A shipbuilding cost analysis comparison between China, Japan and the United States.

Y. Siyuan

NOLOGY • THE UNIVERSITY OF MICHIGAN
ARBOR, MICHIGAN

A SHIPBUILDING COST ANALYSIS COMPARISON BETWEEN CHINA, JAPAN AND THE UNITED STATES

Yang Siyuan
Visiting Scholar

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Professor Howard M. Bunch
Department of Naval Architecture
and Marine Engineering

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I. INTRODUCTION TO CHINA'S SHIPBUILDING INDUSTRY

China was one of the world's first nations to develop shipbuilding and ocean navigation. In later centuries, however, the nation's shipbuilding capacity declined and only in recent years has it experienced a revival. The speed of this revival has been rapid. The country's world position in 1980 was close to that of France as seen in Table I-1. This is true both in shipbuilding tonnage and in fleet size. (In the latter case fleet size almost doubled from 1978 to 1980.)

TABLE I-1*

Annual Shipbuilding Tonnage and Merchant Fleet Size of China and Other Selected Regions and Countries, 1980

Region and Countries	Annual Shipbuilding Tonnage (1000 Tons)	Fleet Size (1000 Tons)
China (PRC)	480	10,000(+)**
Taiwan	220	1,700
USSR	-	30,000
U.S.A.	910	15,000
France	640	11,000
U.K.	820	28,000
Japan	4,800	17,800
India	-	5,500

SOURCE: The World Almanac 1981. Information Please Almanac 1981. The Hammond Almanac 1981. Encyclopedia Britannica 1981. Encyclopedia Britannica Year Book 1980.

*All numbers do not represent the productivities of these regions and countries--just according to the needs of the markets.

**(+) means actually more than this number.

The China State Shipbuilding Corporation (CSSC) was created by merging the country's shipyards, repair yards, and other maritime facilities. As presently constituted, the company is a huge, comprehensive shipbuilding enterprise with 26 large- and medium-sized shipyards, over 100 small yards, and 66 factories specializing in building marine diesel engines, navigation instruments, communication apparatus, and other equipment for ships. There are also 33 complete research institutes within the organization [1].

The shipyards alone employ over 300,000 technicians and workers. There are 81 shipways (the largest for 100,000-ton vessels) and 26 docks (the largest of which can serve 50,000-ton ships) [1].

Between 1962 and 1980, China launched over one hundred 10-25 thousand tons ships. Until recently the Chinese shipbuilding industry mainly served the country's domestic needs; in the last couple of years, the company has turned to the international market. This is in line with the policy of readjusting the national economy toward manufacturing for export. The CSSC currently has signed contracts with foreign firms for the export of more than 80 ships (over 1,000 tons) of various types. These, plus a number of oil drilling platforms and some machinery assembled with customer's materials, have brought the total business volume to more than $600 million in the first half of 1981.[2]

The Chinese government has set up three colleges and two technical schools specializing in shipbuilding. The government has also developed selected shipbuilding specialities at several other universities. In all, 3,000 men and women annually graduate with backgrounds directed to shipbuilding [2].

Looking at the future, China will strive to develop its shipbuilding industry to manufacture several million tons of ships per year and to rank among the biggest ship-producing countries in the world.

II. GENERAL SHIPBUILDING COST ANALYSES BETWEEN CHINA, JAPAN, AND U.S.

For this study, building costs in each country were estimated for 35,000 DWT. The major particulars of the ship are listed in Table II-1. The building period was assumed to occur in 1980.

The cost calculations for the ships built in China are shown in Appendix A. In the calculations, we used the Chinese monetary

TABLE II-1

The Major Particulars of 35,000 L.T. DWT Bulk Carriers [3]

Length	580 feet	(176.786 ms)
Beam	90 feet	(27.432 ms)
Depth	48 feet	(14.631 ms)
Cb	0.829	
Speed	15 knots	
BHP	14,500 BHP	
CN=LBD/100	25,056	(709.544)
Lightship	8,900 tons	
Deadweight	35,000 tons	(35,560)
Crew	30, over 12,900 feet^2	
Generators	1,350 kw	

unit--Yuan which was available in 1980. Then the resulting amounts were converted into U.S. dollars which was available in the same year. The dollar/yuan current relationships are shown in Table II-2. Meanwhile, Appendix B indicates the calculations of this ship if built in the U.S.

TABLE II-2

Official Exchange Rate Between Chinese Yuans and U.S. Dollars

Year	China (Yuans)	U.S. (Dollars)
1956-1970	246.18	100
1971	246.11	100
1972	224.51	100
1973	198.94	100
1974	196.12	100
1975	185.98	100
1976	194.14	100
1977	185.78	100
1978	168.36	100
1979	150.00 (about)	100
1980	151.81	100
1981	173.92	100
1982.5	180.40	100

SOURCE: China's Foreign Money Bureau.

The major estimating results of the above two countries were listed in Table II-3 and Table II-4.

According to Reference [3] material, we have the 1,179,000 man-hours for 35,000 DWT bulk carriers built in the U.S. Then we revised Table II-3 and have the corrected Table II-3B.

Light Weight

From the comparison between Table II-3 and Table II-4, it is seen that the calculated weight of the Chinese ship was heavier than the American weight calculation. The Chinese ship was shown to be 17 percent heavier. There are several possible reasons why a Chinese ship would be heavier:

i. Old design standards are used
ii. Greater safety margin is used
iii. Technique and management control problems

The outfit weight of the Chinese ship is calculated to be about two times greater than the American ship. It is suggested that improvement of outfit design is an urgent task for Chinese shipyards.

Material Costs

The total Chinese material costs were close to the total material costs of the U.S., the material for a Chinese ship as estimated at about 88 percent of the American cost. Among the significant items, the ratio of steel of China to the U.S. was 1.50, the ratio of machinery was 1.17, and the ratio of outfit was only 0.37.

The reason why Chinese shipbuilding has much lower outfit material costs is perhaps that the Chinese shipyards manufacture much of these outfit materials internally.

The main reason Chinese shipyards have the higher steel material cost are the very conservative design standards and too great production margins.

The ratio of direct shipbuilding material cost of the U.S. to that of Japan is 1.45 [*]. Table II-5 shows the comparisons of

* Confidential

TABLE II-3

Summary of Costs for 35,000 DWT Bulk Carrier Built in U.S. in 1980

ITEM	STEEL	OUTFIT	MACHINERY	ELECTRONICS	TOTAL	
					NET LIGHT WEIGHT	TOTAL LIGHT WEIGHT
WEIGHT (L.T.)	7003	1032	935		8970	9239
MATERIAL COSTS ($1000)	$3447	$4489	$7071		$15007	
(MANHOURS) (1000 MHS)	482	278.6	119.4		880	
LABOR COSTS ($1000)	$4821	$2786	$1194		$8801	
OVERHEAD COSTS ($1000)	$4821	$2786	$1194		$8801	
SUBTOTAL ($1000)	$13088	$10062	$9459	$350	$32,959	
10% BUILDER PROFIT ($1000)	$1309	$1006	$946	$35	$3296	
3% OWNER ORGANIZATION COSTS ($1000)	$432	$332	$312	$12	$1088	
1% MISCELLANEOUS EXPENSE ($1000)	$148	$114	$107	$4	$373	
TOTAL	$14977	$11514	$10824	$401	$37716	

Source: Appendix B

TABLE II-3B

Corrected Costs for 35,000 DWT Bulk Carrier Built in U.S. in 1980

ITEM	STEEL	OUTFIT	MACHINERY & PIPE	ELECTRONICS	TOTAL
WEIGHT (L.T.)	7003	1,032	935		8970
MATERIAL COSTS ($1000)	$3447	$4489	$7,071	$350	$15,357
(MANHOURS)* (1000 MHS)	542.1	233.6	209	34.4	1,019.1
LABOR COSTS ($1000)	$5,421	$2,336	$2090	$344	$10191
OVERHEAD COSTS ($1000)	$5,421	$2,336	$2090	$344	$10191
SUBTOTAL ($1000)	$14,289	$9,161	$11,251	$1,038	$35,739
10% BUILDER PROFIT ($1000)	$1,429	$916	$1125	$104	$3,574
3% OWNER ORGANIZATION COSTS ($1000)	$472	$302	$371	$34	$1,179
1% MISCELLANEOUS EXPENSE ($1000)	$162	$104	$127	$12	$405
TOTAL	$16,352	$10,483	$12,874	$1,188	$40,897

* Estimated by A&P Appledore, Limited (July, 1980)

TABLE II-4

Summary of Costs for 35,000 DWT Bulk Carrier Built in China in 1980

ITEM	STEEL	OUTFIT	MACHINERY	ELECTRONIC	TOTAL	
					NET LIGHT WEIGHT	TOTAL LIGHT WEIGHT
WEIGHT (L.T.)	7169	2018	1097		10284	10798
MATERIAL COSTS ($1000)	$5180	$1675	$6350		$13205	
(MANHOURS) (1000 MHS)	795	267	347		1409	
LABOR COSTS ($1000)	$318	$107	$139		$564	
WORKSHOP OVERHEAD COSTS ($1000)	$954	$321	$417		$1692	
SHIPYARD ADMINISTRATION ($1000)	$477	$160.5	$208.5		$846	
SUBTOTAL ($1000)	$6929	$2263.5	$7114.5	$94	$16401	
8% SHIPYARD PROFIT ($1000)	$554	$181	$569	$8	$1312	
5% TAX RATE SALE PRICE ($1000)	$7877	$2573	$8088	$107	$18645	

Source: Appendix A

of direct shipbuilding material costs for China, Japan, and U.S. As seen, Japan has the lowest direct material cost, the U.S. has the highest, and China is in the middle.

Labor Costs

A comparison of direct labor hours between the three countries are shown in Table II-5. Japan had the lowest, the U.S. was in the middle, and China has the highest manhours. China's direct manhours of labor was 4.92 times greater than Japan.

Table II-3 and Table II-4 clearly shows that direct shipbuilding labor hours for China are more than those of the U.S. in almost every item. The total ratio of China to the U.S. was 1.60. While the ratio of steel was 1.65, the ratio of outfit was 0.96, and the ratio of machinery was 2.91. It is pointed out that the ratio of outfit labor hours between two countries are not significant because of differences in how outfit hours are defined.

The findings clearly show the labor cost advantage of China. The total direct labor costs of China are only 6.4 percent of those estimated for an american yard.

The reason for the much lower labor costs is that there is very lower salary system in China. This does not mean, however, Chinese workers have a lower living standard than U.S. workers, because China has very low costs for board and lodging. And, there is also significantly greater social services and benefits.

Though Chinese shipyards expend more direct labor hours, they still have lower direct labor costs. This means that Chinese shipyards have great potentials for the future competition in the world shipbuilding industry.

Table II-5 shows the relationships between direct material costs/direct labor costs. The Chinese ratio was 80/20 85/15. Japan was 70/30 and the U.S.'s was only 50/50.

Overhead Costs

The workshop overhead costs of the Chinese shipyard are about

TABLE II-5

The Comparisons of Direct Shipbuilding Material Cost and Direct Labor Hours Among China, Japan, and U.S. (in 1980) for 35,000 DWT Bulk Carrier

ITEM	CHINA	JAPAN	U.S.
MATERIAL COSTS	$\$13,205 \times 10^3$	$\$10,350 \times 10^3$	$\$15,007 \times 10^3$
RATIO	1.30	1.00	1.45
MANHOURS	$1,409 \times 10^3$	331×10^3	$1,019 \times 10^3$ [3]
RATIO	4.92	1.00	3.08
DIRECT MATERIAL COSTS/DIRECT LABOR COSTS	80/20 ~ 85/15	70/30	50/50

Source: Estimated

100 percent of the direct labor costs.

On a country-by-country comparison, the total overhead costs of the China shipyard are only one-fifth of the U.S. shipyard.

Other Indirect Costs

Chinese shipyards have a very different classification for "other indirect costs," when compared with the U.S. shipyards. The classification is simply called "shipyard administration" in China, the category is about 150 percent of direct labor costs. In the U.S.'s shipyards the indirect costs are some four percent of direct labor costs. The organization costs are about three percent of direct labor costs, and the miscellaneous expenses about one percent of direct labor costs.

The ratio of other indirect costs of China to those of the U.S. was about 0.58.

The detailed description of indirect costs in Chinese accounting system is given in Chapter III.

Total Shipbuilding Price

The total shipbuilding cost comparisons of 35,000 deadweight long tons among China, Japan, and the U.S. are listed in Table II-6. The first item gave the estimating prices which were found from Appendix A and B. The total shipbuilding price of Japanese shipyards was about 52.98 percent of that of the U.S.'s shipyards (Source: Mards).

Fortunately, there was an actual quotation prepared by Livingston in 1980 for a production run of five 35,000-ton bulkers. The quoted price was $\$40 \times 10^6$. Correspondingly, the average price of 5-series ships in China was about $\$19 \times 10^6$ and the average price of 5-series ships in Japan was $\$20 \times 10^6$.

From calculations shown in Table II-6, it is seen that China had the lowest shipbuilding price of the first ship which was about $\$23 \times 10^6$. The U.S. had the highest price, which was about $\$48 \times 10^6$ and Japan had the middle value, which was $\$24 \times 10^6$.

China, Japan, and U.S.

ITEM	CHINA	JAPAN	U.S.
THE ESTIMATING PRICE	$\$18.6 \times 10^6$	$\$19.2 \times 10^6$	$\$40.8 \times 10^6$
THE AVERAGE APPROXIMATE PRICE OF 5-SERIES SHIPS	$\$19 \times 10^6$	$\$20 \times 10^6$ (2)	$\$40 \times 10^6$ (1)
THE FIRST SHIP PRICE	$\$23 \times 10^6$	$\$24 \times 10^6$	$\$48 \times 10^6$
THE RATIO OF FIRST SHIP	0.96	1.00	2.00

Source: Estimated, Marad

(1) Actual quotation
(2) Assumed at 52.8 percent of U.S. Cost (Source: U.S. Maritime Administration)

Notation:

$$\lambda = \frac{1}{2b} = 0.925 \text{ (exponent curve)}$$

$$b = \frac{\log 1.08108}{\log 2} = \frac{0.0338578}{0.30103} = 0.11247$$

$$x = 5 \text{ (the numbers of series ship)}$$

The first ship price:

$$a = \bar{y} \cdot x^b$$

Where: $\bar{y}$ = The average price of series ships
(Exponent which varies with complexity of ship, characteristics of yard, etc.)

The ratio of total shipbuilding price of first ship of China to that of Japan was 0.96. While the total shipbuilding price of first ship of the U.S. was two times more than that of Japan.

Conclusions

From the three countries shipbuilding cost analyses, we have an overview of the productive capacities of these three countries in shipbuilding industry.

Japan has the best position. In spite of a slightly higher building price. Japan has the lowest direct material costs and the lowest direct labor hours. This means Japan is the most efficient and has the best productivity.

China occupies the middle position. Even though it has the lowest building price. Chinese shipyards spend the most for material and labor hours. This means that China has the lowest productivity. However, China's cheap labor cost give a current cost advantage and strong potential for future competition.

The U.S. spends too much for building costs. This puts the U.S. shipbuilding industry into a very poor competition position. The U.S. shipyards have lower direct labor hours than China, but this advantage is no more than offset by the expensive material costs and labor rates.

III. DETAIL ABOUT INDIRECT COSTS

A number of costs in the accounting system of Chinese shipyards are classified as indirect costs. The system of classification is significantly different than that found in U.S. and in Japan yards. The Chinese system has two general divisions:

(1) Workshop overhead

(2) Shipyard administration

 (i) indirect production costs

 (ii) worker social costs

The values of above costs for a specific time period are set by management on the basis of past experience and future expectations. Variances between the expected and actual values are then adjusted in a subsequent time period.

(a) Workshop Overhead

When we calculate overhead in Chinese accounting system, we only consider workshop overhead. In other words, we put all overhead into workshop overhead. Basically, workshop overhead is more or less connected with ship building production. It includes the following:

(1). Workshop real capital property, such as buildings, productive equipments, workshop transportation tools and etc.

(2) Discount charge

(3) Water and electricity

(4) Interest of cash flow of workshop

(5) Other expenditures

Table III - 1 shows the ratios of main items of workshop overhead to direct labor costs for a shipyard. It is also identified that the ratio of total workshop overhead costs to total direct labor costs is about 2.0 $\sim$ 3.0.

TABLE III - 1 THE RATIO OF WORKSHOP OVERHEAD TO DIRECT LABOR COSTS IN CHINA

ITEM	PROPORTION
Mechanical	4.2
Outfitting	3.0
Painting	1.1
Average	2.0 ∽ 3.0

In our estimate the worker basic wage was 0.6 Yuan/manhour in 1978 Chinese money, or about $0.4/manhour in 1978 U.S. dollar. If the Chinese accounting system charges 200∽300 percent of direct labor costs for overhead, then the actual charge would be 1.2 - 1.8 yuan/direct labor manhour.

(b) Shipyard Administration

Shipyard administration costs in Chinese accounting system can be divided into two main parts. First one is connected with production and called indirect production costs. This part includes:

(1) Production planning
(2) Production management
(3) Production quality control
(4) Supplies
(5) Salaries of management

The second part is mostly involved with well-being costs and industrial relation costs. We shall call it worker social costs.

Generally speaking the worker social costs are broken down as follows:

(1) Well being (including mess expenses)
(2) Worker protection

(3) Environmental protection

(4) Death benefits

(5) Health services

(6) Natural damage aids (such as storm, flood and earthquake, etc.)

(7) Labor insurance (including retirement)

(8) Education and training

(9) Entertainment

(10) Safety planning

Table III - 2 shows worker social costs for a CSSC's medium sized shipyard. The worker social costs are shown as a proportion of the shipyard's total annual revenue. We assumed that the total annual revenue of this shipyard was about 33 x 10^6 yuans/year. It was shown from Table III-2 that the total worker social costs if 0.04 ~ 0.05 of total annual revenue.

In the Chinese accounting system the total shipyard administration costs are always indicated as a percentage of direct labor costs. This number is about 100 ~ 150 percent of direct labor costs. Generally it is better to choose the higher.

TABLE III -2 WORKER SOCIAL COSTS FOR A CSSC3 MEDIUM-SIZED SHIPYARD (with revenue of 33 x 10^6 yuan/year)

NO.	ITEM	100 Yuans/Year	Percent of Revenue*
1.	Well-being (incl. Mess)	800	.0242
2.	Working Protection	160	.0048
3.	Environment Afforestation	6	.0002
4.	Death Treatment	16	.0005
5.	Health Services	140	.0042
6.	Labor Insurance(incl. Retirement)	350	.0106
7.	Safety Award	0.6	--
	Worker Social Costs	1472.6	.0446

* Revenue of 33 X10^6 yuan/year

IV. DEVELOPMENT OF COMPARABLE COST ANALYSES

To perform the cost comparison an estimate was made of the costs to building a 35,000 DWT bulk carrier at a medium-sized shipyard in each nation (PRC Japan, USA) during 1978. In China an CSSC medium-sized shipyard was selected, in Japan Aioi Shipyard anonymous of Ishikawajima-Harima Heavy Industries Co., Ltd., (IHI) was selected, and in the U.S. the Levingston Shipyard Company (LSC) was selected. All costs were for the first ship of a series.

The comparisons were made in the context of LSCO's cost accounting system. The monetary system used U.S. dollars in 1978.

The costs in direct material costs and direct labor hours for each account were identified, roughly adjusted to a common baseline and ranked in order of significance.

Total Costs

Until recently, the typical bulk carrier built in a CSSC's medium yard was over 16,000 deadweight tons. This size ship was used as the basic reference for developing costs for the 35,000 DWT bulk.

Table IV-1 shows a breakdown of actual total costs for a CSSC 16,000 DWT bulk carrier. The tabulation is structured differently than both LSCO's and IHI's. The actual Costs for some larger bulkers are shown in Table IV-2. As this table shows, there are data for a 24,000 DWT and 50,000 DWT ship. Then Table IV-3 shows an estimate for a 35,000 DWT ship by combining the data in Table II-2 and in Table IV-2.

Material Costs

In Chinese accounting system the average costs of steel material was 700 yuans/metric ton. It was almost no change from 1978 to 1980. So we have the following steel material costs:

TABLE IV-1

Actual Total Costs of CSSC's 16,000 DWT First Bulk Carrier

Item	Description	Proportion
1 2 3 4 5 6 7 8	Design Contractual Costs Inspection Insurance Mold Loft Construction Services Launching Test	
Subtotal	Preliminary and Productive Speciality	.0183
9 10 11	Hull Metallic Structure of Superstructure Welding	
Subtotal	Hull and Superstructure	.2980
12 13 14	Outfitting Painting and Cementing Engineering Quarters Outfit	.0928 .0303 .0292
Subtotal	Outfit	.1523
15 16 17 18 19 20 21 22	Main Engine Compartments, Decks and Generators Cranes Shafting Propeller Piping Installing Mooring Trail	.1654 .1019 .0129 .0188 .0206 .0608 .0323 .0267
23 24	Electrical Engineering Communication	.0298 .0446
Subtotal	Electrical System	.0744
25 26	Spare-propeller Stem Shaft of Spare-propeller	
Subtotal	Spare-parts and Equipments	.0275
TOTAL	All Items	1.0000

Source: Estimated

TABLE IV-2

The Effect of Shipbuilding Costs of Different Size Tankers in Chinese Shipyards

Items	24,000 DWT Tanker	50,000 DWT Tanker	Effect Radio
1. Preliminary and Speciality	2.44	7.28	2.98
2. Hull and Superstructure	32.11	38.94	1.21
3. Outfit	8.58	6.21	0.72
a. Outfitting	3.71	2.96	0.80
b. Painting and Cementing	1.86	1.33	0.72
c. Quarters Outfit and Carpentry	3.01	1.92	0.64
4. Machinery	48.80	42.32	0.87
a. Main Engine	21.00	18.54	0.88
b. Compartments, Desk & Generator	12.18	8.57	0.70
c. Cranes	0.21	0.10	0.48
d. Shafting	0.75	0.50	0.67
e. Propeller	1.31	0.90	0.69
f. Piping	8.84	9.48	1.07
g. Installing	2.34	2.62	1.12
h. Mooring Trail	2.18	1.65	0.76
5. Electrical Systems	4.82	2.86	0.59
6. Spare-parts and Equipments	3.25	2.88	0.87
TOTAL	100.00	100.00	

Source: Estimated

	Steel Material Costs / L. T.	
Countries	1978	1980
China	$422.45/L.T.	$468.5/L.T.
U.S.	$400 /L.T.	$460 /L.T.

Table IV - 4 gave the breakdown of actual direct material costs of CSSC's 16000 deadweight tons for first bulk carrier.

Generally there are some statistic relationships between direct material costs and direct labor costs for bulk carrier built in China.

Item	Direct Material Costs/Direct Labor Costs		
Hull	75/25	~	80/20
Outfit	75/25	~	80/20
Machinery		90/10	
Electrical		85/15	
Average	80/20		85/15

Finally, Table IV-5 shows the estimate of direct material costs for a 35,000 DWT bulker based on data contained in Table II-2 and in Table IV-3, and in Table IV-4.

Labor Costs

The following proportions of manhours for steel, outfit and machinery for a bulk carrier are the common conditions in the CSSC's medium-sized shipyards.

TABLE IV-3

The Corrected Estimating Total Costs of CSSC's 35,000 DWT First Bulk Carrier Built

Item	Description	Proportion
1	Design	.0300
2	Contractual Costs	-
3	Inspection	.0050
4	Insurance	.0050
5	Mold Loft	.0015
6	Construction Services	.0130
7	Launching	.0005
8	Test	.0002
Subtotal	Preliminary and Productive Speciality	.0548
9	Hull	
10	Metallic Structure of Superstructure	
11	Welding	
Subtotal	Hull and Superstructure	.3606
12	Outfitting	.0745
13	Painting and Cementing Engineering	.0220
14	Quarters Outfit	.0190
15	Main Engine	.1456
16	Compartments, Decks and Generator	.0713
17	Cranes	.0074
18	Shafting	.0059
19	Propeller	.0142
20	Piping	.0651
21	Installing	.0681
22	Mooring Trail	.0245
Subtotal	Machinery	.4013
23	Electrical Engineering	.0176
24	Communication	.0263
Subtotal	Electrical System	.0439
25	Spare-parts	.0239
26	Spare-equipments	
Subtotal	Spare Parts and Equipments	.0239
TOTAL	All Items	1.0000

Source: Estimated

TABLE IV-4

Actual Direct Material Costs of CCSI's 16,000 DWT First Bulk Carrier

Item	Description	Proportion
1	Design	-
2	Contractual Costs	-
3	Inspection	-
4	Insurance	-
5	Mold Loft	.0030
6	Construction Services	.0085
7	Launching	.0005
8	Test	.0001
Subtotal	Preliminary and Productive Speciality	.0121
9	Hull	.2156
10	Metallic Structure of Superstructure	.0575
11	Welding	.0144
Subtotal	Hull and Superstructure	.2875
12	Outfitting	.0916
13	Painting and Cementing Engineering	.0253
14	Quarters Outfit	.0288
Subtotal	Outfit	.1457
15	Main Engine	.1813
16	Compartments, Decks and Generator	.1104
17	Cranes	.0136
18	Shafting	.0092
19	Propeller	.0221
20	Piping	.0522
21	Installing	.0358
22	Mooring Trail	.0296
Subtotal	Machinery	.4542
23	Electrical Engineering	.0276
24	Communication	.0414
Subtotal	Electrical System	.0690
25	Spare-propeller	.0252
26	Stem Shaft of Spare-propeller	.0063
Subtotal	Spare-parts and propeller	.0315
TOTAL	All Items	1.0000

Source: Estimated

TABLE IV-5

The Corrected Estimating Direct Material Costs of CSSC's 35,000 DWT First Bulk Carrier

Item	Description	Proportion
1	Design	.0250
2	Contractual Costs	-
3	Inspection	-
4	Insurance	-
5	Mold Loft	.0020
6	Construction Services	.0150
7	Launching	.0030
8	Test	.0005
Subtotal	Preliminary and Productive Speciality	.0455
9	Hull	.2616
10	Metallic Structure of Superstructure	.0698
11	Welding	.0174
Subtotal	Hull and Superstructure	.3488
12	Outfitting	.0699
13	Painting and Cementing Engineering	.0134
14	Quarters Outfit	.0181
Subtotal	Outfit	.1014
15	Main Engine	.1622
16	Compartments, Decks and Generator	.0778
17	Cranes	.0067
18	Shafting	.0063
19	Propeller	.0157
20	Piping	.0601
21	Installing	.0758
22	Mooring Trail	.0275
Subtotal	Machinery	.4321
23	Electrical Engineering	.0179
24	Communication	.0269
Subtotal	Electrical System	.0448
25 26	Spare-parts Spare-equipments	.0274
Subtotal	Spare-parts and Equipments	.0274
TOTAL	All Items	

Source: Estimated

Item	Proportion of Total Manhours
Hull	0.55
Outfit	0.20
Machinery	0.25
Total	1.00

The actual direct labor manhours recorded by CSSC for 16,000 dead weight tons bulk carrier are presented in a CSSC cost breakdown system in Table IV - 6.

Finally, Table IV - 7 gives an adjusted estimate for direct labor man hours to build a 35,000 DWT bulker based on data shown in Table IV - 6 and in earlier data.

Project Budgeting

CSSC prepares preliminary sales price estimates using the following formula.

$$SE = [DL\ (1 + WOH + SA) + DM]\ (1 + P)\ /\ (1 - t)$$

Where:

SE = sale price in yuans

DL = estimate direct labor costs in yuans

WOH = current average cost of overhead for the workshop calculated as the ratio of the workshop overhead costs to total direct labor costs

SA = current shipyard administration costs calculated as the ratio of shipyard administration to total direct labor costs

DM = estimated direct material costs in yuans

P = shipyard profit factor

t = tax rate

TABLE IV-6

Actual Direct Labor Manhours of CSSC's 16,000 DWT First Bulk Carrier

Item	Description	Proportion
1	Design	.0373
2	Contractual Costs	.0030
3	Inspection	.0030
4	Insurance	.0016
5	Mold Loft	.0090
6	Construction Services	.0623
7	Launching	.0156
8	Test	.0234
Subtotal	Preliminary and Productive Speciality	.1557
9	Hull	.3212
10	Metallic Structure of Superstructure	.0857
11	Welding	.0214
Subtotal	Hull and Superstructure	.4283
12	Outfitting	.0343
13	Painting and Cementing Engineering	.0966
14	Quarters Outfit	.0078
Subtotal	Outfit	.1387
15	Main Engine	.0171
16	Compartments, Decks and Generator	.0109
17	Cranes	.0055
18	Shafting	.0055
19	Propeller	
20	Piping	.1393
21	Installing	.0273
22	Mooring Trail	.0047
Subtotal	Machinery	.2103
23	Electrical Engineering	.0530
24	Communication	.0132
Subtotal	Electrical System	.0662
25	Spare-parts	.0008
26	Spare-equipments	
Subtotal	Spare-parts and Equipments	.0008
TOTAL	All Items	1.0000

Source: Estimated

TABLE IV-7

The Corrected Estimating Direct Labor Manhours of CSSC's 35,000 DWT First Bulk Carrier

Item	Description	Proportion
1	Design	.0459
2	Contractual Costs	.0037
3	Inspection	.0037
4	Insurance	.0019
5	Mold Loft	.0100
6	Construction Services	.0745
7	Launching	.0186
8	Test	.0279
Subtotal	Preliminary and Productive Speciality	.1862
9	Hull	.3242
10	Metallic Structure of Superstructure	.0865
11	Welding	.0216
Subtotal	Hull and Superstructure	.4323
12	Outfitting	.0327
13	Painting and Cementing Engineering	.0769
14	Quarters Outfit	.0052
Subtotal	Outfit	.1148
15	Main Engine	.0227
16	Compartments, Decks and Generator	.0154
17	Cranes	.0052
18	Shafting	.0030
19	Propeller	.0022
20	Piping	.1401
21	Installing	.0169
22	Mooring Trail	.0042
Subtotal	Machinery	.2097
23	Electrical Engineering	.0456
24	Communication	.0114
Subtotal	Electrical System	.0570
25	Spare-parts	-
26	Spare-equipments	-
Subtotal	Spare-parts and equipments	-
TOTAL	All Items	1.0000

Source: Estimated

TABLE IV - 8

THE PROCESS FLOWS

NO.	LEVEL	DETAIL AT IHI	DETAIL AT CSSC	DETAIL AT LSCO
1.	Operation Control	By Shipyard & by Ship	By Shipyard & By Dept.	By Central Planning & Control Dept.
2.	Productive Control	By Dept.	By Dept.	"
3.	Program Control	By Shop	By Dept & By Shop	"
4.	Shop Planning	By Foreman & Assoc. Foreman	By Shop	By Production & Control Dept.
5.	Foreman	Daily Refinement	Daily Refinement	"

Source: Estimated

A typical CSSC shipyard has the following data:

WOH = 200% $\sim$ 300% of direct labor costs

SA = 100% $\sim$ 150% of direct labor costs

P = 0.06 $\sim$ 0.10, average is 0.08

t = 0.05

While Levingston has the sale value according to the following formula: [4]

$$SE = DL\ (1+ OH) + DM \times (1 + GA) \times (1+P)$$

Where:

SE = sales estimate

DL = estimated direct labor cost in $ per manhour

OH = overhead rate

DM = estimated direct material cost in dollars ($)

GA = general and administrative expense rate

P = profit factor

The estimated sales price for an IHI ship estimate is broken down according to the following formula: [4]

$$ESP = DL\ (LR + OH) + DM + DE) \times (1 + GA) \times (1 + P)$$

Where:

ESP = estimated sale price

DL = estimated direct labor manhours

LR = current average direct labor rate for this shipyard in ¥ per manhour

OH = current average cost of overhead for this shipyard calculated as the ratio of total indirect costs to total direct labor manhours

---

4

DM = estimated cost of direct materials to be bought by the shipyard

DE = estimated cost of direct expenses to be incurred by the shipyard

GA = current corporate general and administrative expense rate set by head office

P = profit factor, set by head office

Program Control

Table IV - 8, shows the five hierarchical levels of production control at the three shipyards. It is obvious that IHI has most complete control while Levingston has the least. CSSC is in the middle. IHI's control firmness is seen in the following:

(i) The staff at every level has the best understanding of both the capabilities and the limitations of the shipyard at that level.

(ii) IHI's personnel are all thoroughly familiar with the system. It is quite practical to assign a single staff engineer to work with a single foreman.

It appears CSSC may have too much indirect costs and too many departments connected with program control.

Detail Cost Comparisons Among Three Countries

It is very difficult to accurately compare item-to-item costs between CSSC and LSCO. In fact, their classifications are very different. For example, CSSC has the specific item - "design" in preliminary items. In an attempt to make the costs comparable, We put "design" int o "Contractual Costs" items.

Generally, CSSC has about 25 percent of direct labor manhours and 15～20 percent of direct material costs in "Preliminary and Staff". The percentage of item "staff" is not too much and has not serious influence in both direct labor manhours and direct material costs.

Table IV - 9 was the tabular form of direct material costs and direct labor hours of CSSC's 35,000 DWT first bulk carrier after rearranging according to CSCO's system.

Table IV - 10 and Table IV - 11 identified the comparisons of direct labor manhours and those of direct material costs amont these three counties.

Most of ratio in direct labor manhours between CSSC's and LSCO's were over 1.0. This means China had more direct labor hours expenditure . The total items ratio between China and U.S. was about 1.55. Japan had the lowest direct labor hours expenditure.

Meanwhile most of ratios of direct material costs in CSSC were slightly lower but very close to those at LSCO. So China had a slightly lower expenditure of direct material costs than U.S. Japan had the lowest cost position.

Anyway, the ratio of all direct material costs between CSSC and LSCO was about 0.95, and ratio between Japan and U.S. was 0.7.

TABLE IV-9

The Final Direct Material Costs and Direct Labor Manhours of CSSC's 35,000 DWT First Bulk Carrier

ITEM #	DESCRIPTION	Material	Labor
00	Contractual Costs	.0250	.0346
03	Building Ways and Launching	.0030	.0186
05	Mold Loft	.0020	.0200
06	Warehousing		
07	Construction Services	.0150	.0745
08	Clean Up		
09	Testing and Inspection	.0005	.0016
11	Insurance, Christening, etc.	—	.0019
Sub-total	Preliminary Items	.0455	.1862
01	Engineering	—	—
02	Planning and Production Control	—	—
85	Supervision	—	—
Sub-total	Staff Items	—	—
13	Hull Bottom	.2616	.3242
15	Hull Bulkheads and Framing		
17	Hull Sides and Attachments		
21	Hull Decks and Flats		
23	Hull Inner Bottom		
19	Miscellaneous Hull Structure		
25	Foundations and Tanks		
33	Deck Fittings		
35	Ladders below Deck	.0698	.0865
55	Ladders above Deck		
73	Doors and Hatches		
75	Benches and Shelving		
77	Awnings		
27	Bulworks and Windbreaks		
37	Deckhouses		
87	Steel Scrap	—	—
89	Welding Supplies	.0174	.0216
Sub-total	Hull Steel Items	.3488	.4323
29	Sternframe and Sterntube	.0758	.0169
31	Rudder		
45	Port Lights and Windows		
57	Derricks and Cranes	.0067	.0052
61	Steering Systems	—	—
63	Propellers and Shafting	.0220	.0052
65	Machinery and Equipment	.2400	.0381
69	Mooring Equipment	.0275	.0042
71	Safety Requirements	.0274	—
Sub-total	Machinery Items	.3994	.0696
39	Quarters Outfit	.0181	.0052
67	Heating, Ventilation & Air Conditioning	.0699	.0327
79	Electrical Systems	.0448	.0570
81	Blasting and Painting	.0134	.0769
83	Piping Systems	.0601	.1401
Sub-total	Outfitting Items	.2063	.3119
Total	All Items	1.0000	1.0000
Sub-total	Preliminary and Staff Items	.0455	.1862
Sub-total	All Steel Items	.3488	.4323
Sub-total	All Outfitting Items	.6057	.3815
TOTAL	All Items	1.0000	1.0000

Source: Estimated

TABLE IV-10

Comparison of Direct Labor Manhours
The Ratios of CSSC's Estimate to LSCO's Estimate And
IHI's Actual Figures To LSCO's Estimate

ITEM #	DESCRIPTION	RATIO OF CHINA VS U.S.A	RATIO OF JAPAN TO U.S.A
00	Contractual Costs	32.23	.4493
03	Building Ways and Launching	1.91	.3410
05	Mold Loft	1.68	.2956
06	Warehousing		1.4638
07	Construction Services	} 1.60	.5070
08	Clean Up		.1160
09	Testing and Inspection	1.70	.6768
11	Insurance, Christening, etc.	3.26	—
Sub-total	Preliminary Items	2.10	.3634
01	Engineering	—	.9902
02	Planning and Production Control	—	.2157
85	Supervision	—	.1081
Sub-total	Staff Items	—	.3744
13	Hull Bottom		.2842
15	Hull Bulkheads and Framing		.1752
17	Hull Sides and Attachments		.3777
21	Hull Decks and Flats		.4451
23	Hull Inner Bottom	1.33	.5319
19	Miscellaneous Hull Structure		1.0394
25	Foundations and Tanks		.6909
33	Deck Fittings		.1372
35	Ladders below Deck		.3039
55	Ladders above Deck		.3169
73	Doors and Hatches		.1872
75	Benches and Shelving	1.92	.1463
77	Awnings		—
27	Bulworks and Windbreaks		.1041
37	Deckhouses		.2847
87	Steel Scrap	—	—
89	Welding Supplies	—	—
Sub-total	Hull Steel Items	1.41	.2656
29	Sternframe and Sterntube		.0113
31	Rudder	} 1.38	.0575
45	Port Lights and Windows		.3090
57	Derricks and Cranes	.50	.1940
61	Steering Systems	—	.3322
63	Propellers and Shafting	1.71	.2181
65	Machinery and Equipment	2.69	.2944
69	Mooring Equipment	1.51	.1903
71	Safety Requirements	—	.9723
Sub-total	Machinery Items	1.57	.2259
39	Quarters Outfit	3.10	.5818
67	Heating, Ventilation & Air Conditioning	1.52	.3134
79	Electrical Systems	2.05	.2924
81	Blasting and Painting	1.93	.4473
83	Piping Systems	3.99	.4623
Sub-total	Outfitting Items	2.91	.4321
Total	All Items	1.55	.3249
Sub-total	Preliminary and Staff Items	1.00	.3729
Sub-total	All Steel Items	1.41	.2656
Sub-total	All Outfitting Items	2.52	.3817
TOTAL	All Items	1.55	.3249

Source: Estimated, Marad

TABLE IV-11
Comparison of Direct Material Costs
The Ratios of CSSC's Estimate to LSCO's Estimate
Ane IHI's Actual Figures to LSCO's Estimate

ITEM #	DESCRIPTION	RATIO OF CHINA VS U.S.A	RATIO OF JAPAN TO U S A
00	Contractual Costs	.71	1.6510
03	Building Ways and Launching	.43	1.0534
03	Mold Loft	.65	—
05	Warehousing		—
07	Construction Services	} 1.48	—
08	Clean Up		—
09	Testing and Inspection	.18	.6689
11	Insurance, Christening, etc.	—	.0786
Sub-total	Preliminary Items	.47	.8555
01	Engineering	—	.7499
02	Planning and Production Control	—	—
85	Supervision	—	—
Sub-total	Staff Items	—	.7499
13	Hull Bottom	} 1.63	.7945
15	Hull Bulkheads and Framing		.7942
17	Hull Sides and Attachments		.7823
21	Hull Decks and Flats		.7466
23	Hull Inner Bottom		.7944
19	Miscellaneous Hull Structure		1.8076
25	Foundations and Tanks		2.6918
33	Deck Fittings		.1270
35	Ladders below Deck	} .80	.5447
55	Ladders above Deck		.8772
73	Doors and Hatches		.6621
75	Benches and Shelving		.4091
77	Awnings		.5166
27	Bulworks and Windbreaks		.8673
37	Deckhouses		.5428
87	Steel Scrap		—
89	Welding Supplies	1.11	.6956
Sub-total	Hull Steel Items	1.33	.7055
29	Sternframe and Sterntube	} 4.53	1.6612
31	Rudder		3.3006
45	Port Lights and Windows	.27	.3167
57	Derricks and Cranes		.7241
61	Steering Systems	—	.4472
63	Propellers and Shafting	1.68	.8984
65	Machinery and Equipment	.93	.6436
69	Mooring Equipment	.82	.4692
71	Safety Requirements	1.81	.4067
Sub-total	Machinery Items	1.11	.6568
39	Quarters Outfit	.25	.5758
67	Heating, Ventilation & Air Conditioning	3.93	.9690
79	Electrical Systems	.66	.4739
81	Blasting and Painting	.66	.5783
83	Piping Systems	1.05	.7584
Sub-total	Outfitting Items	.88	.6023
Total	All Items	.95	.6778
Sub-total	Preliminary and Staff Items	.23	.8461
Sub-total	All Steel Items	1.33	.7055
Sub-total	All Outfitting Items	1.02	.6379
TOTAL	All Items	.95	.6778

Source: Estimated, Marad

V. INDUSTRIAL RELATIONSHIP IN SHIPBUILDING

Shipyard Organization and Employee Distribution a CSSC shipyard in basic working unit just like any general factories in China. A "Chinese working unit" is like a small kingdom in that it does production and also is totally responsible for the personnel and their family. The organizational structure for a CSSC's medium-sized shipyard are shown in Figure V - 1 and Figure V - 2. "The Personnel Congrees" is the top group, it holds the annual meetings and decides the big events in shipyard. Two top offices -- the director's office and the chief engineer's office -- are in charge of operations and technology. Below them are about fifteen administration and overhead sections and eight shops.

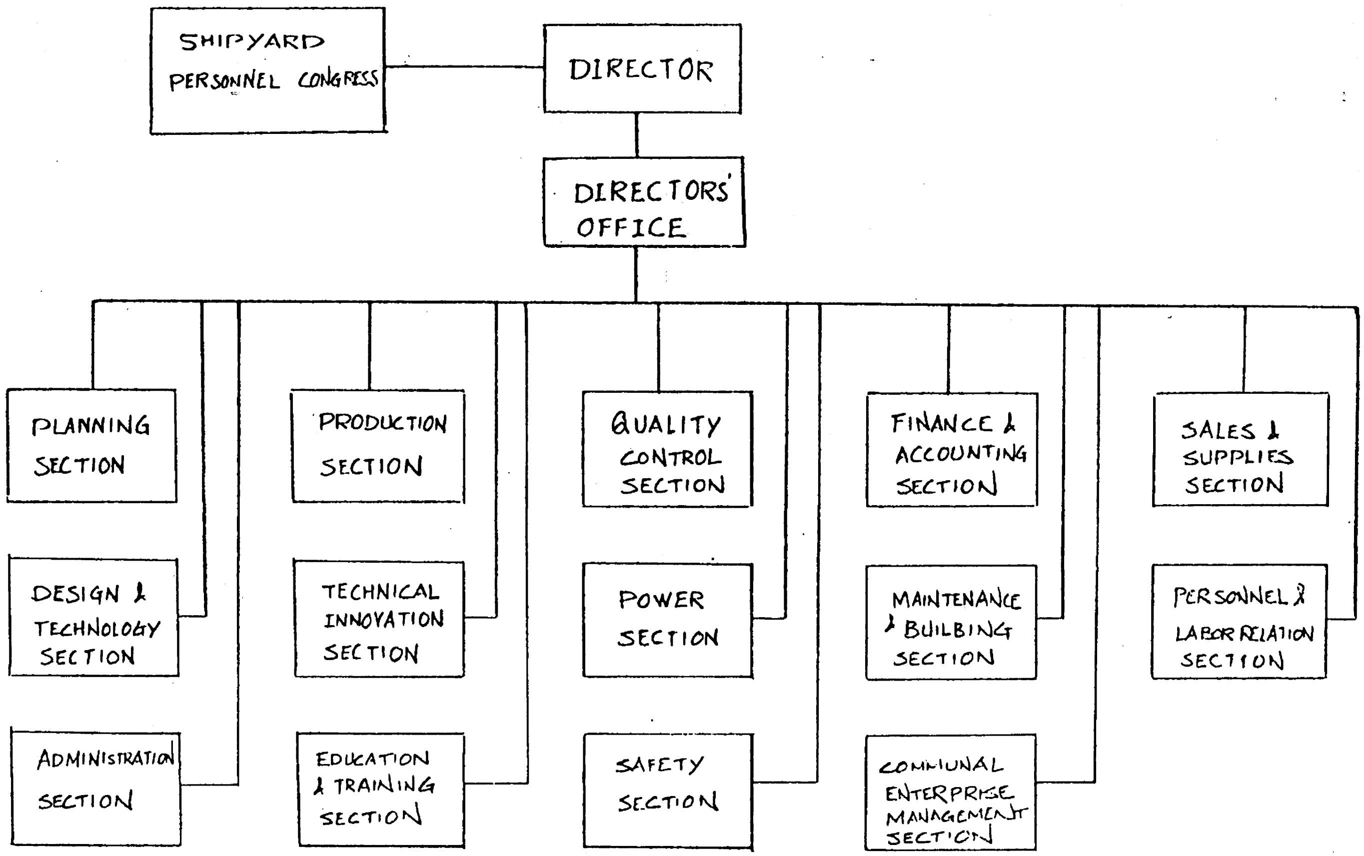
The yard has 3,300 persons; 1056 (about 32 percent of total) are women. This indicates the role that Chinese women play in the heavy industry.

Table V - 3 gives the employee distribution of shipbuilding in a CSSC's medium-sized shipyard and Table V - 4 makes a comparison with the other yards in the study.

Generally, the workers involved in hull production is about one-eighth to one-seventh of total in CSSC's yards. The First Number is for big yards; the second is for small yards.

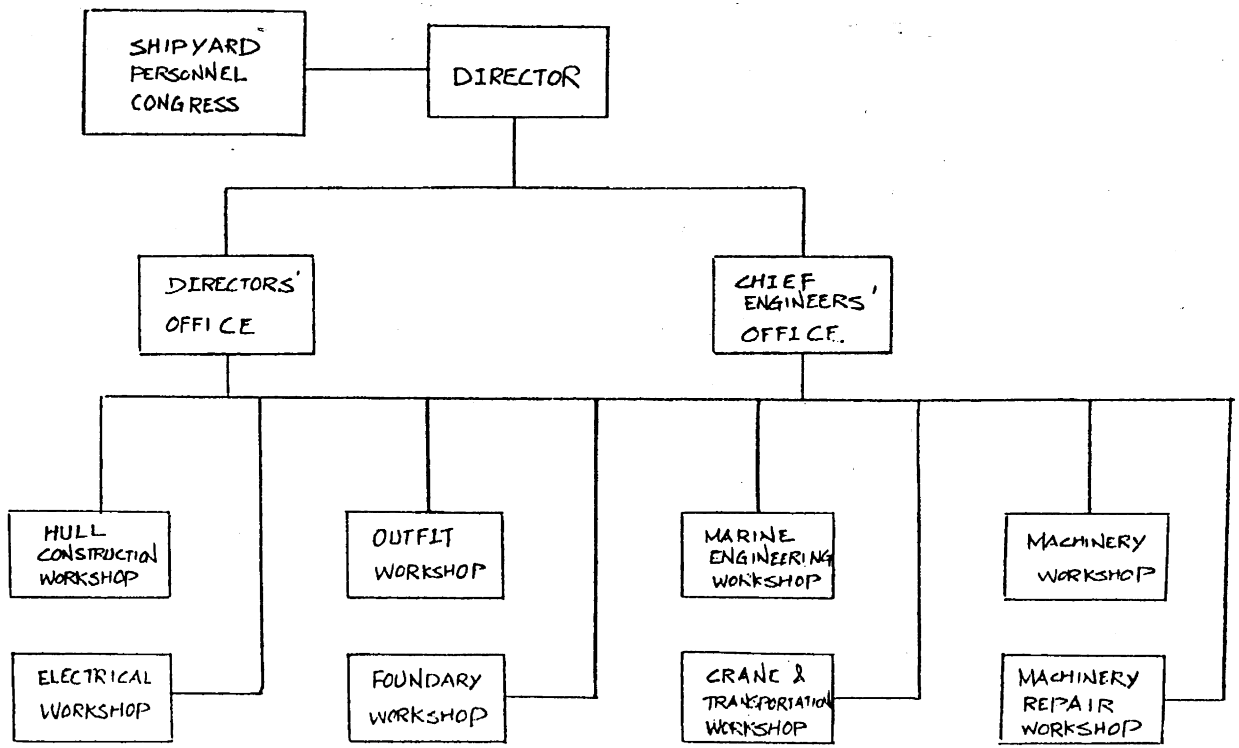
Table V - 5 lists the employee ratios of hull and outfit among three shipyards. An evaluation of the level of supervision provided to the workers indicates IHI is the best, LSCO is the poorest and CSSC is in the middle.

Table V - 6 gives an overview comparisons of employment profile for each company. Because the administrators in CSSC include managers, foremen and some staff and the ratio of managers and foremen to staff is three-fifth to two-third. We get the following correction:



Source: Confidential

Figure V-1. The Administration and Overhead Organization in a CSSC's Medium Shipyard



Source: Confidential

Figure V-2. The Production Organization
In a CSSC's Medium Shipyard

TABLE V - 3 EMPLOYEE LIST IN A
CSSC's MEDIUM-SIZED SHIPYARD
(For Shipbuilding Only)

NAME OF WORKSHOP AND GROUP	MANAGER	STAFF (INCL. ENGINEERS)	FOREMEN	INDIRECT WORKER		DIRECTOR WORKER		TOTAL
				ASST. FOREMEN	WORKER	ASST. FOREMEN	WORKER	
<1> HULL CONSTRUCTURE WORKSHOP								
PRODUCTION PLAN & ENGR'G GROUP	4	15	1		2	1	8	31
HULL FABRICATION SHOP	1	2	3		1	6	95	108
ASSEMBLE STAGE SHOP		2	4			8	110	124
ERECTION WORKSHOP	1	1	5	1	2	10	140	160
ALLOCATION CONTROL GROUP	1	3	4	2	6	8	80	104
TOTAL	7	23	17	3	11	33	433	527
<2> OUTFIT WORKSHOP								
PRODUCTION PLAN & ENGR'G GROUP	3	7	1	1	5			17
DECK FITTING SHOP	1	3	4	1	2	8	70	89
LIVING QUARTER FITTING SHOP	1	3	4		2	8	70	98
MACHINERY FITTING	1	2	3			6	60	82
ELECTRIC FITTING SHOP	1	3	3			6	65	78
PAINTING SHOP	1	1	3		1	6	45	57
TOTAL	8	19	18	2	10	34	310	401

Source: Estimated

TABLE V - 4. THE COMPARISONS OF SHIPBUILDING EMPLOYEE AMONG THREE COUNTRIES' SHIPYARDS

FUNCTION	Workers			Assistant Foremen			Foremen			Staff			Managers			Total		
	CSSC	IHI	LSCo	CSSC	IHI	LSCo	CSSC	IHI	LSCo	CSSC	IHI	LSCo	CSSC	IHI	LSCo	CSSC	IHI	LSCo
HULL CONSTRUCTION	444	944	790	37	129	51	17	33	10	23	40	29	7	7	10	527	1153	890
-Fabrication	96	214	157	6	28	9	3	7	3	2	6	9	1	1	2	108	256	180
-Assembly	110	228	362	8	26	24	4	6	4	2	5	3	-	-	2	124	265	395
-Erection	142	284	163	11	44	12	5	9	2	1	4	1	1	1	2	160	342	180
-Transportation	86	162	108	10	22	6	4	8	1	3	5	2	1	1	1	104	198	118
-Planning/Control/Management	10	56	-	2	9	-	1	3	-	15	20	14	4	4	3	31	92	17
OUTFITTING	318	532	308	34	114	18	17	36	7	16	53	9	8	10	7	421	745	349
-Module Outfitting	160	88	40	6	19	3	3	6	1	2	5	1	1	1	1	189	119	46
-Onboard Outfitting		37	27		10	2		4	1		6	-		1	1		58	31
-Deck Outfitting	72	124	40	9	26	3	4	8	1	3	8	-	1	1	-	98	167	44
-Accom. Outfitting	70	131	40	6	24	3	3	8	1	2	4	-	1	1	1	82	168	45
-Electrical	65	91	20	6	19	1	3	4	1	1	9	-	1	1	1	78	124	23
-Painting	46	51	141	6	13	6	3	5	2	1	10	1	1	1	1	57	80	151
-Planning/Control/Management	5	10	-	1	3	-	1	1		7	11	7	3	4	2	17	29	9

Source: Estimated

TABLE V - 5. EMPLOYEE RATIO OF HULL AND OUTFIT

CRITERION OF EVALUATION	UNIT OF MEASUREMENT	CSSC			IHI			LSCo		
		HULL	OUTFIT	TOTAL	HULL	OUTFIT	TOTAL	HULL	OUTFIT	TOTAL
First-Line Supervision	Workers per Ass't Foreman	12.0	9.4	10.7	7.3	4.7	6.1	15.5	18.2	16.2
Second-Line Supervision	Workers Per Ass't Foreman and Foreman	8.2	6.2	7.2	5.8	3.5	4.7	12.9	13.1	13.0
Total Supervision	Workers Per Asst. Foreman, Foreman & Manager	7.3	5.4	6.3	5.6	3.3	4.5	11.1	10.2	10.9
Welding / Fitting	Fitters Per Welder				5.0	–	–	1.7	–	–
Welding Support	other Workers Per Welder (New Construction)				–	–	6.2	–	–	2.7
Hull / outfit	Hull Workers Per Outfit Worker	1.4	–	–	–	–	1.8	–	–	2.4
Staff Support	Workers Per Staff Engineer	19.3	19.9	19.6	23.6	10.0	15.9	27.2	36.4	29.4
Indirect Support	Direct Workers & Ass't. Foreman per other Worker				–	–	2.9[1]	–	–	3.3[1]
					–	–	4.4[2]	–	–	4.0[2]

Source: Estimated

Note: 1: Including engineering

2: Excluding engineering

TABLE V - 6. EMPLOYEE RATIO OF SHIPYARDS

ITEMS	CSSC		ITEMS	IHI		LSCO	
	Employee	Proportion		Employee	Proportion	Employee	Proportion
Direct Workers & Asst. Foremen	2,376	.72	Direct Workers & Asst Foremen	2,414	.74	1,458	.77
Administrators	231	.07	Managers & Foremen	151	.05	74	.04
Technicians & Engineers	198	.06	Staff & Engineers	591	.18	270	.14
Indirect Workers & Asst. Foremen			Indirect Workers & Asst. Foremen	87	.03	102	.05
<i> Servers	396	.12					
<ii> Others	99	.03					
Total	3,300	1.00	Total	3,243	1.00	1,904	1.00
Total Direct Labor / Total Indirect Labor	2.6		Total Direct Labor / Total Indirect Labor	2.9		3.2	
Direct Workers & Asst. Foremen / Indirect Workers & Asst. Foremen	4.8		Direct Workers & Asst. Foremen / Indirect Workers & Asst. Foremen	27.7		14.3	
Administrators / Direct Workers & Asst. Foremen	0.1		Managers & Foremen / Direct Workers & Asst. Foremen	0.06		0.05	

Source:
CSSC - Confidential
IHI - Marad
LSCO - Marad

Item	Employees	Proportion
Managers & Foremen	146	0.044 (Average 0.063)
Staff & Engineers	316	0.096

Table V - 7 shows some significant manpower ratios based on the preceeding tables. The Table permits some important conclusions.

(i) The three countries' proportions of direct workers and assistant foremen are very close.

(ii) The same findings also exist in the number of leaders.

(iii) CSSC has a lack of staff and engineers. The proportion to total is only 0.096. IHI's is 0.18 and LSCO's is 0.14.

(iv) CSSC has the highest indirect labor force. It is 5 times greater than IHI's and 3 times greater than LSCO's. This means that CSSC shipyard has a huge indirect labor force performing the social services associated with employees' jobs and lives (such as mess. Kindergarton even barber shop, etc.) This worker social service involvement leads to close relationships between the shipyard and the employee.

Age, Tenure and Education

In general, older, long-serving and better-educated employees are the most productive. Table V - 8 tabulated these factors for each shipyard. The age and tenure values are accurate, but the educational values are only approximations.

CSSC's working force has almost the same tenure as IHI's, which assumes that they work from age of 20 to the age of 60 for men, and to the age of 55 for women. In any case, China has not any lay-off or unemployment system.

With regard to educational level, there are two such differences in CSSC. One is that CSSC's management has a low

TABLE V-7. Employee Ratio of Shipyeard Revised
From Table 5-6

ITEMS	CSSC		IHI		LSCo	
	Employee	Proportion	Employee	Proportion	Employee	Proportion
Direct Workers & Asst. Foremen	2,376	.72	2,414	.74	1,458	.77
Management & Foremen	146	.044	151	.05	74	.04
Staff & Engineers	316	.096	591	.18	270	.14
Indirect Workers & Asst. Foremen	495	.15	87	.03	102	.05
Total	3,300	1.00	3,243	1.00	1,904	1.00
Total Direct Labor / Total Indirect Labor	2.6		2.9		3.2	
Direct Workers & Asst Foremen / Indirect workers & Asst. Foremen	4.8		27.7		14.3	
Mangers & Foremen / Direct Workers & Ass't. Foremen	0.061		0.063		0:051	

Source:
CSSC - Confidential
IHI - Marad
LSCO - Marad

TABLE V - 8
Age, Tenure and Education

ITEM	CCSI	IHI	LSCo
AGE			
Average Age (1)	35 years	37 years	34 years
Mean Age (2)	—	38 years	41 years
TENURE			
Average Tenure (1)	—	17 years	5 years
Mean Tenure (2)	25 years (women) 30 years (men)	20 years	23 years
EDUCATION			
Senior Management	80% college 20% tech. High school	100% college	100% college
Middle Management	50% college 50% tech. High school	100% college	40% college 60% high shool
Staff	10% college 60% high school 30% junior high school	10% college 60% high school 30% junior high shool	10% college 50% high school 40% junior high shool
Foremen and Assistant Foremen	50% high school 50% junior school	60% high school 40% junior high school	50% high school 50% junior high school
Work force	10% high school 80% junior high school 10% others	10% high school 90% junior high school	10% high school 60% junior high school 30% lower levels

Source: LSCO - Marad
CSSC - Estimated
IHI - Marad

Note: (1) Age and Tenure of work force at time of study.
(2) Age and Tenure of work force if it worked from such as age 20 to 60 for men (or to 55 for women) in Japan

educational level when compared with IHI. The other is that China's workers generally have a basic junior highschool education system. This workforce education profile looks slightly better than LSCO's. But CSSC has the same deficiencies with U.S. management system as compared to that of Japan --- the lack of a thorough technical education at the manageMent and staff levels.

Wages

Table V - 9 presents a comparison of average direct labor wages in each shipyard, including premiums, overtime and bonuses. The values for CSSC has been escalated to 1980, the values for IHI were current in July 1979 and those for LSCO were those in effect at February, 1980. All values are shown in U.S. dollars. Fluctuation in the exchange rate have a noticable impact on this comparison. If adjusted to the same point in time (February 1980) as that shown for LSCO, CSSC's total direct wage rate would be worth $0.6/hour, still only 7.2% of LSCO's. IHI's direct wage rate would be worth $9.32/hour, 13% greater than LSCO's.

There are four substantial differences for CSSC in the comparisons:

(i) CSSC pays the lowest basic wage rate; it is only several percent of other two countries.

(ii) CSSC has the longest working time and less overtime (because China has six-work days system per week and only seven national holidays annually).

(iii) CSSC pays the lowest overtime rates because of low wage system. In fact, many volunteer jobs are fulfilled by workers on overtime.

(iv) Overtime rate of CSSC has the highest effect on wage which is about 10% of basic average rate. IHI has the figure of 9% and LSCO shows only 3%.

(v) CSSC uses a bonus similar to IHI, but the amount is over

TABLE V - 9. Wages

ITEM	CCSI	IHI	LSCo
Base			
Basic Average Rate	$0.4/hour	$5.03/hour	$7.91/hour
Premiums			
Premium Rates	$0.02/hour	None	$0.30/hour (shift) $0.50/hour (dirty)
Effect on Average Rate	$0.02/hour	None	$0.12/hour
Overtime			
Overtime Rates	100% after 8 hours 100% on Sundays 200% on holidays	130% after 8 hours 160% after 10½ hours	150% after 8 hours 150% on Saturdays 200% on Sundays 200% on holidays
Average Hours/month	2.1 hours/month	15 hours/month	5 hours/month
Effect on Average Rate	$0.04/hour	$0.46/hour	$0.23/hour
Bonuses			
Average Bonus Rate	$89/year	$3,272/year	None
Average Aid Rate	$45/year		
Effect on Average Rate	$0.06/hour	$1.65/hour	None
Total			
Average/hour	$0.52	$7.11	$8.26
Average/day	$4.16	$57.12	$66.08
Average/week	$24.96	$285.60	$330.40
Average/month	$104.00	$1237.60	$1,431.73
Average/year	$1,248.00	$14851.20	$17180.80

Source: CSSC - Estimated
IHI - Marad
LSCO - Marad

15% of basic wage, while IHI bonus is almost one-third of the basic wages. But the use of a bonus system also shows that CSSC also uses an incentive system to encourage the employee to work better and to do more productivity improvements.

Benefits and Welfare

CSSC does its best to take care of the employee and his families in both benefits and in welfare. This leads to the good relationship between the yard and employee. The ultimate result will be higher worker morale, which causes higher productivity.

Table V - 8 presents the principle benefits at each shipyard, in summary form.

Surely CSSC has the most benefits. As a rough approximation, the cost of benefits andwelfare of CSSC listed in Table V - 10, amount to about $0.50 to $0.60 per hour which is 125% to 150% of direct basic wage rate. IHI's cost $3.0 to $3.5 per hour more which is 60% to 70% of direct basic wage rate and LSCO's cost is roughly $2.0 to $2.5, which is 25% to 32% of direct basic wage rate.

Table V - 11 presents the principles of the welfare program at each yard. The same comparative conclusions may be reached for welfare as was reached for the benefit program. All these make for stability, security and well-being of the workforce, and hence lead to higher productivity.

Labor Relations

The basic organizational structure of Chinese Workers' Union in CSSC's shipyard is shown in Figure V - 12, and Table V - 13 presents some of the principal characteristics of the labor management relationship in each yard. One of them is that the Union, includes the most of persons in shipyard (including administrators) and represents more than 95% of the personnel.

TABLE V-10. Benefit

ITEM	CCSI	IHI	LSCo
Vacation	10% 14 to 30 days /year	14 to 20 days	5 to 20 days
Holidays	17 days	18 days	12 days
Marriage Allowance	pay as normal 10 days' leave	¥35,000 5 days' leave	1 day's leave
Birth Allowance	pay as normal 2 months' leave	¥ 5,000 5 days' leave	Nothing
Death in Family	pay as normal 3 days leave	¥30,000 7 days leave	1 days leave
Travel Expenses	Commuter ticket, day and night allowance	Commuter ticket, or milage allowance	Nothing
Mid-day Meal	At cost of materials	At cost of materials	Nothing
Longevity Pay	Complex system based on employee's age	Complex system based on employee's age	$0.5/hour extra after 18 months
Longevity Awards	Nothing	Every 5 years starting at 20 years' service	Every 5 years starting at 10 years' service
Safety Awards	Period lottery if safety goal reached	Nothing	Monthly lottery if safety goal reached
Saftely Equipment	Provided	Provided	Provided
Working Environment	Adequate, but much less thorough	Close attention to safety, sanitation, aesthetics	Adequate, but much less thorough
Official Breaks	Time allowed for clean-up, etc	Two, 10-mins. each	Time allowed for clean-up, etc
Retirement	75% pay monthly	¥8,385,250 minimum (1978)	Pension plan

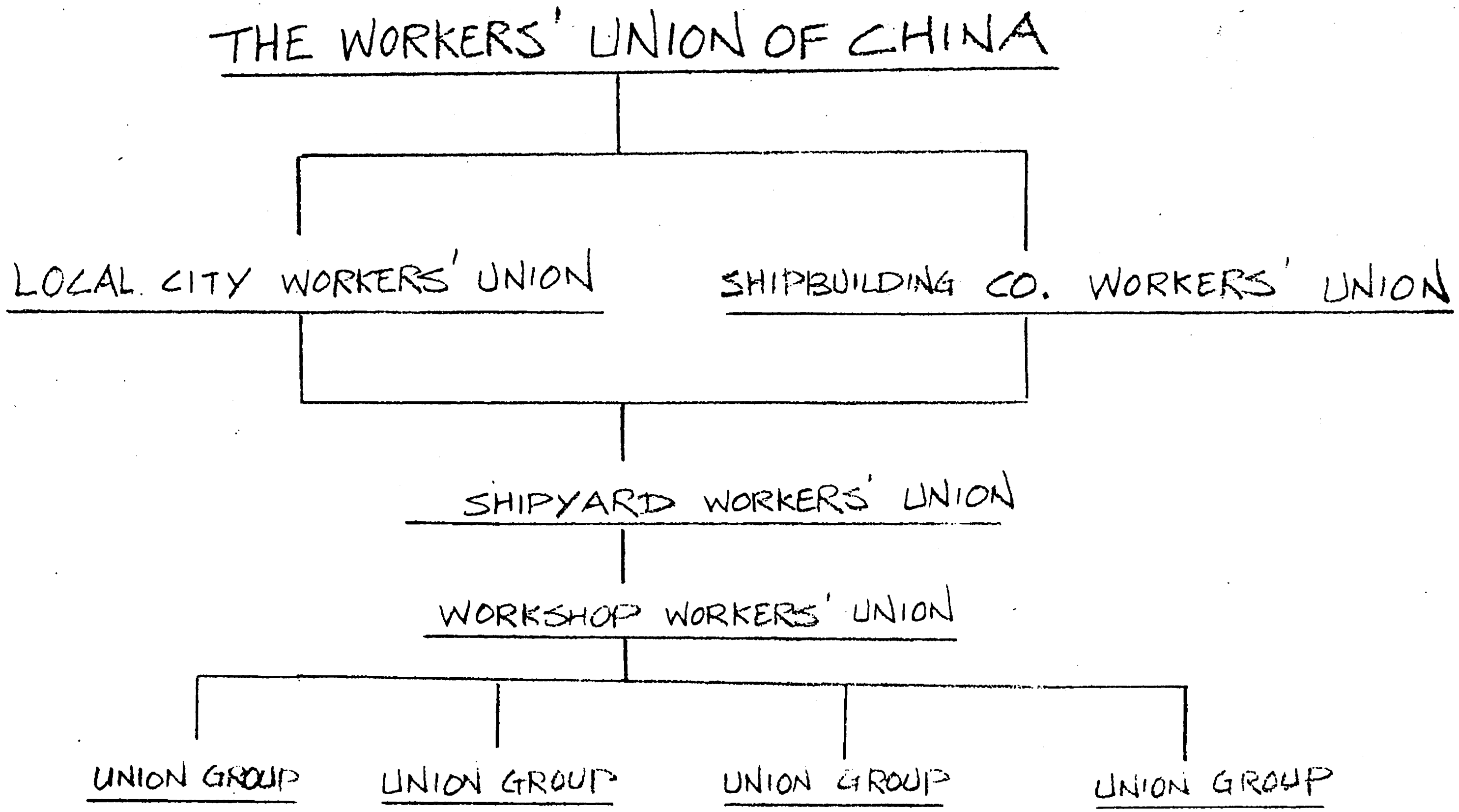
Source: CSSC - Confidential
IHI - Marad
LSCO - Marad

TABLE V-11. Welfare

ITEM	CCSI	IHI	LSCo
Housing	Provided for rent, about 5~10% of wage for rent charge	Provided for short-term. if needed: low-interest loans for house purchase	Nothing
Death of Employee	two months wages for treatment 6~12 months wages for relatives	¥ 200,000	$2,000 life insurance
Unemployment	Not happened	¥ 40,000 /month	Federal insurance
Scholarships for Children of Deceased & Unemployed	15~20 yuan for living and free education/month (under 18)	¥15,000/month (over 18) ¥10,000/month (under 18)	Nothing
Health Insurance	Full free service for employee Half free service for family	Insurance coverage	Insurance coverage
Medical Assistance	Full doctor service at shipyard as well as at connected hospitals	Full doctor and dentist service at shipyard	First aid only
Storm Damage to Home	Aid	Paid for	Nothing
Retail Sales	Shipyard co-op	Company co-op	Tools, working clothes company products only
Tuition Assistance	Paid	Paid	Paid
Recreation	Extensive facilities provided by shipyard: sport-field, pool, etc	Extensive facilities provided by company: stadiums, pools, etc	Nothing directly provided by company: employee-funded recreation association subsidized by company

Source: CSSC - Confidential
IHI & LSCO - Marad

Figure V-12. The Organization System of the Workers' Union of China



Source: Confidential

TABLE V-13. Labor Relations

Item	CSSC	IHI	LSCo
Number of Unions	One	One	Eight
Representation Membership	95 to 100%	92%	45 to 50%
Goals of Unions	Similar	1. Fair labor standard	Similar
	Similar	2. Prosperity of members	Similar
	Similar	3. Growth of the union	Similar
	Similar	4. Growth of union movement	Similar
	Similar	5. Strengthening of labor management relations	Similar
	Similar	6. Improvement of working conditions	Similar
	Similar	7. Stabilization of industry	Similar
	Similar	8. Strengthening of labor union movement	Similar
	Similar	9. International cooperation	—
	11 Belongs to Chinese Workers Union	10. Support for Democratic Socialist Party	—
	11 Fair members life and entertainment	—	—
	12 Fair members family	—	—
	13. Supervision to management	—	—
Negotiations	Daily communication Annual congress to supervise shipyard policy	Three times a year	Once every three years
Regular Meetings with Management with IR personnel	Monthly As required	Monthly As required	Monthly As required
Attitudes	Co-operative	Co-operative	Co-operative

Source: CSSC - Estimated; IHI, LSCO - Marad

This Union maintains daily communication and cooperation between labor and management. The Union in China never has the headache of a shipyard bankruptcy, while it often happens in both U.S. and Japan.

Generally, there are two tasks for Chinese Workers' Union:

(i) to improve the relationship between labor and management for reaching higher productivity.

(ii) to keep an eye on its members' benefits and welfare.

Training

The training procedures used in each shipyard are summarized in Table V - 14. One obvious conclusion is that IHI's personnel are the best trained, not only from the day they first enter the shipyard but also in terms of their whole working lives (for expanding their knowledge). CSSC's workforce are better-trained than LSCO's.

CSSC's shipyards have developed many ways for continuing employee education, such as evening school and TV-college. The shipyard encourages every one to study and pays all tuitions. The result of this effort is that the training level of CSSC's workforce is expected to catch up with IHI's in the near future.

Conclusions

From the above study, it is shown that CSSC has a reasonably good industrial relations. Perhaps the most important benefit for every Chinese employee is the life job warrant. This means that Chinese workers never worry about being unemployed.

It should be noted that CSSC is going to adopt new and better worker incentive methods, such as using a new wage system and a revised system of rewards and penalties to achieve better economic results in production.

TABLE V-14. Training

PROGRAM	CCSI	IHI	LSCo
Apprentices (entering from school)	3 years on-the-job. part-time at shipyard Training school	Fitters: 3 years at training school. 1 year on-the-job Welders: 1 year at training school. 3 years on-the-job	2 years on-the-job part-time at local technical school. part-time at Shipyard training school
Technical High School Graduates	Several months practice	4 months general training course	No training
University Graduates	1 year practice	3 months general training course	No training
Unskilled Workers	No training	1 month general training course	No training
Inspectors and QC Engineers	Rotation	1 year course	No training
Continuing Education	Continuous at all levels: extensive use of the spare-time school	Continuous at all levels: extensive use of local technical high school	No training
Supervisors	Rotation through shipyard workshops	Assistant foreman and foreman training programs	No formal training: part-time study encouraged
Staff and Management	Rotation through shipyard departments	Extensive internal and external programs - including transfers and overseas assignments	Rotation through shipyard departments

Source: CSSC - Estimated
IHI - Marad
LSCO Marad

There are two basic advantages in Chinese industrial management.

(i) Central planning management

(ii) Personnel democratic management

The first can save productive time and avoid the unnecessary repitition. The second can achieve better cooperation between management and labor, which will lead to higher productivity.

The major problem of CSSC is that the shipyard has too complicated an administrative organization and the organization must deal with too many things not connected with production. This sometimes results in confusion and duplication with what the social welfare organizations do.

The extremely low wage system in CSSC shows the great potential for competition in the international shipbuilding market.

The following suggestions may be useful for improving the industrial relations at CSSC.

(i) simplify administrative organization

(ii) increase number of engineers and professional staff

(iii)leave some social responsibility to social welfare organizations.

(iv) improve training of skilled managers and workers

(v) improve actual system of rewards and penalties

(vi) increase employee wages

VI SHIPBUILDING PRODUCTIVE CAPABILITY

Shipyard Layout

A CSSC's medium-sized shipyard layout is shown in Figure VI-1, while those of Levingston and Aioi are given in Figure VI-2 and Figure VI-3.

Comparing these illustrations one notices deficiencies at CSSC and at LSCO. The workshop layouts are not orderly, and consequently not directed toward efficient material processing. This results in substantial delays for craftsmen and material handling equipment and poor utilization of area for material storage and buffer storage.

Scheduling

Figure VI-4 and Figure VI-5 shows independently samples of construction schedules for China and for Japan.

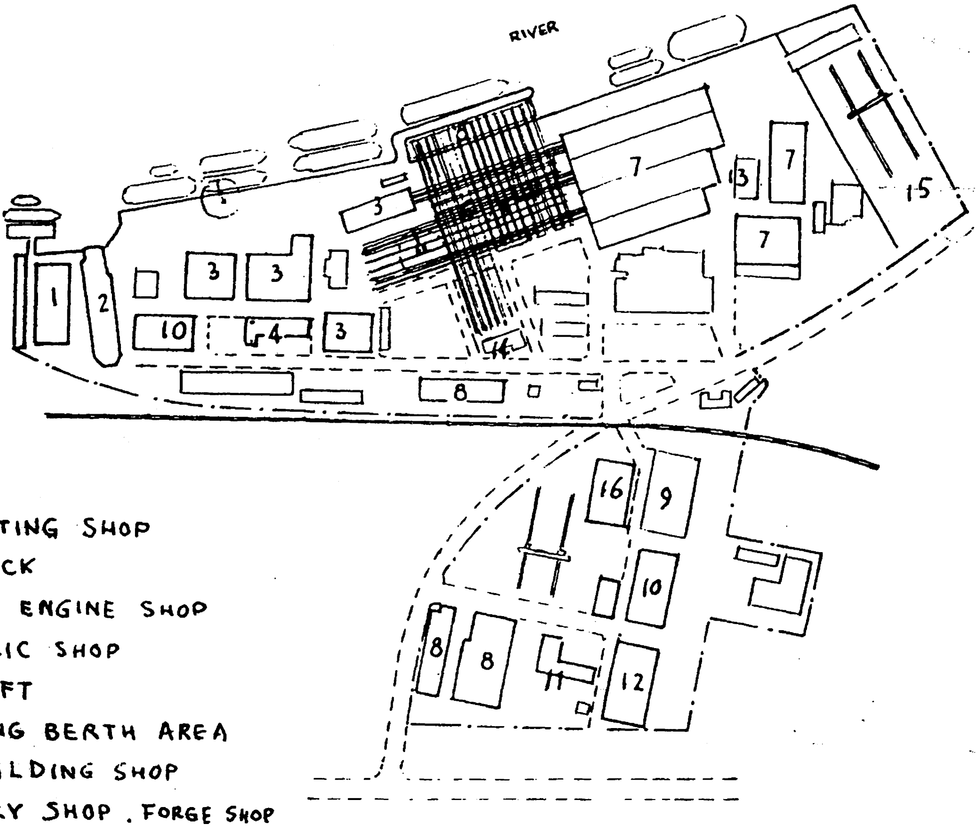
A typical Japanese Milestone Schedule for the construction of a new design non-standard bulk carrier is about 14 months, which is approximately one-half that of U.S. or China. The reasons for Japans shorter time schedule are believed to be:

(i) advanced management
(ii) high technologies
(iii) skilled workforce
(iv) parallel design, material procurement and production procedure (illustrated in Figure VI-6)

Facility Study

The main facilities of a CSSC's medium-sized shipyard are shown in Table VI-1.

It is difficult and no particularly meaning to make a simple comparisons of overall facilities among these three countries. Generally, CSSC's facility looks good, at least better than LSCO's.



1.	OUTFITTING SHOP	12	HYDRAULIC SHOP
2.	DRY DOCK	13.	OFFICE
3.	MARINE ENGINE SHOP	14.	HEAD OFFICE
4.	ELECTRIC SHOP	15	STEEL STOCK YARD
5.	SHIP LIFT	16	TECHNICAL OFFICE
6.	BUILDING BERTH AREA		
7.	SHIPBUILDING SHOP		
8	FOUNDRY SHOP . FORGE SHOP		
9	REPAIR SHOP		
10	MACHINE SHOP		
11	TRANSPORT & DOCKING SHOP		

		L x B (M)	Capacity (ton)
Dry Dock		80 x 12.2	1500
Ship lift		100 x 14.5	2000
wharf	south	150 x 12	
	north	195 x 7	
	ship lift	110 x 9	
crane, portal		25T x 3	
		12T x 1	
	Floating	60T x 1	
	Travelling	40T x 3	
		30T x 2	
		15T x 1	

Source: Confidential

Figure VI-1. A CSSC's Medium-sized Shipyard Layout

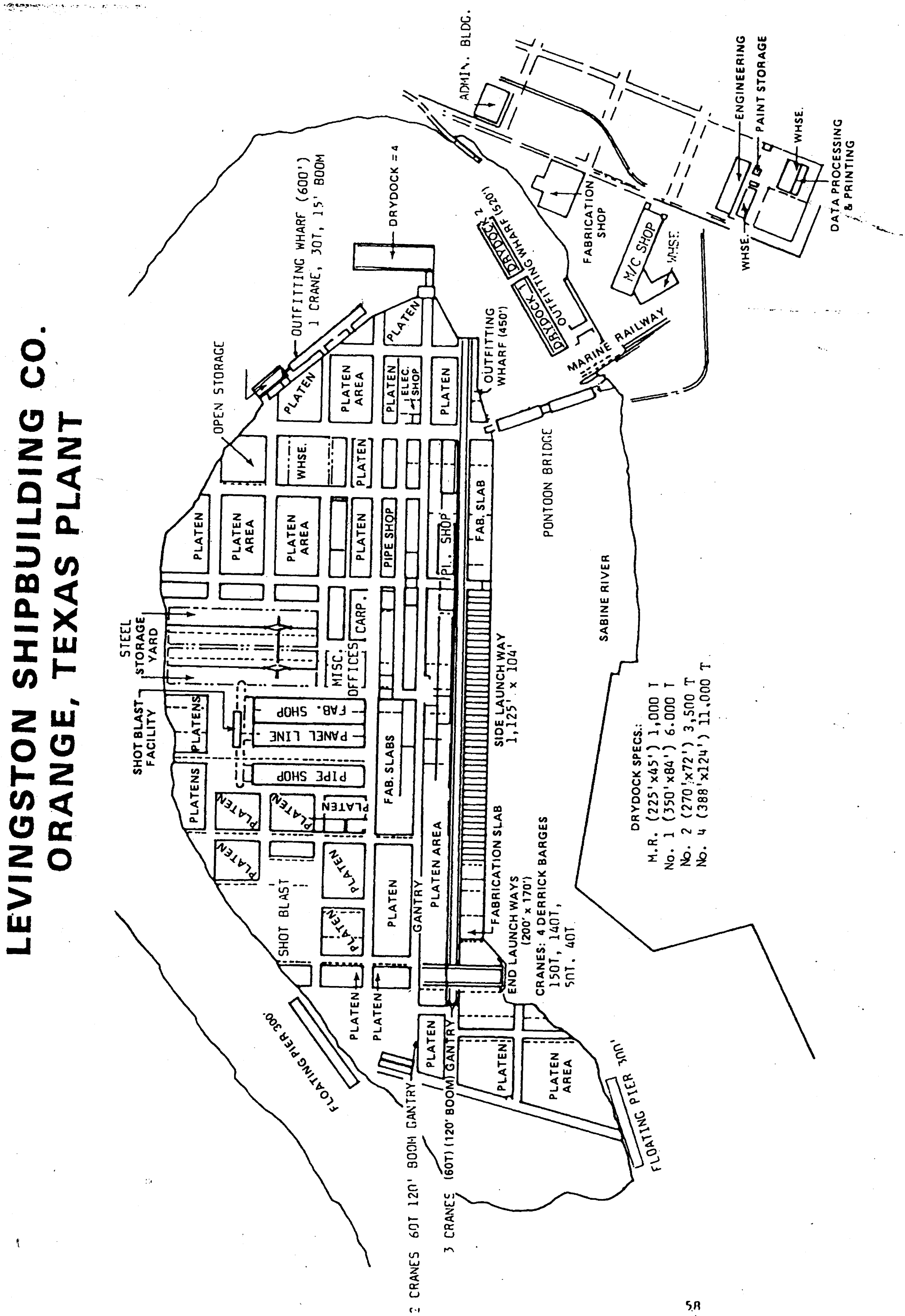


Figure VI-2. Levingston Shipbuilding Company
Orange, Texas Plant

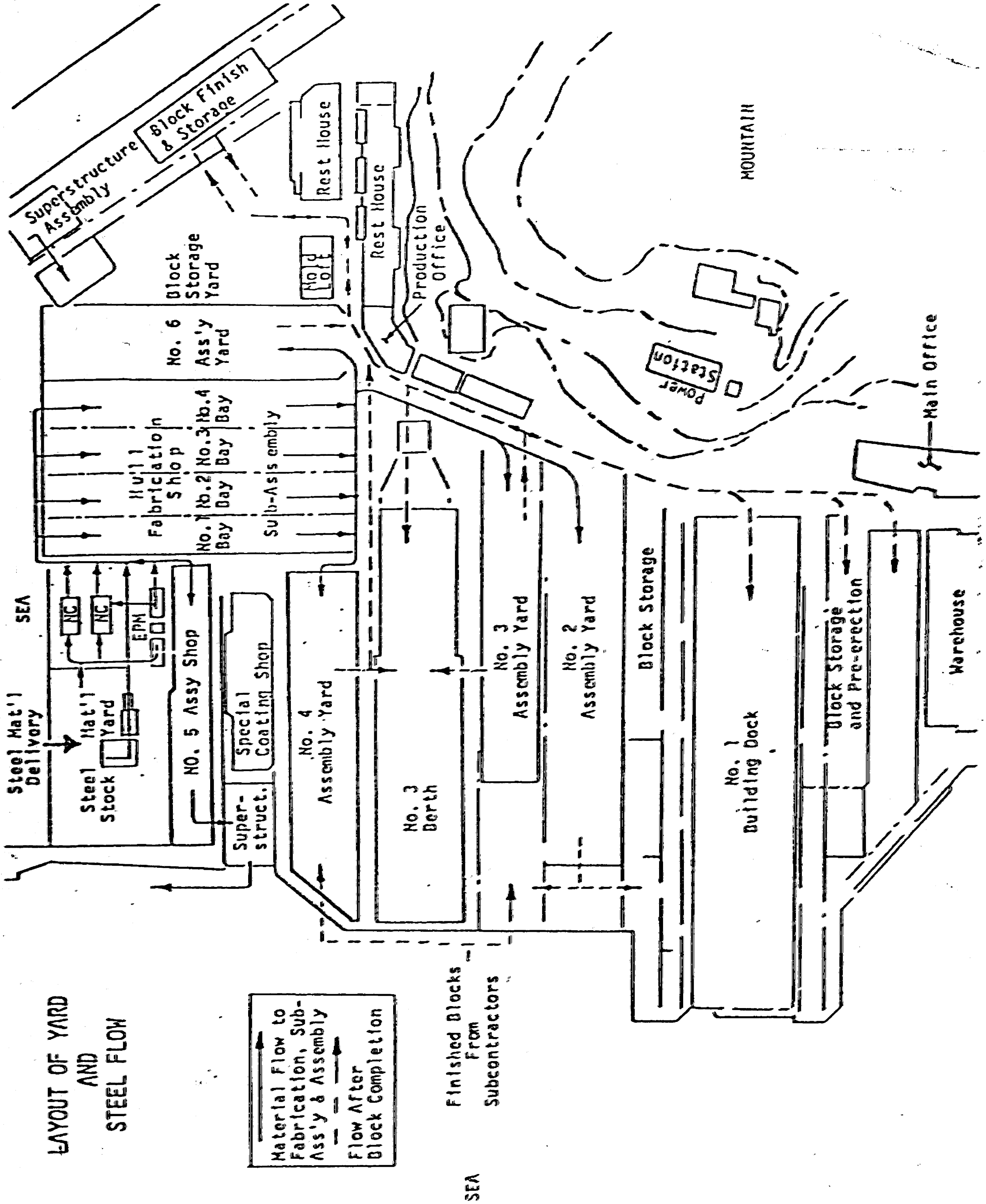


Figure VI-3. IHI AIOI Shipyard

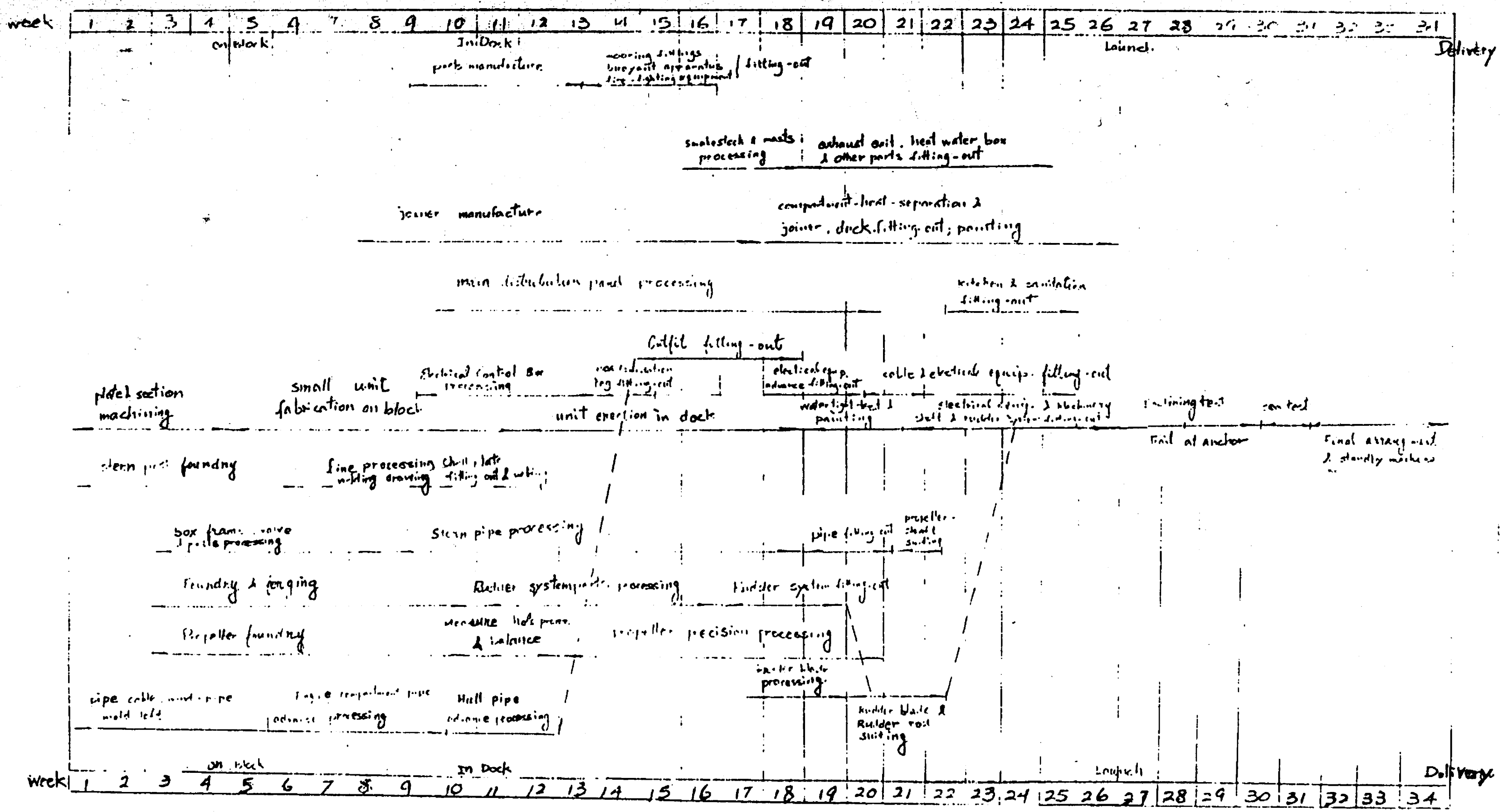


Figure VI-4. Chinese Milestone Schedule for Seagoing Salvage Tug (55m Length)

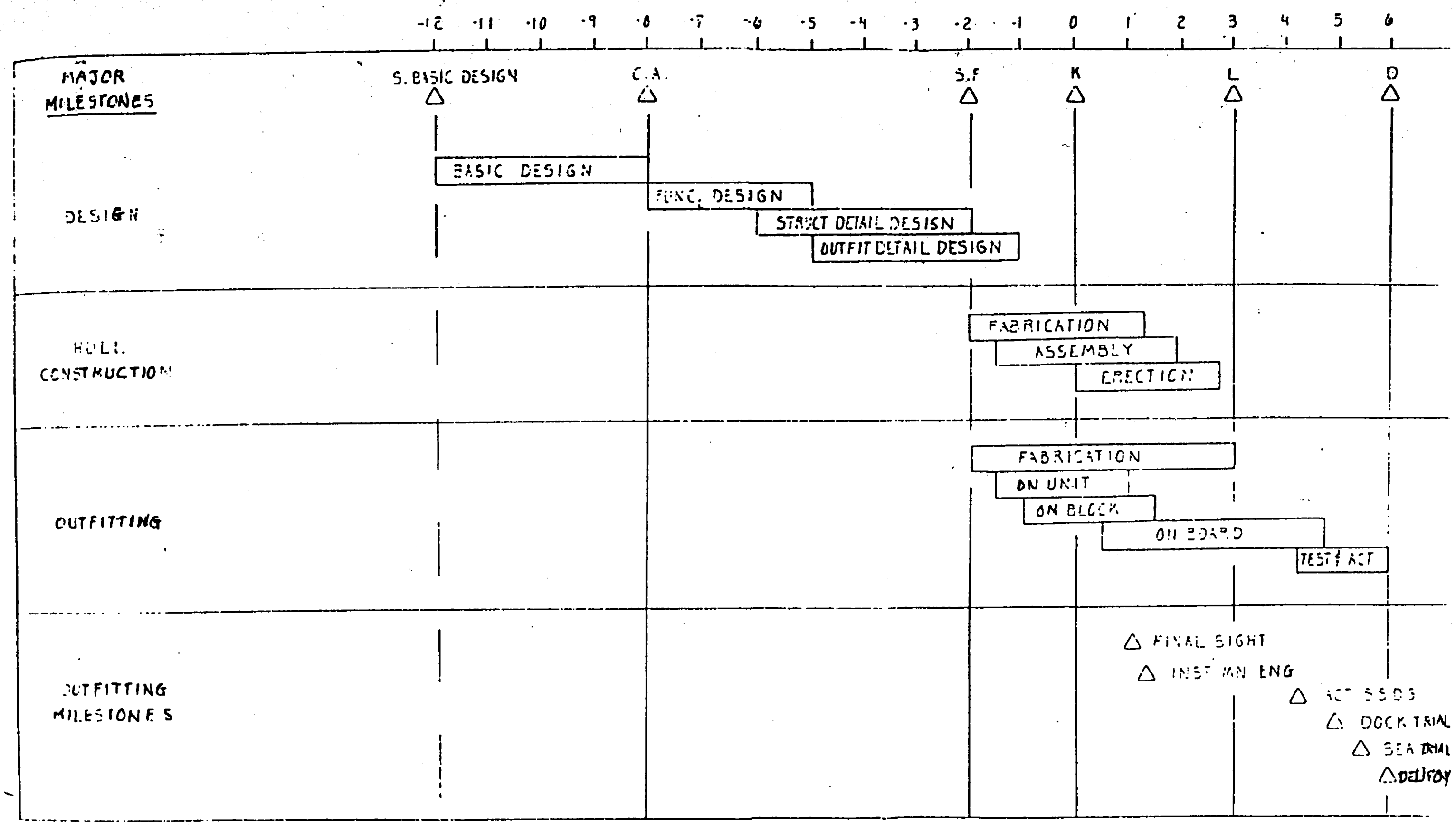
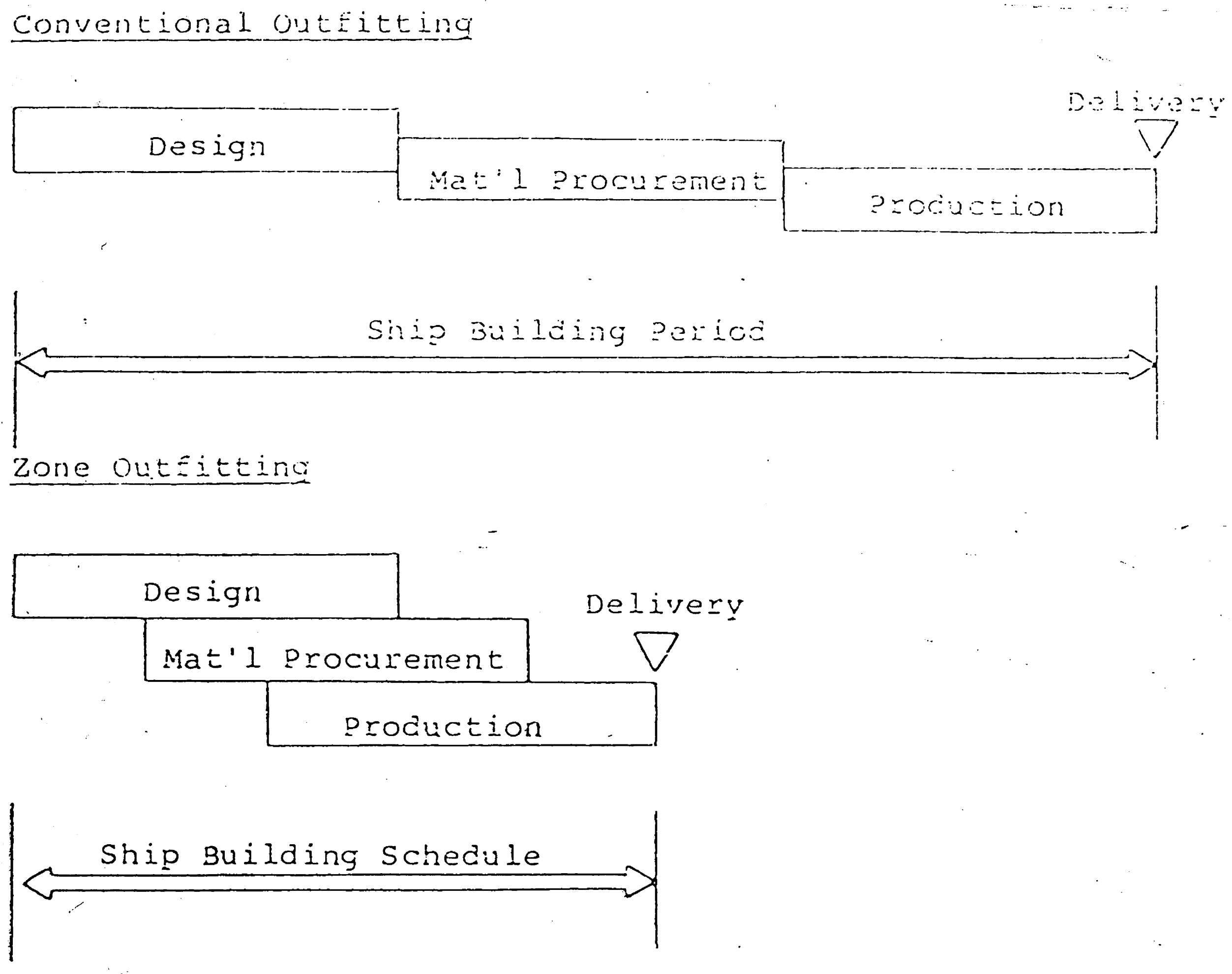


Figure VI-5 Typical Japanese Milestone Schedule For Commercial Construction

Note: (1) Typical with minor adjustments for a non-standard cargo, bulk, container or RC/RC ship.
(2) Based upon Ref (E) and notes on IHI



NOTE: Parallel design material procurement and production is more readily scheduled and controlled with a product oriented detailed design.

Figure IV-6 The Parallel Design Material Procurement And Production Procedure

TABLE VI-1. Facility Comparisons
A CSSC's Medium-Sized Shipyard Area Allocation
(ft^2)

Total Ground Area	1,617,000
Technical high school & its dormitory	107,800
Actual shipyard	1.509,200
Total Building Area	808.500
Including:	
i> Basic workshops	345,000
ii> Auxiliary workshops	140.100
iii> Other workshops	23.700
iv> Warehousing & Supplies	61,400
v> Test & Laboratory	1,100
vi> Offices	21,600
vii> Workers dormitory	53.900
viii> Education & Recreation	107,800
ix> Others	5.400

The Comparison of Shipyard Area Allocation (ft^2)

	CSSC	IHI	CSLo
Total Ground Area	1.617.000	6.832.965	5.235,200
Total Unilized Area	808.500	1,715,750	1.239,950
Total Covered Area	—	834.050	154,350

(Continued)

(Table IV-1 continued)

One CSSC's Medium-sized Yard's Facilities

<1>. Dry dock : 2 — 120m x 24M (5000 DWT capacity)

Wharf : 1 — 150m x 12m, 1 — 195m x 17m

1 — 110m x 9m

The efficiency of the dock : 92%

<2>. Main facilities of steel workshop.

Hydraulic press: 1 — 75 tons, 1 — 200 tons

1 — 300 tons, 1 — 350 tons

Gate shears : 1 — 2.5 M

Combined punch & shear : 1 — 4M, 2 — 3M.

Beveling machine : 1 — 16M

Cold-frame bender : 80 tons

Numerical-control flame cutting machine : 1

12-burners cutting machine : 1

Autogencus cutting plate : 4 — 2.5M x 12M

Numerical control drawing machine : 1 — 1.8M x 2M

Bending machine, etc.

<3>. Other workshops:

Various kinds of machine : about 280

<4>. Shipyard:

Self-service tugboats : 1 — 300 HPS, 1 — 600 HPS

1 — 1000 HPS

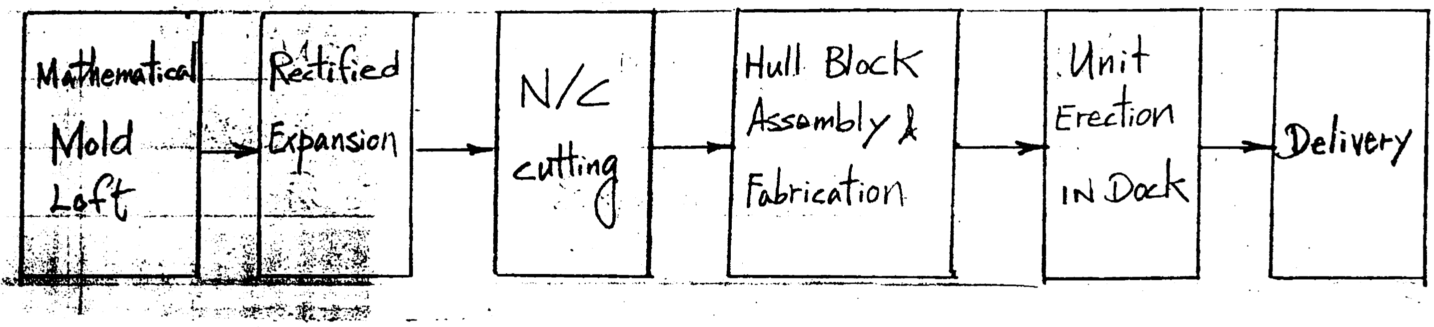
Source: CSSC - Confidential
IHI - Marad
LSCO - Marad

But IHI's facilities are designed for an assembly line operation in order to maximize throughput of any given machine or piece of equipment.

The management questions for CSSC are how to perform long-term facility planning and to emplace equipment more efficiently.

Chinese Shipbuilding Technology

The procedure of shipbuilding technology in CSSC is as follows:



Welding

The types of welding method employed in CSSC are manual, automatic, semi-automatic angle-welding, and CO_2 gas shield arc welding. The processes includes one-side welding. Those techniques are not significantly different from those used at LSCO and IHI. The only difference perhaps is that there is a greater proportion of manual welding at CSSC.

The "block-sandblast-rust-preventing" method is utilized at CSSC too.

Piping

CSSC has the pipe - cable comprehensive mold loft. This results in more efficient productivity, and saves cost and time. The main machines which process pipes are hydraulic pipe benders.

The Characteristic of Shipbuilding Technology in CSSC

Figure VI-7 gives the view of the fitting-out order of a 45 m length tugboart built in a CSSC's medium-sized shipyard.

CSSC also widely applies preoutfitting of hull blocks. The ships will be launched after fitting-out of main engine, auxiliary machinery and piping. It's shipbuilding technology is not so efficient as IHI, but much better than U.S.

Computer Aided Design (CAD)

Computers can have a significant effect on both production and management in shipyards. The results of saving are great in both cost and time.

In China, the shipyards started to try computer application in 1970's. They have had some success in a few areas (such as designs from mold loft to N/C cutting processing, financial accounting, etc). They have to do much to reach the level of general application of computers found in U.S.A. and in Japan. The comfort is that most managers have recognized its importance and are doing their best to develop CADKAM Systems.

In the U.S. the shipyards have tended to develop CAD. They have reached the level of the general purpose computer programs. What the U.S. shipyards must do is to develop the data bases to accommodate their specific needs.

In Japan, computer aid is used in all area of design, production and management. It has reached high levels. Specific use of computers is done in material control and outfit scheduling procurement and palletizing of material, piping design and production system and use of standards for dimension control. According to IHI practice, return on investMent is great. For example, an advanced interactive computer aided design system using a data base concept developed by IHI can

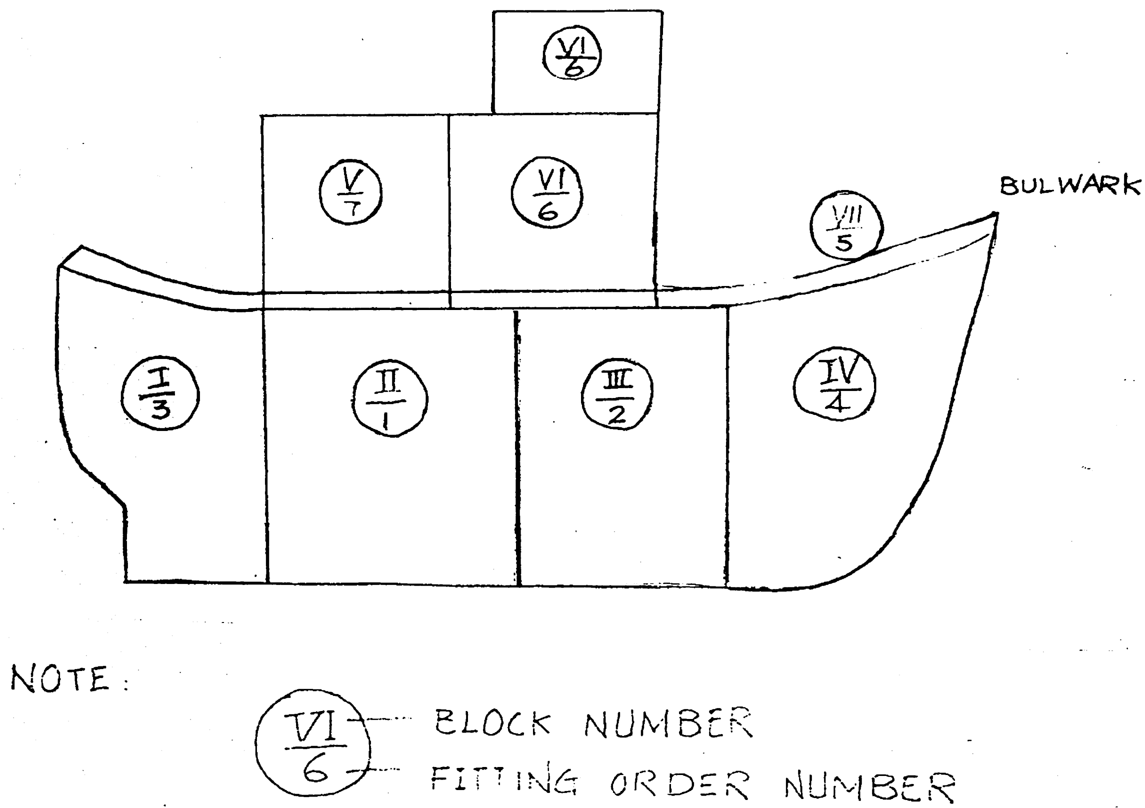


Figure V-7 The Fitting-out Order of 45 M Length Tugboat in A CSSC's Medium-Sized Shipyard result in 30% savings in design cost and time.

Other

In Japan, shipyards have widely developed the use of shipbuilding standards and dimensional control. The use of standards is a key element in significantly reduced design and production costs and schedules. The dimensional control system is considered key in their low assembly and erection costs and time as fit up is excellent and rework is minimal.

Chinese shipyards have started to pay more attention about these two advanced technologies and are now expanding their application.

The U.S. shipyards have had limited development of both shipbuilding standards and dimensional control. U.S. yards have also initiated expended programs to implement more standards.

Conclusions

The productivity of Japanese shipyards are consistently high. For example, production figures peaked at 12,000 tons per month with a total employment of about 4,000 during the shipbuilding boom at Aioi yard. This means about 30 tons/man per month productivity meanshile a modern chinese shipyard has some 5 tons/man per month productivity. It is noted that Aioi figures do not include employment and production from the large group of subcontractors which are also heavily involved with the IHI yards.

Chinese shipyards have a large quantity of facilities. These dates indicate that recently Chinese shipyards have made significant capital investment in the development of facilities. China has the great potential in the international shipbuilding industry. The problem right now is that Chinese shipbuilding technology is not advanced in techniques such as scheduling, organization of work, preoutfit approach, shipbuilding standards dimensional control, quality control and computer aid. Now they start to catch up with other advanced countries. Some implementation has already occurred. There have been changes in the operating system. China will be a very strong challenger before the end of this century, according to some authorities.

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Appendix A

35,000 DWT Bulk Carrier Built in China in 1980
(Source: Confidential from Zhengiang Shipbuilding Institute in China)

I. Light ship weight

<1> Hull steel

$$W_S = K_1 \cdot DW^{0.81}$$

where: $K_1 = 1.5$ for bulk carrier

$$\therefore W_S = 1.5 \times 35560^{0.81}$$
$$= 7284 \text{ (M.T.)} = 7169 \text{ (L.T.)}$$

<2> Outfit

$$W_o = K_2 \cdot DW^{0.58}$$

where: $K_2 = 4.7$ for bulk carrier

$$W_o = 4.7 \times 35560^{0.58}$$
$$= 2050 \text{ (M.T.)} = 2018 \text{ (L.T.)}$$

<3> Machinery

RPM = 115

$$W_M = 9.38 \left(\frac{BHP}{RPM}\right)^{0.84} + 0.68 \, (BHP)^{0.7}$$
$$= 9.38 \times \left(\frac{14703}{115}\right)^{0.84} + 0.68 \times (14703)^{0.7}$$
$$= 1114 \text{ (M.T)} = 1097 \text{ (L.T.)}$$

<4> Light ship weight

i> Net light ship weight

$$W_{NL} = W_S + W_o + W_M = 7169 + 2018 + 1097$$
$$= 10,284 \text{ (L.T.)}$$

ii> Total weight margin: 5%

$$W_{LT} = 1.05\, W_{NL} = 1.05 \times 10284$$
$$= 10,798 \text{ (L.T.)}$$

Direct Labor (Manhours)

<1> steel :

$$MH_S = \frac{280\ W_{si}^{2/3}\ L^{1/3}}{C_B}$$

$$= \frac{280 \times 8595^{2/3} \times 176.78^{1/3}}{0.829}$$

$= 795,397$ (MHS) ≈ 795400 (MHS)

<2> Outfit

$MH_o = 130\ W_o$

$= 130 \times 2050$

$= 266,500$ (MHS)

<3> Machinery

about 25% of total manhours

795 400	55%
266, 500	20%
MH_M	25%

from the relationship between MH_S and MH_M

$$MH_{M1} = \frac{795400 \times .25}{.55} = 361500 \text{ (MHS)}$$

from the relationship between MH_o and MH_M:

$$MH_{M2} = \frac{266500 \times .25}{.20} = 333100 \text{ (MHS)}$$

$$\therefore MH_M = \frac{MH_{M1} + MH_{M2}}{2} = \frac{361500 + 333100}{2}$$

$= 347300$ (MHS)

47. Total direct labor:

$$MH_T = MH_S + MH_O + MH_M$$

$$= 795{,}400 + 266{,}500 + 347{,}300$$

$$= 1{,}409{,}200 \text{ (MHS)}$$

1. Building Costs of Steel, Outfit, Machinery and Electrical

<1>. steel:

$$W_{si} = 1.18\,W_s = 1.18 \times 7284 = 8595 \text{ (M.T.)}$$

$$C_s = 1100\,W_{si} = 1100 \times 8595 = 9454500 \text{ (yuans)} = \$\,6228 \times 10^3$$

<2>. Outfit

$$C_o = 1500\,W_o = 1500 \times 2050 = 3075 \times 10^3 \text{ (yuans)} = \$\,2025.6 \times 10^3$$

<3>. Machinery

$$C_M = 37.6 \times 700 \cdot \left(\frac{V}{15}\right)^3 \cdot DW^{0.57} = 37.6 \times 700 \times \left(\frac{15}{15}\right)^3 \times 35560^{0.57} = 10{,}335{,}562 \text{ (yuans)} = \$\,6808.2 \times 10^3$$

<4>. Electrical systems

$$C_E = 175 \cdot \exp\left(-\frac{2800}{DW}\right) \cdot 10^3 = 175 \times 2.718^{\left(-\frac{2800}{35560}\right)} \times 10^3 = 162{,}000 \text{ (yuans)} = \$\,94 \times 10^3$$

<5>. Others

about 8% of total building costs

$$C_{OTHER} = 0.08\,C_{ship}$$

I. Shipbuilding Material Costs

<1> Hull steel

Margin coefficient of hull weight = 1.15 ~ 1.22

let us choose 1.18.

$W_{si} = 1.18\, W_s = 1.18 \times 7284$

$= 8595$ (M.T.)

$= 8460$ (L.T.)

i> Hull material

$C_{HMS} = 700\, W_{si} = 700 \times 8595$

$= 6016.5 \times 10^3$ (yuans)

$\approx \$3963 \times 10^3$

ii> Welding rods & solders

$C_{ds} = W_{si} R_2 r_2$

$= 1.8 \times 31 \times 8595$

$= 479601$ (yuans)

$\approx \$316 \times 10^3$

iii> Oxyacetylene

$C_{gs} = 31\, W_{si} = 31 \times 8595$

$= 266445$ (yuans)

$\approx \$175.5 \times 10^3$

iv> Total

$C_{SM} = C_{HMS} + C_{ds} + C_{gs}$

$= \$3963 \times 10^3 + \$316 \times 10^3 + \$175.5 \times 10^3$

$= \$4454.5 \times 10^3$

$$C^{*}_{SM} = C_S - C_{SL} - C_{SO}$$
$$= \$6228 \times 10^3 - \$524 \times 10^3 - \$524 \times 10^3$$
$$= \$5180 \times 10^3$$

2> Outfits

$$C_{OM} = C_O - C_{OL} - C_{OO}$$
$$= \$2025.6 \times 10^3 - \$175.5 \times 10^3 - \$175.5 \times 10^3$$
$$= \$1674.6 \times 10^3$$

3> Machinery

$$C_{MM} = C_M - C_{ML} - C_{MO}$$
$$= \$6808 \times 10^3 - \$229 \times 10^3 - \$229 \times 10^3$$
$$= \$6350 \times 10^3$$

4> Total material costs:

$$C_M = C^{*}_{SM} + C_{OM} + C_{MM} + C_E$$
$$= \$5180 \times 10^3 + \$1675 \times 10^3 + \$6350 \times 10^3 + \$94 \times 10^3$$
$$= \$13{,}205 \times 10^3$$

Ship Price Correction after considering indirect cost in China

Labor costs and overhead:

1> worker's actual wage:

0.5 ~ 0.6 yuan / MH in 1978 - 1980

we choose 0.6 yuan / MH

about \$0.356/MH in 1978

or \$0.395/MH in 1980

∴ in 1980: *

wage: \$0.4/MH

2> workshop overhead:

200 ~ 300% of direct labor costs

shipyard administration

100 ~ 150% of direct labor costs

shipyard profit factor:

0.06 ~ 0.10, average: 0.06

tax rate:

5%

3> <u>Re-estimate:</u>

Labor cost: 1,409,200 MHS x \$0.4/MHS = \$563,680

$\approx \$564 \times 10^3$

Workshop overhead:

$3 \times \$564 \times 10^3 = \$1692 \times 10^3$

Shipyard administration

$1.5 \times \$564 \times 10^3 = \$846 \times 10^3$

Shipyard profit at 8%

$0.08(\$564 \times 10^3 + \$1692 \times 10^3 + \$846 \times 10^3$

$+ \$13205 \times 10^3 + \$94) = \$1312 \times 10^3$

Sale price.

$$SE = [\$564\times10^3\times(1+3+1.5)+\$13205\times10^2+\$94\times10^3]\times(1+0.08)/(1-0.05)$$

$$=\$18,645\times10^3$$

Appendix B

35,000 DWT Bulk Carrier Built in the U.S. in 1980

Note: The following estimate is based on H. Benford's and R. M. Scher's formulas [1] in 1980 except specifical notification.

1. Light ship weight

<1> Hull steel [9]

$$W_s = C_s \left(\frac{CN}{1000}\right)^{0.9} C_1 C_2 C_3$$

where: $C_s = 340 \sim 360$ (choose 340)

$$C_1 = 0.675 + \frac{C_B}{2} = 0.675 + \frac{0.829}{2} = 1.0895$$

$$C_2 = 1 + 0.36 \times \frac{0.1L}{L} = 1.036$$

$$C_3 = 0.006\left(\frac{L}{D} - 8.3\right)^{1.8} + 0.939$$

$$= 0.006 \times \left(\frac{580}{48} - 8.3\right)^{1.8} + 0.939$$

$$= 1.005$$

$$\therefore W_s = 340 \times \left(\frac{25056}{1000}\right)^{0.9} \times 1.0895 \times 1.036 \times 1.005$$

$$= 7003 \text{ (L.T.)}$$

<2> Outfit

$$W_o = 0.0290\,LB - 1.59 \times 10^{-5} L^2 B$$

$$= 0.0290 \times 580 \times 90 - 1.59 \times 10^{-5} \times 580^2 \times 90$$

$$= 1032 \text{ (L.T.)}$$

<3> Machinery

RPM = 115

$$f = 1.299\,(\log_{10} \text{RPM})^{-.44}, \quad f \le 1$$

$$= 1.299\,(\log_{10} 115)^{-.44}$$

$$= 0.945$$

$$W_M = 0.124\,(BHP)^f\,(RPM)^{-0.167} + 0.555\,BHP^{0.7}$$
$$= 0.124 \times (14500)^{0.945} \times (115)^{-0.167} + 0.555 \times (14500)^{0.7}$$
$$= 935 \quad (L.T)$$

4). Light ship weight

i). Net light ship weight :

$$W_{NL} = W_S + W_O + W_M$$
$$= 7003 + 1032 + 935$$
$$= 8970 \quad (L.T.)$$

ii). Total weight margin = 3% [ ]

$$W_{LT} = 1.03\,W_{NL}$$
$$= 1.03 \times 8970$$
$$= 9239 \quad (L.T.)$$

II. Shipbuilding Material Costs

<1>. Steel

$W_{si} = W_s(1.167 - 0.117\,C_B)$

$= 7003 \times (1.167 - 0.117 \times 0.829)$

$= 7493$ (L.T.)

$C_{SM} = \$460 \times 7493$

$= \$3447 \times 10^3$

<2>. Outfit

$C_{OM} = \$4350\, W_o = \$4350 \times 1032$

$= \$4489 \times 10^3$

<3>. Machinery

$C_{MM} = \$8{,}090\,(BHP)^{.7} + \$450{,}000$

$= \$8{,}090 \times (14500)^{.7} + \$450{,}000$

$= \$7.071 \times 10^3$

<4>. Total Material Costs

$C_M = C_{SM} + C_{OM} + C_{MM}$

$= \$3447 \times 10^3 + \$4489 \times 10^3 + \$7071 \times 10^3$

$= \$15{,}007 \times 10^3$

III. Direct Labor (Manhours)

<1>. Steel

$$MH_S = 157 \cdot W_{si}^{.9} = 157 \times 7493^{.9}$$

$$= 482{,}048 \text{ (MHS)}$$

<2>. Outfit

$$MH_o = 270 \cdot W_o = 270 \times 1032$$

$$= 278{,}640 \text{ (MHS)}$$

<3>. Machinery

$$MH_M = 24000 \left(\frac{BHP}{1000}\right)^{.6} = 24000 \times \left(\frac{14500}{1000}\right)^{.6}$$

$$= 119{,}408 \text{ (MHS)}$$

<4>. Total Direct Labor

$$MH_T = MH_S + MH_o + MH_M$$

$$= 482048 + 278640 + 119408$$

$$= 880{,}096 \text{ (MHS)}$$

IV. Direct Labor Costs and Overhead

<1> Steel

$$C_{MHS} = \$10 \times 482048$$
$$= \$4820.5 \times 10^3$$

$$C_{SO} = \$4820.5 \times 10^3$$

<2> Outfit

$$C_{MHO} = \$10 \times 278640$$
$$= \$2786.4 \times 10^3$$
$$C_{OO} = \$2786.4 \times 10^3$$

<3> Machinery

$$C_{MHM} = \$10 \times 119.408$$
$$= \$1194.1 \times 10^3$$
$$C_{MO} = \$1194.1 \times 10^3$$

<4> Total direct labor costs:

$$C_{MHT} = \$10 \times 880096 = \$8801 \times 10^3$$

<5> Total overhead

$$C_{OVT} = \$8801 \times 10^3$$

V. Electronics & automatic logging

$$C_{EAL} = \$ 350 \times 10^3$$

VI. Total Price [2]

10% builder profit

3% owner organization cost

1% miscellaneous expense

$$C_{TP} = (C_M + C_{MHT} + C_{OVT} + C_{EAL}) \times 1.10 \times 1.03 \times 1.01$$

$$= (\$15007 \times 10^3 + \$8801 \times 10^3 + \$8801 \times 10^3 + \$350 \times 10^3)$$

$$= \times 1.1 \times 1.03 \times 1.01$$

$$= \$37,716 \times 10^3$$

$$\approx \$38 \times 10^6$$