crew's welfare and competition balance. Further, it reduces ship design possibilities because of the strict constraints for designers.

An approach from the minority's point of view, quantitative analyses were made with the sample ships of world fleet focusing on the characteristics of INF ships. The analyses found that the major categories of ships operating in the same segments are following the rivalry principle, which seems to be built by an optimal design, and focus on GT distribution and relationship to other factors, i.e. DWT, NT and MRE. On the contrary, the minor categories, such as INF ships show an unusual figure of large GT, about twice as large as other cargo ships' GT, which may have certain reasons not to follow the major trends.

These reasons are, for example, competition context, reputation protection, marketing strategy and regulatory framework; further, as a result of these combinations, three example ships including INF ships were introduced to describe these factors.

Finally, as the INF ships are carrying very dangerous cargo, it was clarified that they are designed without considering GT as a main priority; in other words, safety comes first. In return, it might result that most merchant ships are losing opportunities of prioritizing safety and crews' welfare, as those spaces onboard are included in the total volume, i.e. GT.

The old Convention never thought today's shipping could not fit the present situation. As a yardstick, and to keep the vested right continuous, the principle of tonnage measurement cannot be changed easily; however, to meet today's situation and to keep the principle in practice, it is necessary to be able to shift or adjust the Convention to the reality. It is time to consider the amendment of ITC-69.

6.2. Recommendations

ITC-69 should be amended as follows:

- Long-term and internationally agreed solution is expected.
- To support safer and comfortable design as well as to free innovation, the tacit amendment procedure is welcomed to be accepted; and
- Extra spaces should be considered positively if they enhance safety, crew well-being and environmental protection.

REFERENCES

Booker, P.A. (2003). *Development of the INF Code and its relationship to the Ships of the Pacific Nuclear Transport Fleet*. PNTL. Retrieved from text

Building the world's biggest ship. (2013) Retrieved from http://www.maersk.com/innovation/leadingthroughinnovation/pages/buildingtheworldsbiggestship.aspx

Fresh Dongedijk capsize theory. (2001, December 10). *Lloyds List*. Retrieved from http://www.lloydslist.com/ll/sector/containers/article191986.ece?src=Search.

Intergovermental Maritime Consultative Organization (IMCO). (1969, June 23). *Final act of the International Conference on Tonnage Measurement of Ships, 1969.* London: Author.

International Maritime Organization (IMO) (1977, December 19) *Interim scheme for tonnage measurement of certain ships.* London: Author.

International Maritime Organization (IMO) (1978) *International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto.(MARPOL-73/78)* London: Author.

International Maritime Organization (IMO). (1982, January 4). *Revised Interim scheme for tonnage measurement of certain ships. (Res.A.494(XII)).* London: Author.

International Maritime Organization (IMO) (1983). *International conference on Tonnage Measurements of Ships, 1969 – final act of the conference with attachments.* London: Author.

International Maritime Organization (IMO) (1992, October 19). *Livestock carriers and other ships requiring interpretations of their tonnage measurement aspects submitted by Australia (SLF 37/12)* London: Author.

International Maritime Organization (IMO) (1993a, November 4). *Application of Tonnage Measurement of Segregated ballast tanks in Oil tanker. (Resolution A.747(18)).* London: Author.

International Maritime Organization (IMO) (1993b, June 23).*Provisional formula to calculate a reduced Gross Tonnage of Open-top container ships. (TM.5/Circ.4).* London: Author.

International Maritime Organization (IMO) (1994, June 10). *Interpretations of the provisions of the International Convention on Tonnage measurement of Ships, 1969, (TM.5/Circ.5).* London: Author.

International Maritime Organization (IMO) (1999, May 27). *Adoption of the International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on board Ships (INF Code) (MSC.88(71)).* London: Author.

International Maritime Organization (IMO). (2005a, June 10). *Tonnage measurement of open-top container ships. Analysis of application of a maritime real estate tonnage measure to world fleet. Submitted by Australia (SLF 48/INF.4).* London: Author.

International Maritime Organization (IMO) (2005b, June 10). *Tonnage measurement of open-top containerships - Proposals to address long-term effect with regard to safety Submitted by Australia (SLF 48/12)* London: Author.

International Maritime Organization (IMO). (2006, February 07). *Review of 1969 tonnage measurement convention. Submitted by ICFTU. (MSC 81/23/18).* London: Author.

International Maritime Organization (IMO). (2007, February 22). *Development of options to improve effect on ship design and safety of the 1969 TM convention. Safety, training and welfare of seafarers. Submitted by ICFTU. (SLF 50/6/2).* London: Author.

International Maritime Organization (IMO). (2008, May 13). *Code of Safety for Special Purpose Ships, 2008. (Resolution MSC.266(84).)* London: Author.

International Maritime Organization (IMO) (2010). *The International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships (INF Code).* London: Author.

International Maritime Organization (IMO) (2012, March 13). *Stability, load lines and fishing vessels safety/ Short study on the 1969 TM Convention's impacts on crew well-being, vessel safety, limitation on innovation and competition distortion. Submitted by International Transport Workers' Federation. (MSC 90/INF.3).* London: Author.

Jacobsen, E. (2001, May 15). *Stena V-Max – Investment in safety and flexibility*. Retrieved from http://www.dnv.no/din_bransje/maritime/publikasjoner/publications/maritime_news/2001/No_2_2001/StenaVMax.asp

Lane, F.C. (1964). Tonnages, Medieval and Modern. *The Economic History Review, Second Series*, *17*(2), 213-233.

Moorsom, G. (1855, July). Analysis of the British tonnage laws [Electronic version]. *The monthly nautical magazine and quarterly review, 2*, 372-378.

Pacific Nuclear Transport Limited (PNTL):Pacific Heron. (2012). Retrieved from:http://www.pntl.co.uk/our-fleet/pntl-ships/pacific-heron-2008/)

Petroleum Geo-Services (PGS): Ramform Titan. (2013). Retrieved from: http://www.pgs.com/Pressroom/Media_Gallery/Media-Pictures/Ramform-Titan/

Q4000 platform. (2012). Retrieved from: http://static.subseaworldnews.com/wp-ontent/uploads/2012/02/Q4000-platform.jpg

Transport of MOX fuel from Europe to Japan. (2013). Retrieved from: http://www.areva.com/EN/operations-1391/transport-of-mox-fuel-from. -europe-to-japan-the-stakes.html

Vasudevan, A. (2010). *Tonnage measurement of ships: Historical evolution, current issues and proposals for the way forward*. Malmö, Sweden: World Maritime University

APPENDICES

APPENDIX: A   Figure 12

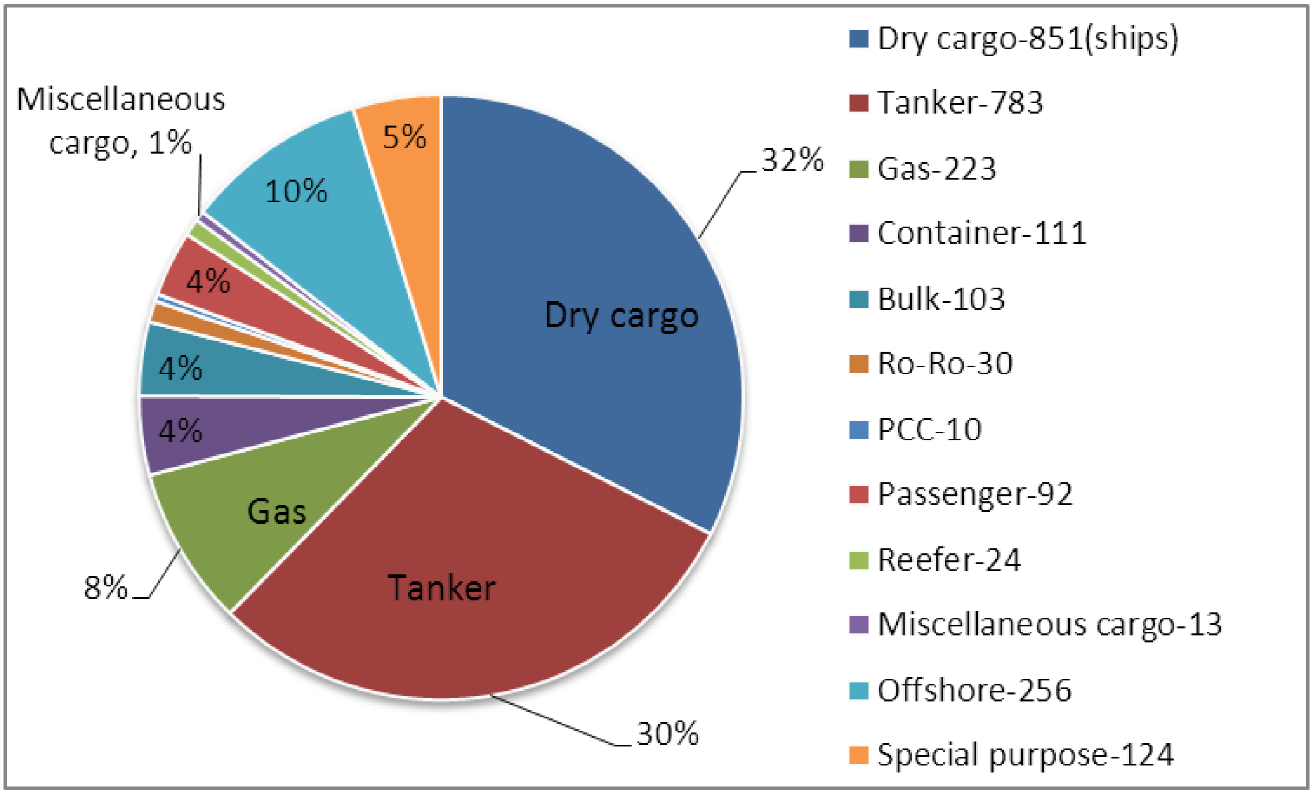


FIGURE 12 FREQUENCY BY TYPES IN NEW SHIPS' DISTRIBUTION OF GT (LOA: 90-105M) (N = 2620)

APPENDIX: B Figure 13

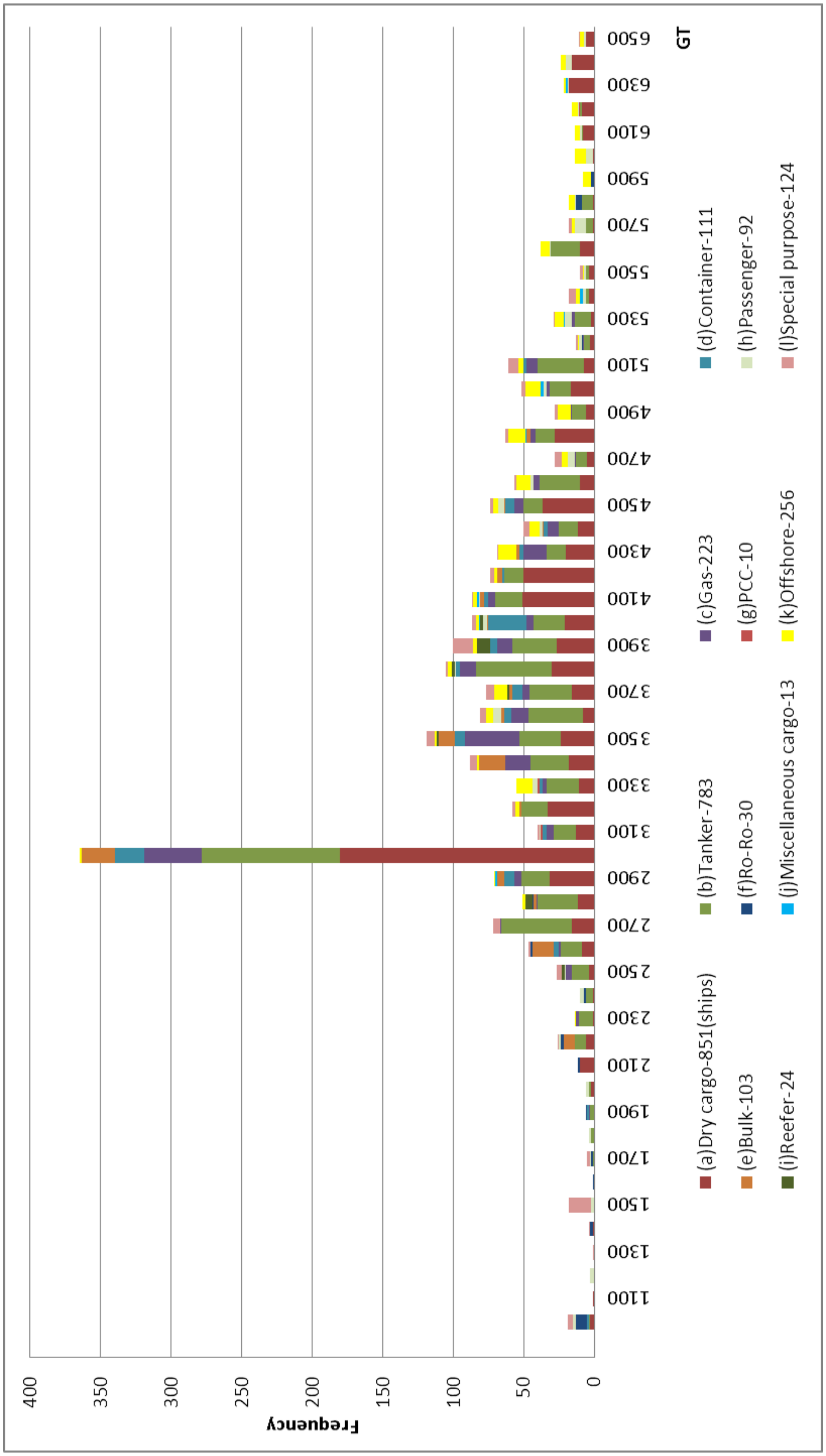


Figure 13 Distribution of GT of new ships colored by types (Loa: 90-105m) (N = 2620)

* The ships of which GT is 6,500 and more represent 3.82 % are not on this chart to improve visibility of the rest of 96 %.

FIGURE 13 DISTRIBUTION OF GT OF NEW SHIPS COLORED BY TYPES (LOA: 90-105M) (N = 2620)

APPENDIX: C   Figure 14

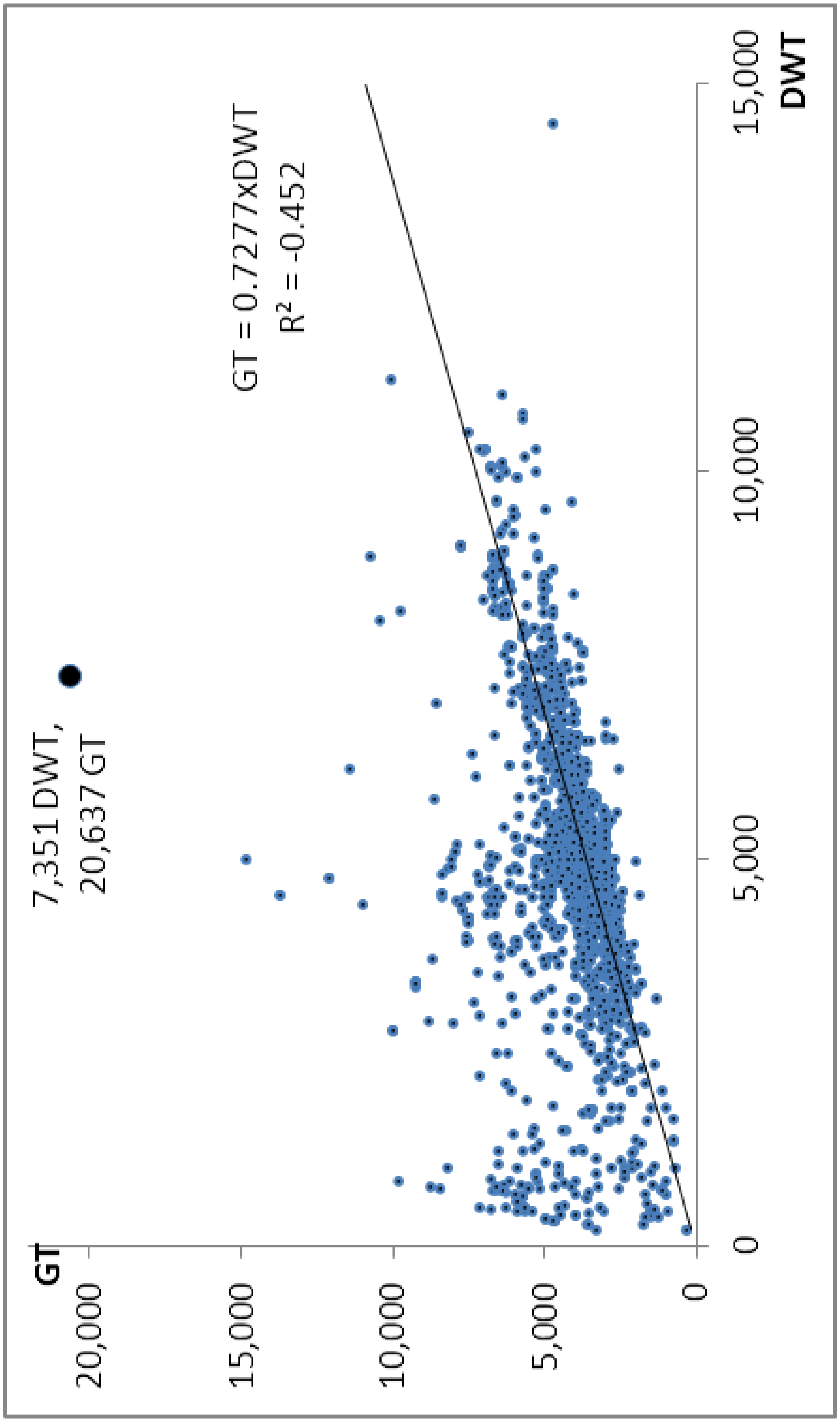
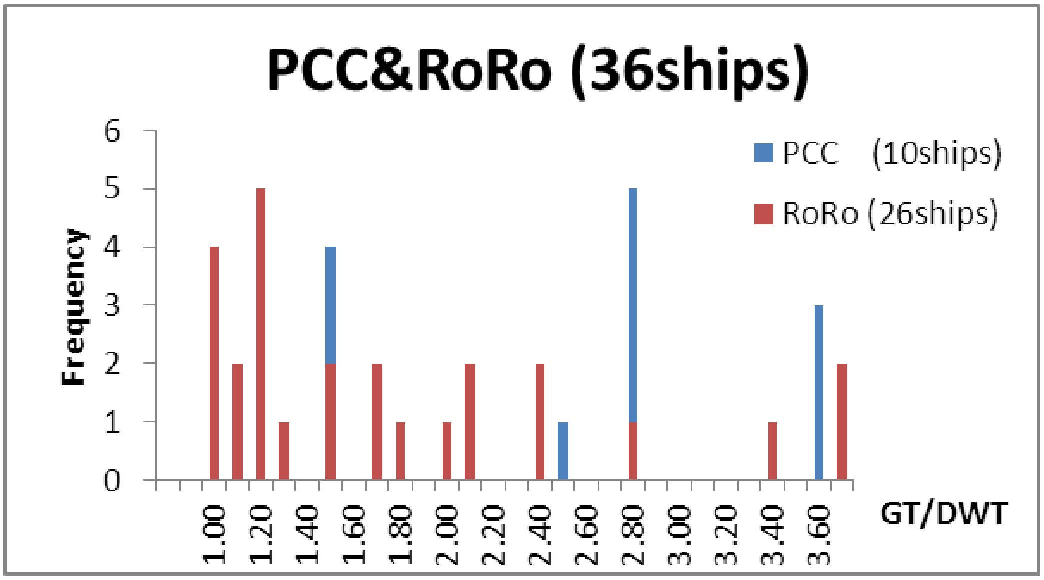


Figure 14 Relationship between GT and DWT (N=2552)

*One data of the ship which has 52,733DWT with 1,498 GT is out of the screen to improve visibility.

FIGURE 14 RELATIONSHIP BETWEEN GT AND DWT (N=2552)



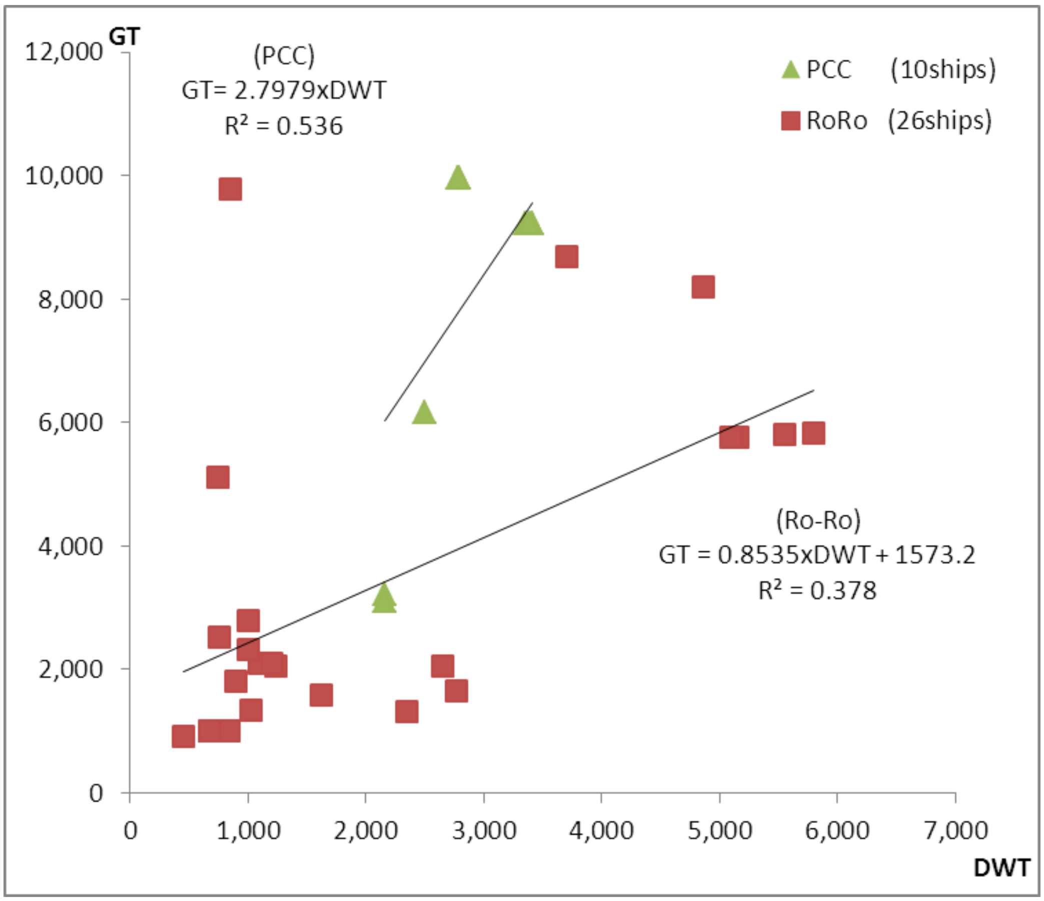


FIGURE 15 DISTRIBUTION OF THE RATIO OF GT/DWT AND

RELATIONSHIP BETWEEN GT AND DWT (PCC AND RO-RO SHIP)

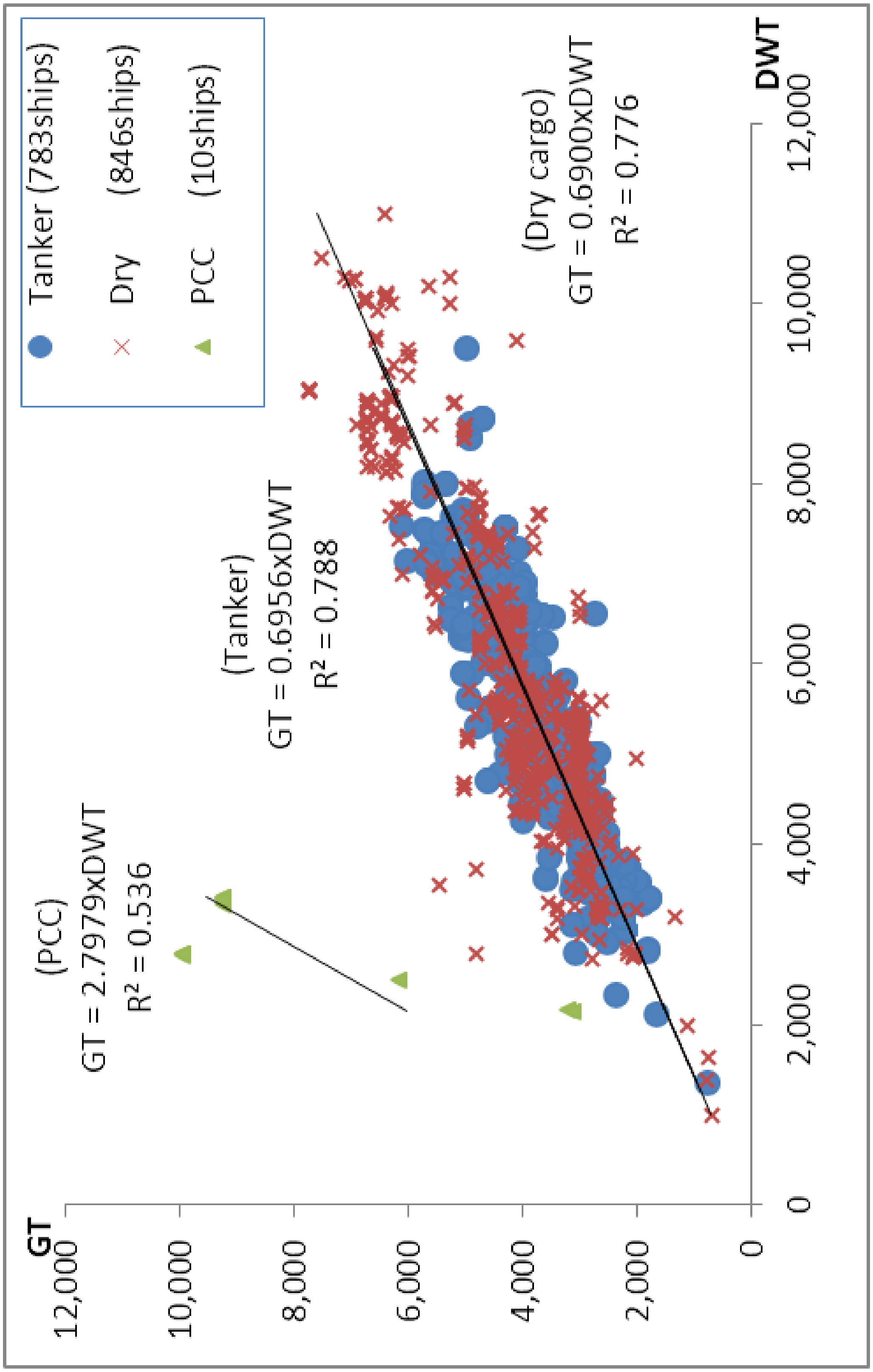


Figure 16 Relationship between GT and DWT (Tanker, Dry cargo and PCC)

FIGURE 16 RELATIONSHIPS BETWEEN GT AND DWT (TANKER, DRY CARGO AND PCC)

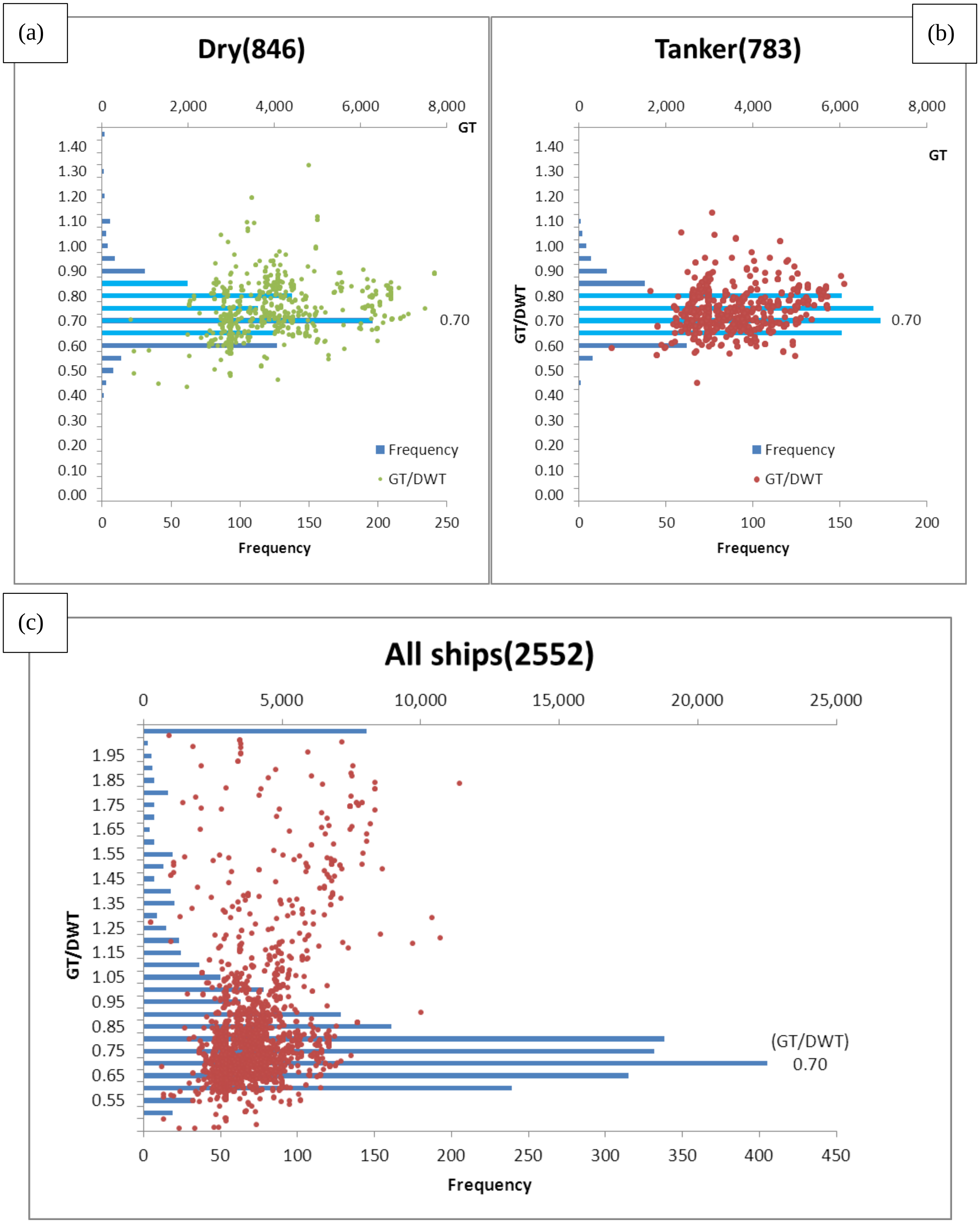


FIGURE 17 RATIO OF GT/DWT OF FREQUENCY (BAR), AND DISTRIBUTION (DOT),

(A) DRY CARGO (B) TANKER AND (C) ALL SHIPS

APPENDIX: G   Figure 18

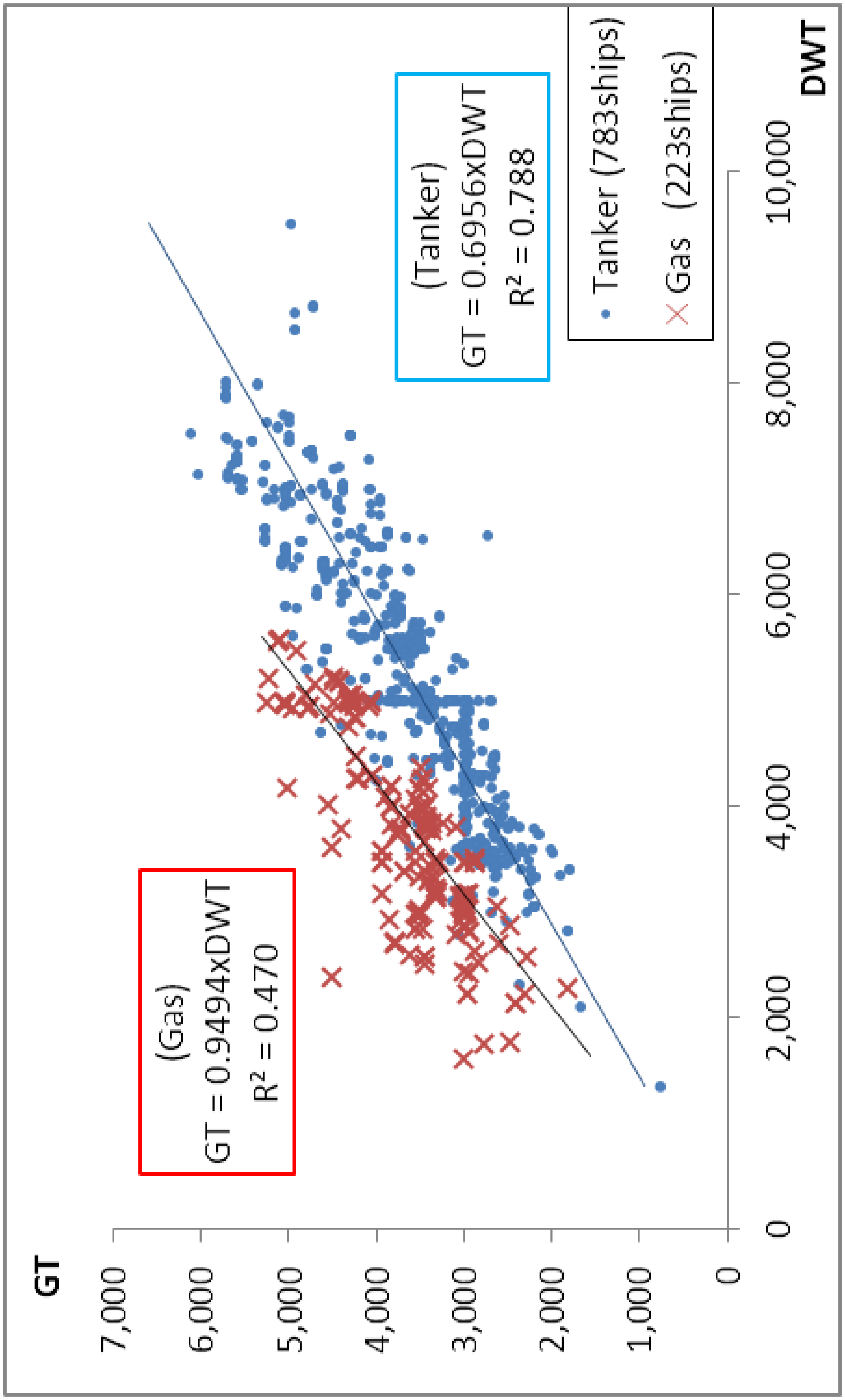


Figure 18 Relationship between GT and DWT (tanker and gas carrier)

FIGURE 18 RELATIONSHIPS BETWEEN GT AND DWT (TANKER AND GAS CARRIER)

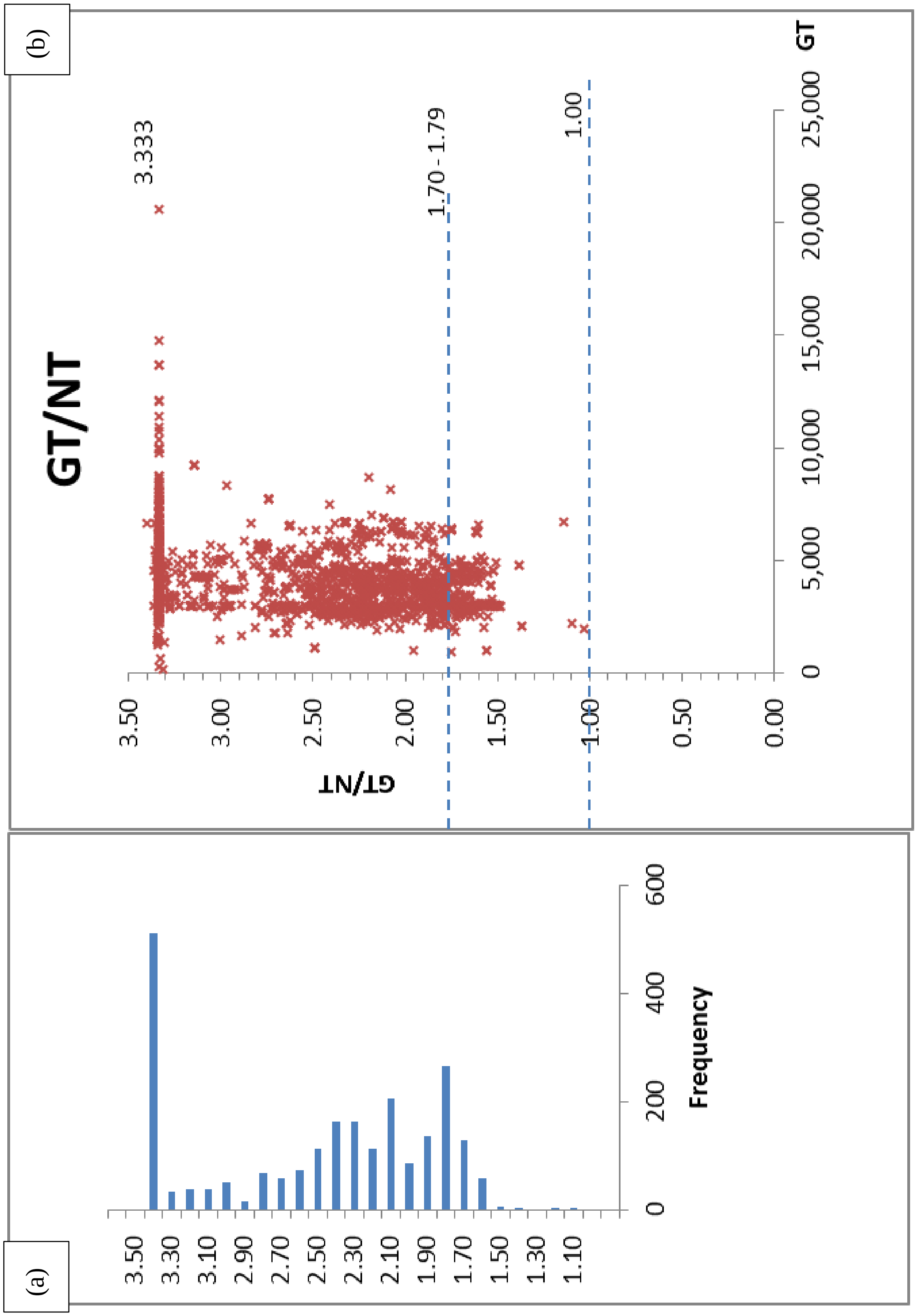


Figure 19 Ratio of GT/NT (a) Frequency (b) Distribution

FIGURE 19 RATIO OF GT/NT (A) FREQUENCY (B) DISTRIBUTION

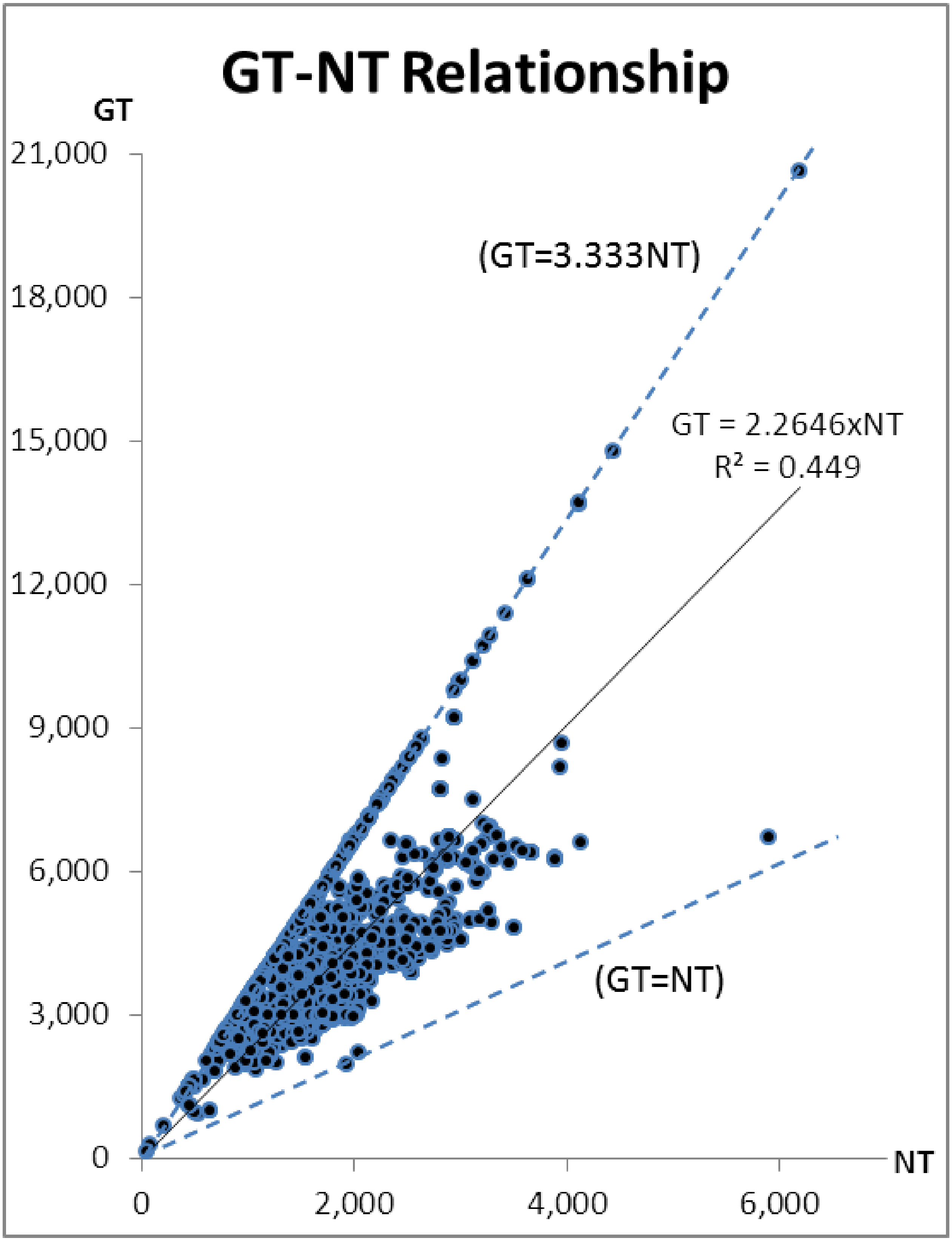


FIGURE 20 RELATIONSHIP BETWEEN GT AND NT (N=2328)

APPENDIX: J Figure21

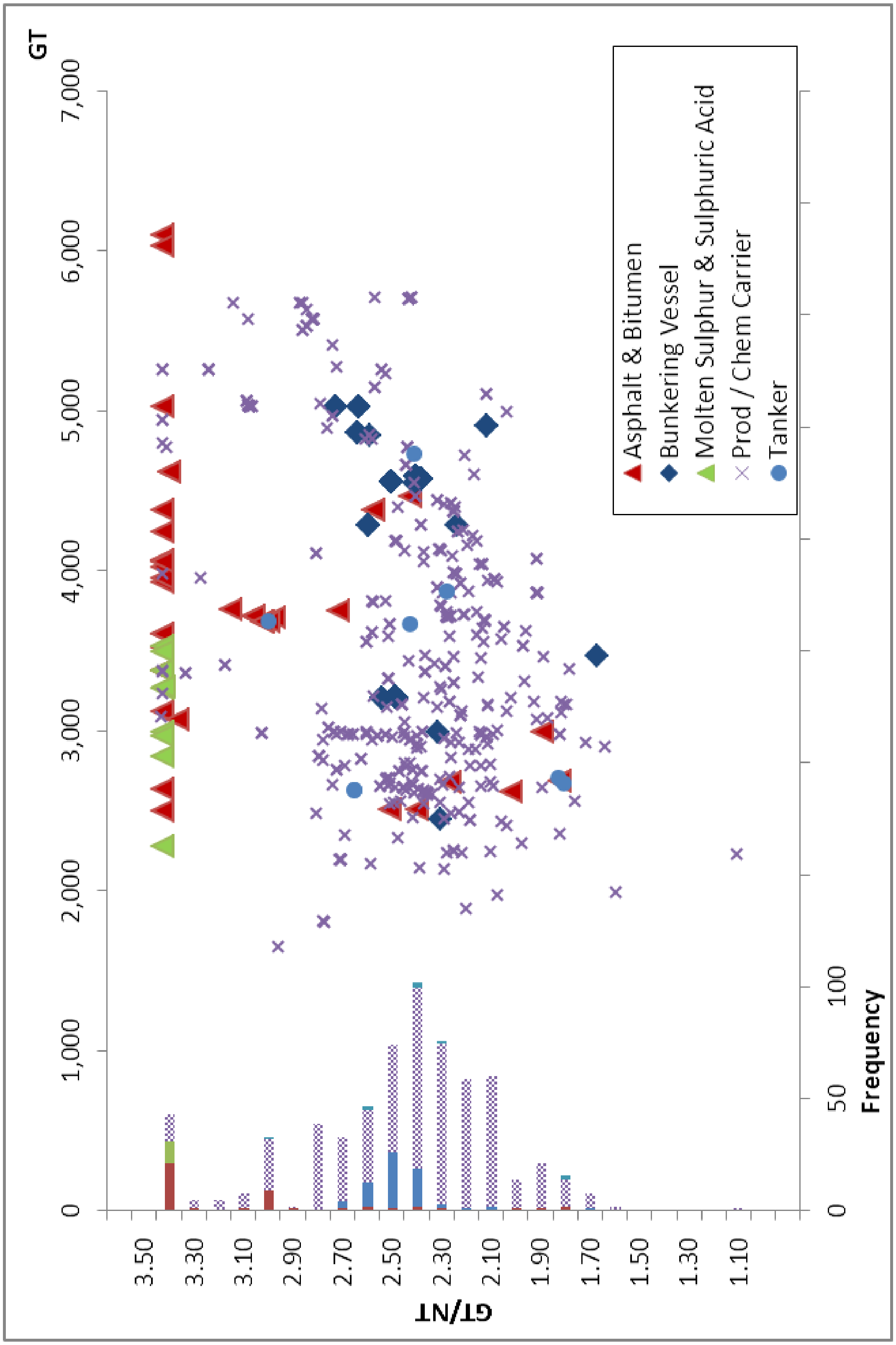
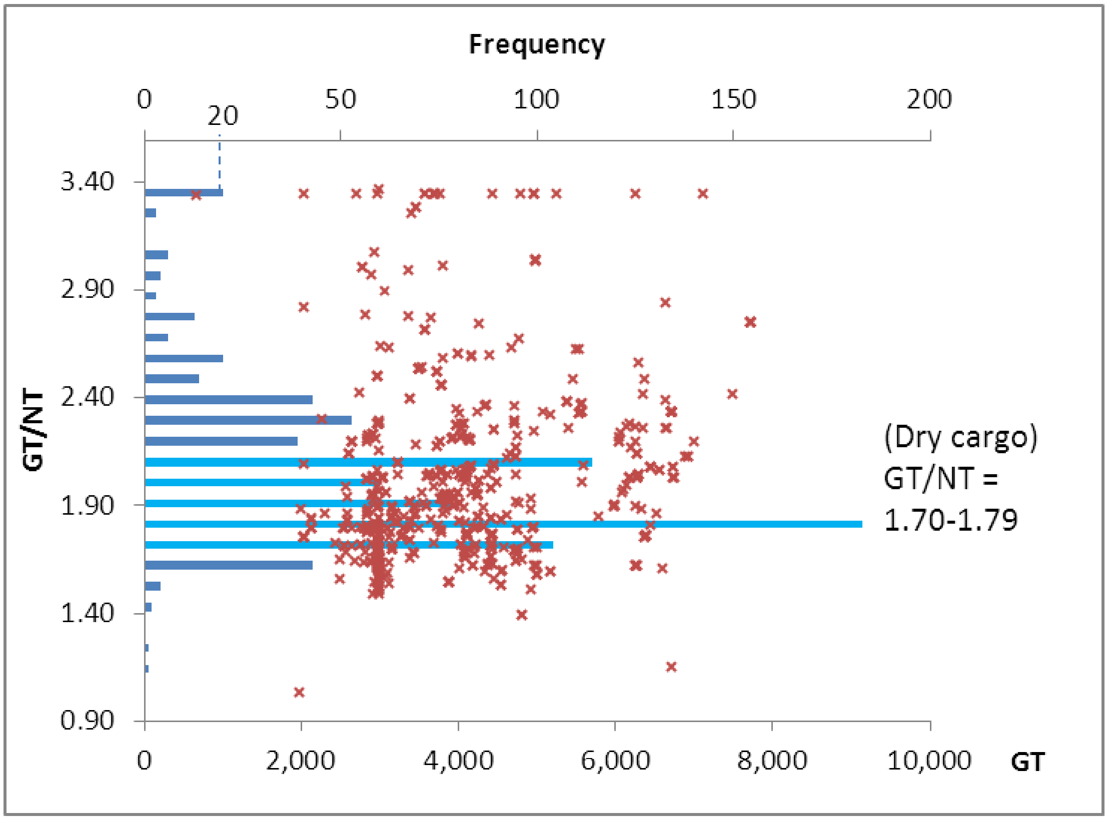


Figure 21 Frequency (bar) and Distribution (dot) of the ratio of GT/NT distinguished by types of Tanker

FIGURE 21 FREQUENCY (BAR) AND DISTRIBUTION (DOT) OF THE RATIO OF GT/NT DISTINGUISHED BY TYPES OF TANKERS



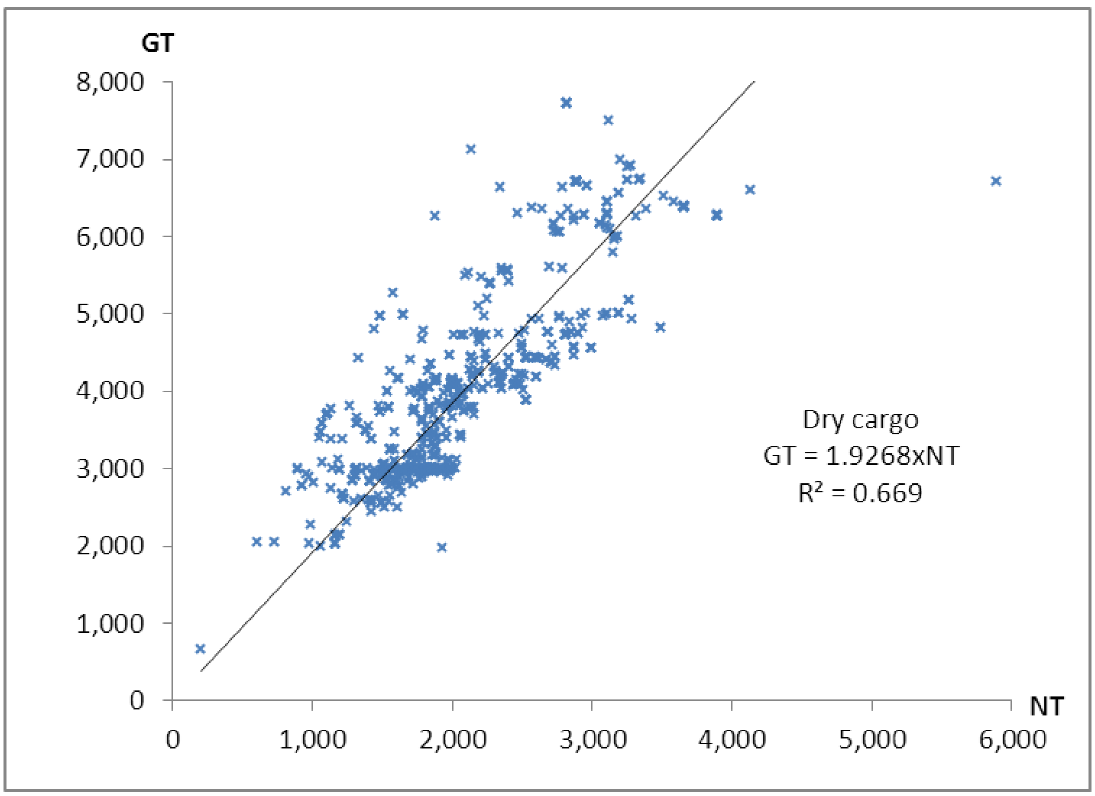


FIGURE 22 (A) FREQUENCY (BAR) AND DISTRIBUTION (DOT) OF THE RATIO OF GT/NT AND (B) RELATIONSHIP BETWEEN GT AND NT OF DRY CARGO SHIP (N = 816)

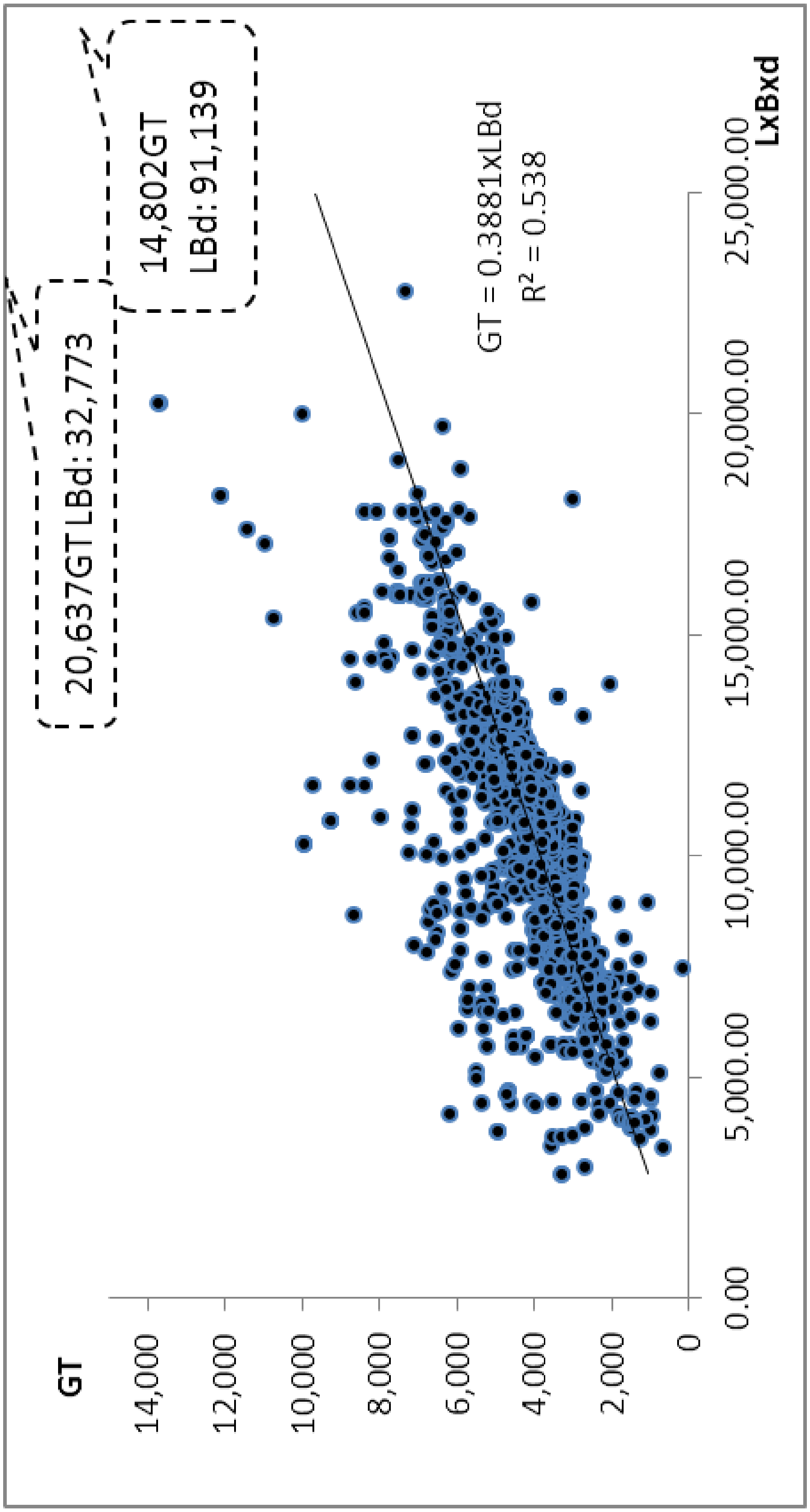


Figure 23 Relationship between GT and MRE (LxBxd) (N=2539)

*Two ships shown in column are out from the screen to improve visibility.

FIGURE 23 RELATIONSHIP BETWEEN GT AND MRE (N=2539)

APPENDIX: M Figure24

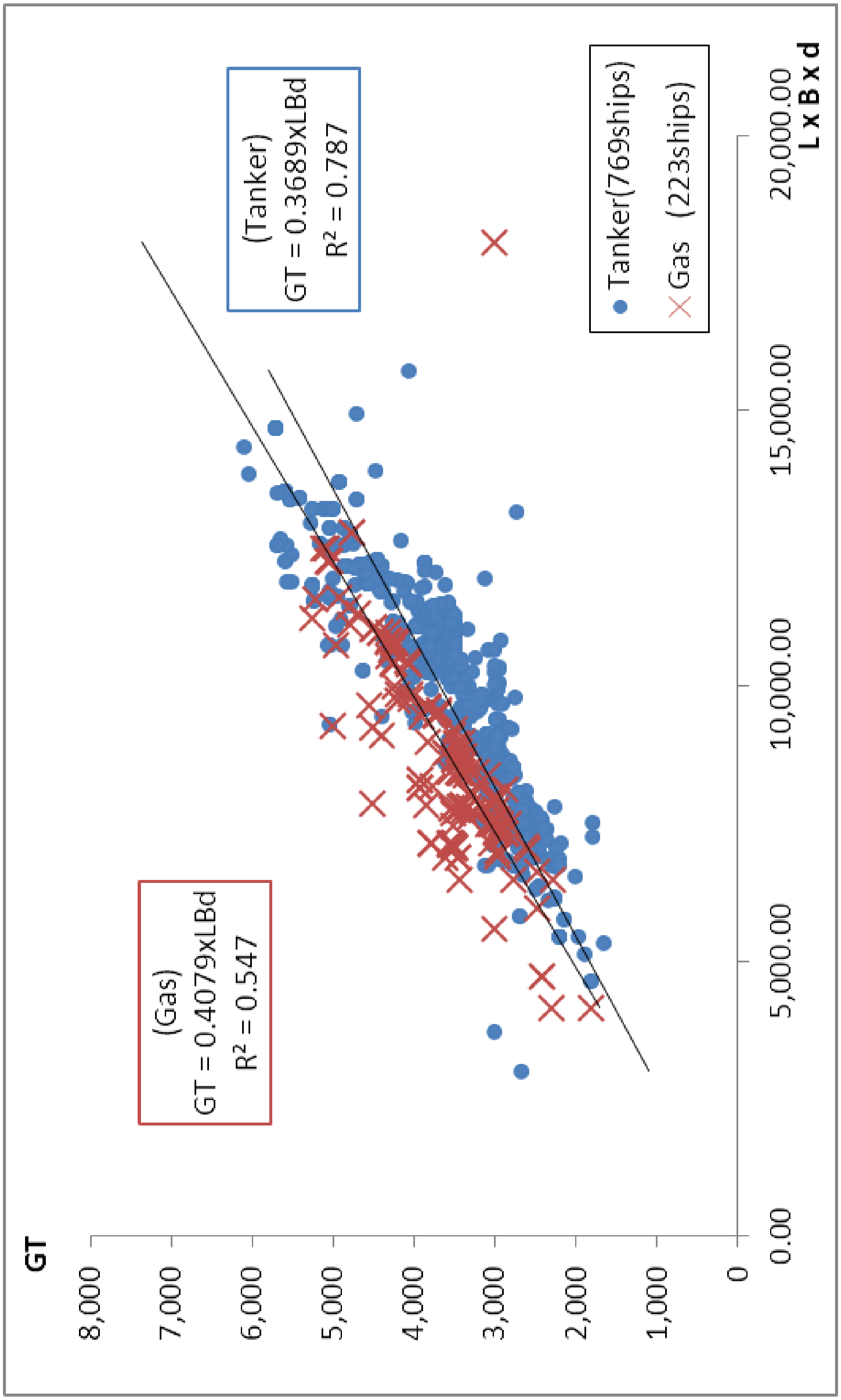


Figure 24 Relationship between GT and MRE (LxBxd) of Tanker and Gas carrier

FIGURE 24 RELATIONSHIPS BETWEEN GT AND MRE OF TANKER AND GAS CARRIER

APPENDIX: N   Table 3   List of INF Ships

Ship name	Pacific Egret	Pacific Grebe	Pacific Heron	Orient Pintail	SIGYN	SIGRID	Serebryanka	Rokuei-maru	Kaiei-maru
IMO No.	9364097	9364098	9364096	8601408	8025941	9631840		9137935	9364095
Port of registry					Oskarshamn	Oskarshamn		Rokkasho-mura, Kamikita-gun, Aomori	Tokyo
Flag state	UK	UK	UK	UK	Sweden	Sweden		Japan	Japan
Owner	Pacific Nuclear Transport Ltd.	Pacific Nuclear Transport Ltd.	Pacific Nuclear Transport Ltd.	Nuclear Decommissioning Management Company	Svensk KB	SKB		Nuclear Fuel Transport Co., Ltd.	Nuclear Fuel Transport Co., Ltd.
Manager	Serco Marine Services	Serco Marine Services	Serco Marine Services	Serco Marine Service	Furutank rederi AB		Murmansk Shpg. Co.	Nippon Shipping Co.,Ltd.	SHINWA NAIKO KAIUN KAISHA Co.,Ltd.
Builder	Mitsui Ship Building	Mitsui Ship Building	Mitsui Ship Building		S.N.A.C. Du Havre, Le Havre, France	DAMEN SHIPYARD GORINCHEM - GORINCHEM, NETHERLANDS	Oka Shipyard	Mitsui Ship Building	Mitsui Ship Building
Ship's type/purpose	Nuclear Fuel Tranpsort Vessel	Nuclear Fuel Tranpsort Vessel	Nuclear Fuel Tranpsort Vessel		Ro-Ro	Ro-Ro		Irradiated Nuclear Fuel Tranpsort Vessel	Irradiated Nuclear Fuel Tranpsort Vessel
Loa [m]	103.9	103.9	103.9		90.33	99	102	Approx. 100m	Approx. 100m
Beam [m]	17.25	17.25	17.25		18.04	18	15.02	Approx. 16.5m	Approx. 16.5m
Depth [m]	10	10	10		6.65	6.5	6.71	–	–
draught [m]	6.75	6.75	5.6		3.99	5	4.19	–	–
Gross Tonnage [ton]	6766	6840	6776		4,166	6694	2836	4913(GRT)	4924(GRT)
Net Tonnage [ton]	2033	2052	2033		1249	2008	1080	N/A	N/A
DeadWeight Tonnage [ton]	4408	4902	4916		2,044	1600	1625	Approx. 3,000	Approx. 3,000t
Engine power [kW] or [HP]	–	–	–		1177 x 2	3300	-	–	–
Thruster (Fore/Aft) [number]	–	–	–		-	-		–	–
Propeller [type] and [number]	–	–	–		-	-		–	–
Speed [knot]	14	14	14		12	-	11.5	–	–
Deck load Cargo [Yes/No]	No	No	No		unknown	unknown		No	No
Crew [persons]	–	–	–		-	-		–	–

Table 3 is organized by the author with the information from:

- Clarksons World Fleet Register;
- AIS ship tracking website (www.);
- shipowners' website and interviews to workers of owning company by email.