1. Introduction

Important conditions that are applied to plan and design mooring facilities, fairways, and other port facilities are the length over all, full load draft and other dimensions of the design ship. If the design ship can be specified, it is possible to set its dimensions as conditions. But in fact, only conditions such as the category and size (DWT or GT) of the design ship can be provided, and designers must estimate the dimensions of the ship through a variety of conditions based on these conditions.

In order to respond appropriately to this situation, Japan's Technical Standards and Commentaries of Port and Harbor Facilities[1)] statistically analyze ship dimension data to stipulate the dimensions such as length over all and breadth molded according to the size of the ship for every category of ship.

This report presents the results of research[2)] on ship dimensions and the Standards for the Main Dimensions of Ships (Draft) based on statistical analysis carried out by the Port Planning Division, Port and Harbour Department, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport in preparation for the revision of the Technical Standards and Commentaries of Port and Harbor Facilities (scheduled for 2006). Therefore the contents of this report conform with the Concept of the Standards in Japan's Technical Standards and Commentaries of Port and Harbor Facilities.

2. Basic concepts of the analysis of the main dimensions

2.1 Data analyzed

The data used for the statistical analysis are Lloyd's Maritime Intelligence Unit Shipping Data (below called, "LMIU Data") for January 2004. This LMIU Data is data that was supplied by the LMIU Division of Informa PLC. **Figure 2-1** shows the relationship with the LMIU Division within Informa PLC.
An outline of each organization follows.

(1) Informa PLC

Informa PLC was founded by a merger of the LLP Group that is the publishing division of Lloyds Insurance with the IBC Group in 1998. The origin of the LLP Group dates back to 1734 in Edward Lloyd's Coffee House, the place where maritime information was exchanged, and where Lloyd's List, the world's first journal of maritime information, was posted on the wall.

It now provides technological, specialized, and business related special information and services throughout the world, and its range of concerns is extremely wide, including social science, natural science, finance, law, electrical communication, maritime transport, energy, agriculture, food products, and so on.

(2) Informa Maritime & Transport Division

The Informa Maritime & Transport Division is the division that handles maritime information for the entire group. It sells maritime information such as the Lloyd's List to corporations in 134 countries through a daily journal and as electronic data.

(3) LMIU Division

The LMIU Division has constructed its own data base of information concerning more than 117,000 oceangoing ships including those under construction, ships in service, and decommissioned ships, more than 163,500 maritime companies, and more than 8,000 ports around the world. It provides necessary data according to the desires of its customers.

In particular, it collects principal types of data concerning main dimensions every month from all the classification societies of the International Association of Classification Societies (IACS) and has constructed a vast database of data collected from other organizations. It also provides data from its database with contents adapted to the demands of its users.
Therefore, the LMIU Data (Jan. 2004) that were analyzed for this report are not an off-the-shelf package of data; rather the data were assembled according to items that the Port Planning Division, Port and Harbour Department, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport requested from the LMIU.

The LMIU constantly updates its data and corrects,

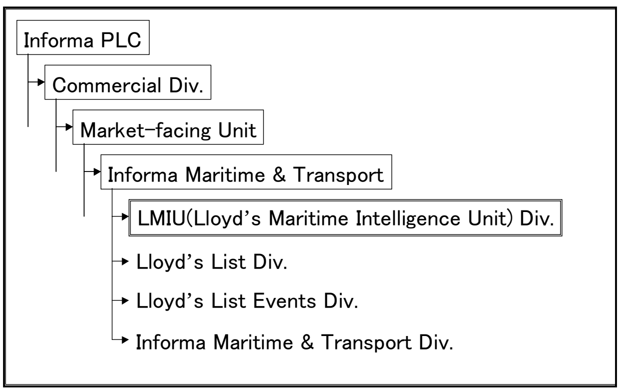

Figure 2-1 Lloyd's Maritime Intelligence Unit

updates, etc. past data, so even data regarding the same item in the same period varies according to the time it was ordered. Data concerning all items regarding the same ship is not necessarily presented, for example, in some cases, Loa is presented but not Lpp. It is assumed that some of the values are incorrect, so the analysis must be done with adequate care.

2.2 Ages of the ships analyzed

The statistical analysis was limited to ships with age of 15 years or less, for the following reasons.

1) Ships that cruise the world begin to be decommissioned about 25 years after completion, while Japan's Technical Standards and Commentaries of Port and Harbor Facilities are revised approximately every ten years, so the final period that the standards are applied should be ships up to the 25^{th} year after their completion. Therefore, ship age up to 15 years (25 – 10) is considered to be the suitable analysis time.

2) Under Japan's Ministry of Finance statutes concerning the number of years of service of depreciable assets, the service life of a steel ship of 2,000 GT or more is 15 years. But because passenger ships are older than ordinary ships when they are decommissioned, ships up to 30 years were included in the analysis.

2.3 Categorization of design ships

(1) Categorization based on type of ship

Categorization of ships varies widely, according to the cargoes they carry, the method of loading cargoes, and ocean lane, so the finer the categorization, the more clearly their characteristics can be clarified. Because categorizing them in detail reduces the number of data handled by the statistical analysis, the precision of the analysis results is reduced.

So the following nine-type categorization is set based on Japan's existing Technical Standards and Commentaries of Port and Harbor Facilities.

"Cargo Ship" includes "General Cargo Ship" (ships that transport cargo in crates and barrels etc.), Bulk Carrier, and Ore Carrier.

1) Cargo Ship
2) Container Ship
3) Oil Tanker
4) Roll on/Roll off Ship
5) Pure Car Carrier
6) LPG Ship
7) LNG Ship
8) Passenger Ship
9) Ferry

(2) Number of ship data that are analyzed

The numbers of ship data analyzed by ship class by category of ship are shown in **Table 2-1**. It shows the numbers of data, relative ratio, cumulative ratio based on the same ship class (in the small scale, set in detail, and in large scale, set roughly) according to the ship categorization that has been established. These data are existing data; both DWT and GT data. And results for Cargo Ship include results categorized as "General Cargo Ship" and as "Bulk Carrier and Ore Carrier". The Vessel Type Decode that uses the LMIU Data ship categorization is shown in **Table 2-2**.

As a result, it has been clearly shown that the numbers of data for each category of ship vary greatly from 5,846 for Cargo Ship to 161 for LNG Ship and that the distributions are completely different between ship classes. Regarding cargo ships, it has been confirmed that below 15,000 DWT, many are general cargo ships and that at and above 15,000 DWT, many are bulk carries and ore carriers.

2.4 Analysis items

The following four items are established as the main dimensions according to the GT or the DWT classification of each category of ship analyzed in accordance with Japan's Technical Standards and Commentaries of Port and Harbor Facilities.

• Loa: Length over all
• Lpp: Length between perpendicular
• Breadth molded: B
• Full load draft: d

Table 2-1 Numbers of ship data analyzed by ship class by category of ship

DWT \ Type	Cargo Ship			Container Ship			Oil Tanker		
	N of data	Relative ratio	Cumulative ratio	N of data	Relative ratio	Cumulative ratio	N of data	Relative ratio	Cumulative ratio
0 — 499	74	1.3%	1.3%	0	0.0%	0.0%	0	0.0%	0.0%
500 — 999	136	2.3%	3.6%	0	0.0%	0.0%	0	0.0%	0.0%
1,000 — 1,999	462	7.9%	11.5%	1	0.0%	0.0%	4	0.4%	0.4%
2,000 — 2,999	425	7.3%	18.8%	7	0.3%	0.3%	2	0.2%	0.6%
3,000 — 4,999	946	16.2%	34.9%	82	3.5%	3.8%	3	0.3%	0.8%
5,000 — 9,999	902	15.4%	50.4%	371	15.7%	19.6%	5	0.5%	1.3%
10,000 — 14,999	159	2.7%	53.1%	259	11.0%	30.5%	1	0.1%	1.4%
15,000 — 29,999	673	11.5%	64.6%	592	25.1%	55.6%	7	0.7%	2.1%
30,000 — 49,999	687	11.8%	76.4%	520	22.1%	77.7%	4	0.4%	2.4%
50,000 — 99,999	971	16.6%	93.0%	499	21.2%	98.9%	212	19.9%	22.4%
100,000 — 199,999	382	6.5%	99.5%	27	1.1%	100.0%	446	41.9%	64.3%
200,000 —	29	0.5%	100.0%	0	0.0%	100.0%	380	35.7%	100.0%
Total	5,846	100.0%		2,358	100.0%		1,064	100.0%	

GT \ Type	Roll-on/Roll-off Ship			Pure Car Carrier			LPG Ship		
	N of data	Relative ratio	Cumulative ratio	N of data	Relative ratio	Cumulative ratio	N of data	Relative ratio	Cumulative ratio
0 — 499	59	11.8%	11.8%	1	0.5%	0.5%	46	4.5%	4.5%
500 — 999	44	8.8%	20.5%	1	0.5%	1.0%	218	21.5%	26.1%
1,000 — 1,999	42	8.4%	28.9%	4	1.9%	2.9%	94	9.3%	35.3%
2,000 — 2,999	33	6.6%	35.5%	0	0.0%	2.9%	101	10.0%	45.3%
3,000 — 4,999	35	7.0%	42.4%	1	0.5%	3.4%	191	18.9%	64.2%
5,000 — 9,999	110	21.9%	64.3%	22	10.7%	14.1%	138	13.6%	77.8%
10,000 — 14,999	41	8.2%	72.5%	5	2.4%	16.5%	35	3.5%	81.2%
15,000 — 29,999	96	19.1%	91.6%	24	11.7%	28.2%	62	6.1%	87.4%
30,000 — 49,999	17	3.4%	95.0%	58	28.2%	56.3%	123	12.1%	99.5%
50,000 — 99,999	25	5.0%	100.0%	90	43.7%	100.0%	4	0.4%	99.9%
100,000 — 199,999	0	0.0%	100.0%	0	0.0%	100.0%	1	0.1%	100.0%
200,000 —	0	0.0%	100.0%	0	0.0%	100.0%	0	0.0%	100.0%
Total	502	100.0%		206	100.0%		1,013	100.0%	

GT \ Type	LNG Ship			Passenger Ship			Ferry		
	N of data	Relative ratio	Cumulative ratio	N of data	Relative ratio	Cumulative ratio	N of data	Relative ratio	Cumulative ratio
0 — 499	1	0.6%	0.6%	61	16.0%	16.0%	145	63%	63%
500 — 999	2	1.2%	1.9%	18	4.7%	20.7%	44	19%	82%
1,000 — 1,999	1	0.6%	2.5%	34	8.9%	29.6%	12	5%	87%
2,000 — 2,999	1	0.6%	3.1%	13	3.4%	33.0%	17	7%	94%
3,000 — 4,999	0	0.0%	3.1%	29	7.6%	40.6%	8	3%	98%
5,000 — 9,999	0	0.0%	3.1%	42	11.0%	51.6%	5	2%	100%
10,000 — 14,999	0	0.0%	3.1%	31	8.1%	59.7%	0	0%	100%
15,000 — 29,999	9	5.6%	8.7%	30	7.9%	67.5%	0	0%	100%
30,000 — 49,999	11	6.8%	15.5%	37	9.7%	77.2%	0	0%	100%
50,000 — 99,999	77	47.8%	63.4%	72	18.8%	96.1%	0	0%	100%
100,000 — 199,999	59	36.6%	100.0%	15	3.9%	100.0%	0	0%	100%
200,000 —	0	0.0%	100.0%	0	0.0%	100.0%	0	0%	100%
Total	161	100.0%		382	100.0%		231	100.0%	

DWT \ Type			General Cargo Ship			other General Cargo ship		
			N of data	Relative ratio	Cumulative ratio	N of data	Relative ratio	Cumulative ratio
0	─	499	73	2.3%	2.3%	1	0.0%	0.0%
500	─	999	135	4.2%	6.5%	1	0.0%	0.1%
1,000	─	1,999	449	14.0%	20.4%	13	0.5%	0.6%
2,000	─	2,999	402	12.5%	32.9%	23	0.9%	1.4%
3,000	─	4,999	926	28.8%	61.8%	20	0.8%	2.2%
5,000	─	9,999	876	27.3%	89.0%	26	1.0%	3.2%
10,000	─	14,999	124	3.9%	92.9%	35	1.3%	4.5%
15,000	─	29,999	176	5.5%	98.4%	497	18.9%	23.4%
30,000	─	49,999	38	1.2%	99.5%	649	24.7%	48.1%
50,000	─	99,999	15	0.5%	100.0%	956	36.3%	84.4%
100,000	─	199,999	0	0.0%	100.0%	382	14.5%	98.9%
200,000	─		0	0.0%	100.0%	29	1.1%	100.0%
Total			3,214	100.0%		2,632	100.0%	

Table 2-2 Vessel Type Decode

Type	Vessel Type Decode	
Cargo Ship	bulk	BBU
	ore carrier	BOR
	general cargo	GGC
Container Ship	container carrier	UCC
Oil Tanker	crude oil tanker	TCR
Roll-on/Roll-off Ship	ro/ro	URR
Pure Car Carrier	vehicle carrier	MVE
LPG Ship	lpg	LPG
LNG Ship	lng	LNG
Passenger Ship	passenger	MPR
Ferry	ferry	OFY

2.5 Analysis methods and coverage rate concept

(1) Analysis methods

The statistical analysis methods applied to obtain the main dimensions according to the ship class for each ship category are the following three types, and the optimum method is selected according to the data distribution properties in each case.

1) Logarithmic regression analysis method

i) Ships of the same category are spatially generally analogous regardless of their size, so their main dimensions are approximately proportional to 1/3 power of the ship size. The relationship of the main dimensions with the ship size is, therefore, represented by the following equation.

$$Y = \alpha X^{\beta} \qquad (1)$$

Where:

Y : Loa, Lpp, B, d

X : GT, DWT

ii) Equation (1) is changed to equation (2) by transforming both sides into common logarithms, so that it is easy to perform statistical analysis such as calculating the simple linear regression equation and the standard differential.

$$\text{Log } Y = \log \alpha + \beta \log X \qquad (2)$$

Specifically, the results of the analysis of the category "Cargo Ship" are shown in **Figure 2-3**, **4**.

Figure 2-3 is a distribution diagram of Loa and DWT, and **Figure 2-4** shows the transformation of both axes into common logarithms. The analysis of the standard dimensions was done using a common logarithm with base of 10. In **Figure 2-4**, log (Loa) is clearly linear regressed based on log (DWT).

The actual analysis confirms high correlation: coefficient of determination (R^2) = 0.957, and β in equation 2 was confirmed to be a value near 0.295 and 1/3. In this report, in the representations of (log). the base is not written as ($\log_{10}$), but all signify a common logarithm.

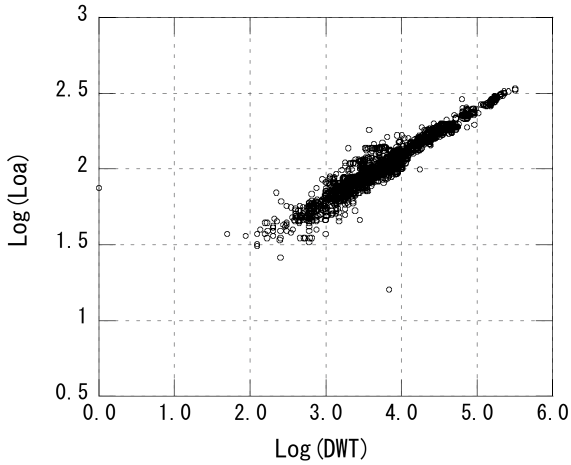

Figure 2-4 Cargo Ship Log(Loa)-Log(DWT)

2) Average value analysis method

The most conspicuous example of the application of this method is the B – DWT relationship for container ships shown in **Figure 2-5**. As this figure clearly shows, it is confirmed that up to about 35,000 DWT, as DWT increases, B also tends to rise, but afterwards it is constant. This is a result of the fact that because these travel through the Panama Canal, B is limited to the maximum value that can pass through this canal. Under these circumstances, the shape of ships is generally not spatially analogous, so it is not appropriate to apply 1) the logarithmic regression analysis method.

Therefore in a case where a dimension is constant regardless of the rise of GT and DWT in this way, the average value of the data that is analyzed is calculated at the same time as the standard differential from the standard value is analyzed. In this report, average value analysis is done to clearly differentiate this analysis method from the linear regression analysis method that

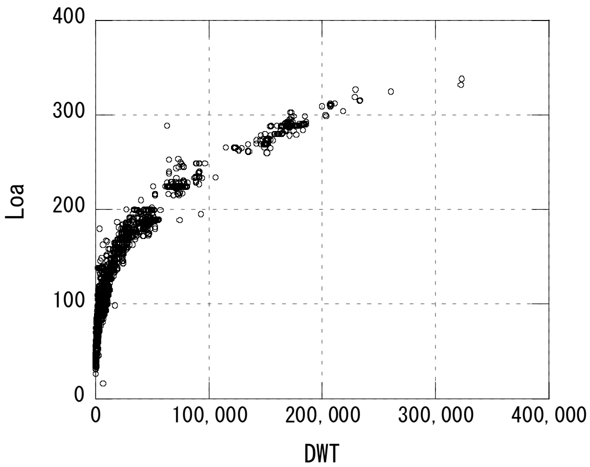

Figure 2-3 Cargo Ship Loa-DWT

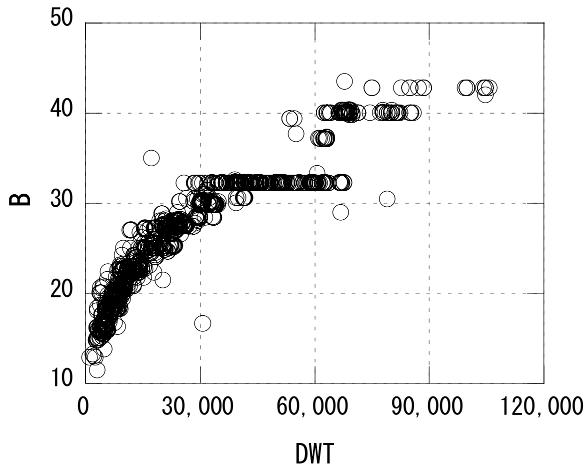

Figure 2-5 Container Ship B-DWT

follows.

3) Linear regression analysis method

The method of performing regression analysis based on a normal straight line without logarithmic conversion of the data is, in this paper, linear regression analysis. A representative example is the relationship of the number of containers that can be loaded on a container ship (TEU unit) with DWT that is shown in **Figure 2-6**. The actual analysis confirms good correlation: coefficient of determination (R^2) = 0.980.

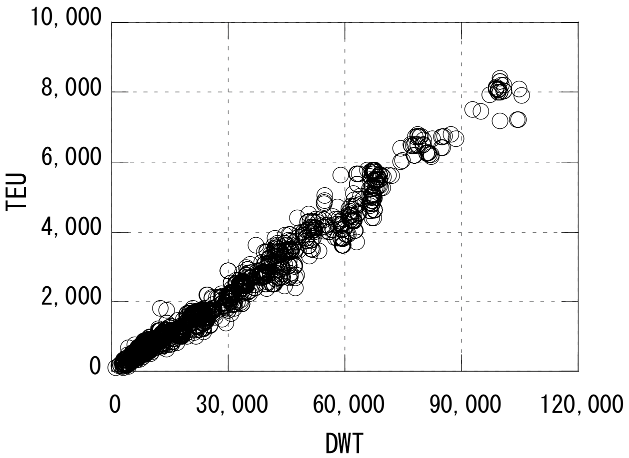

Figure 2-6 Container ShipTEU-DWT

(2) Analysis method selection concept

The analysis method is selected basically to ensure that the coefficient of determination (R^2) in the analysis results obtained by the analysis method that was selected is 0.64 or higher, in other words, that the coefficient of correlation (R) is 0.8 or more.

However, even though a value of 0.64 or higher is ensured as the coefficient of determination (R^2) based on the method that is applied, there are cases where it is judged that the properties of the main dimensions are not adequately reflected, or cases where there is a range where the correlation is remarkably low. Therefore, an appropriate method is selected for each dimension at the same time as a method is selected by appropriately distinguishing ship classes.

Therefore, even when the category is identical, the analysis methods applied to each main dimension and the range of the ship classes to which each is applied vary.

(3) Coverage rate: concept and setting

The values of Loa, Lpp, B, and d obtained by regression equations adapted to GT and DWT by each of the analysis methods shown above are average values (50% values). In other words, statistically, of the number of ships that were objects of analysis, less than 50% were below this average value and more than 50% were above this average value. The purpose of this research is to specify the standard main specifications according to ship size in a case where the size based on DWT or GT of ships that are analyzed is set, but the main dimensions are not specified. Therefore, it is not adequate for only about half of the number of ships to be covered by the main dimensions, and an important challenge is to answer the question: “Of all the ships corresponding to the set tonnage, what percentage should the value statistically cover?” The percentage it covers is the “coverage rate.”

Because setting the coverage rate is an important factor in determining the level of service in a port, a port manager should set it based on his own concepts at the port facility planning and design stage. For example, in a case where the coverage rate is set at approximately 50%, mainly in order to lower port improvement costs, and ships with dimensions greater than this will enter the port, studying safety as necessary is considered. Another concept is, inversely, setting the coverage rate higher regardless of the higher cost to focus high service level on port sales.

It is possible to set a regression equation according to an optional coverage rate by assuming that the distribution of the data around the regression equation is a normal distribution, causing parallel translation of the regression equation of the average value based on the value obtained from the standard differential. The concept of this parallel translation is shown in **Figure 2-7** at the same time as this parallel translation quantity is calculated based on $k * \sigma$ (standard differential). The relationship of the value k with the coverage rate is

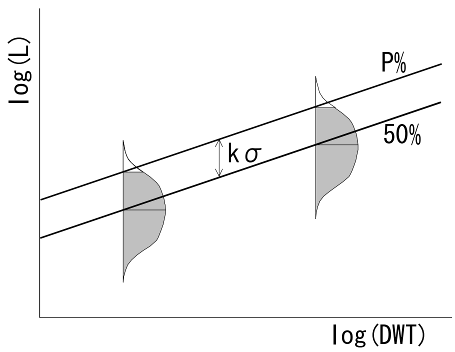

Figure 2-7 Line of P% coverage rate

shown in **Table 2-3**.

Under Japan's Technical Standards and Commentaries of Port and Harbor Facilities, the coverage rate had been 75%, so in this paper specific analysis is done for a coverage rate of 75%. But because the results of individual analyses show both regression equation and standard differential of the average value, it is possible to find a regression equation corresponding to an optional coverage rate.

Table 2-3 Relation between coverage rate and k

P	50%	60%	75%	90%	95%	99%
k	0. 000	0. 253	0. 674	1. 282	1. 645	2. 326

2.6 Setting the ship classes

The ship classes whose main dimensions are analyzed are shown on a table appropriately set by category of ship, based on the characteristics of each type of ship, values stipulated by Japan's former Technical Standards and Commentaries of Port and Harbor Facilities and on the opinions of concerned organizations. But in this report, it is possible to calculate the main dimensions according to optional ship classes because individual analysis results show the regression equation of a coverage rate of 75%.

3. Analysis of the main dimensions of ships

The concept of selecting the analysis method for each ship category and each dimension, an analysis results diagram and the final regression equation that are the basis for judgments are presented below. Analysis results according to typical ship classes are presented on summary tables. It shows two regression lines of curved lines and straight lines on the figure of each analysis result (regression equations finally selected assuming the top part is 75% coverage rate and bottom part is 50% coverage rate).

Loa and Lpp show similar trends, so the same analysis method is selected for all ship classes. And there are characteristics dimension values in the ship classes that are the maximum class in each ship category, so in cases where the results are separated from the statistical analysis results, specifications for individual ships are especially presented.

3.1 Cargo Ship

Figure 3-1 to **Figure 3-3**show the results of analysis of Loa, B, and d for DWT. And the following are the analysis methods applied to each main dimension and the range of the ship classes to which each method was applied. And **Table 3-1** shows the results of analysis of each main dimension according to the ship class that was set.

(1) Loa, Lpp (**Figure 3-4**,**5**)

All ship classes were analyzed by the logarithmic regression analysis method, obtaining R^2 = 0.957 for Loa and R^2 = 0.963 for Lpp.

(2) B (**Figure 3-6**)

All ship classes were analyzed by the logarithmic regression analysis method, obtaining R^2 = 0.951. For the 55,000DWT class and 70,000DWT class it was 32.3 m instead of the analytic value assuming they are Panamax type.

(3) d (**Figure 3-7**,**8**)

The ships were divided into two classes with 30,000DWT as the boundary and the logarithmic regression analysis method was applied to each class, obtaining R^2 = 0.847 for less than 30,000DWT and R^2 = 0.850 for 30,000DWT or more.

Table 3-1 The results of analysis of main dimensions (Cargo Ship)

Dead Weigth Tonnage (t)	Length Overall (m)	Length P.P. (m)	Breadth Molded (m)	Full Load Draft (m)
1,000	67	61	10.7	3.8
2,000	82	75	13.1	4.8
3,000	92	85	14.7	5.5
5,000	107	99	17.0	6.4
10,000	132	123	20.7	8.1
12,000	139	130	21.8	8.6
18,000	156	147	24.4	9.8
30,000	182	171	28.3	10.5
40,000	198	187	30.7	11.5
55,000	217	206	32.3	12.8
70,000	233	222	32.3	13.8
90,000	251	239	38.7	15.0
120,000	274	261	42.0	16.5
150,000	292	279	44.7	17.7