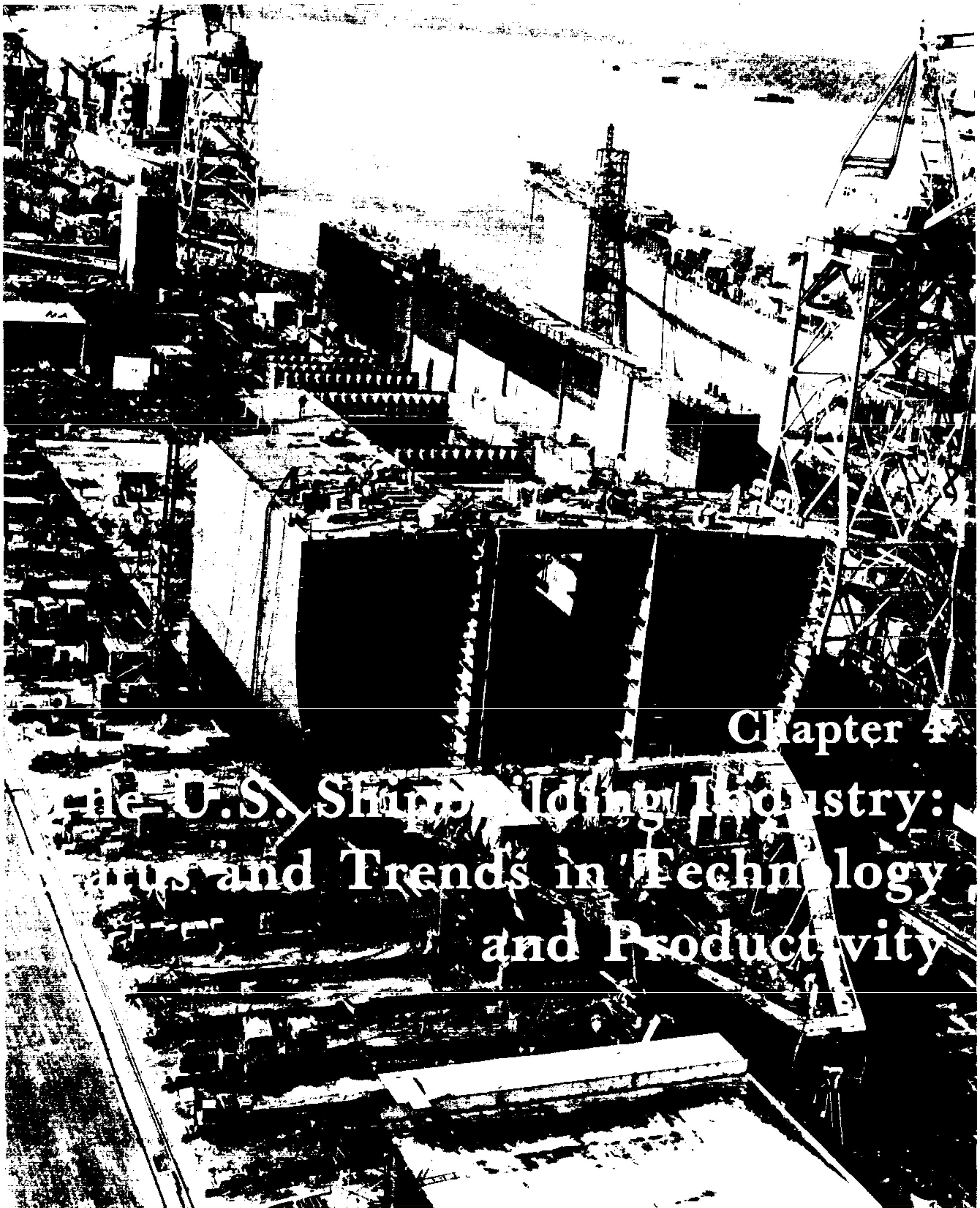


Photo credit: Avondale Shipyards, Inc.

Contents

Chapter 4

The U.S. Shipbuilding Industry: Status and Trends in Technology and Productivity

OVERVIEW

This chapter examines the productive capacity of U.S. shipbuilding. It traces the historic development of the industry and describes its present situation. It analyzes the status of technology employed and the level of competitiveness for construction of today's major merchant ships. Finally, it presents possible approaches to maintaining and improving the health of the industry,

Over the past two decades, the United States has only built major merchant ships when Federal subsidies were used to pay a large portion of the cost or when laws, such as the Merchant Marine Act of 1920 ('Jones Act), required that the ship be built in a U.S. yard. The United States has, therefore, been isolated from international competition for these types of vessels.

In many other major maritime countries, shipbuilding is viewed on a global perspective. This is not the same in the United States, where only 1 to 2 percent of the world merchant fleet is now built. The U.S. shipbuilding industry is basically quite different from that of Europe, Japan, and Korea. Those countries have built most of today's modern shipping fleets and compete for orders in a world market. The United States does not.

However, the United States does have a large and diversified shipbuilding industry. Its total employment (175,000 in 1982) is even larger than Japan's. The U.S. industry has some very productive and technologically innovative segments, including those who build barges, tugs, supply boats, and offshore drilling rigs. Moreover, U.S. shipyards are foremost in construction of large, complex, and sophisticated naval warships.

In commercial shipbuilding, the Japanese, and more recently the Koreans, have based their recent success on responsiveness to developments in the international shipping arena. They did this by:

- obtaining the best combination of inputs, including skilled but low-cost labor, a strong work ethic, advanced technological capabilities (universities, technical institutes, etc.), financial means, qualified management, and many new facilities;
- tenaciously pursuing the largest volume ship markets in recent decades, particularly liquid- and dry-bulk vessels. This has allowed them to ' 'go up the learning curve, making personnel and technical improvements, enabling them to build ships much more cheaply than their rivals. A key aspect of their improvement program has been standardization and integration of processes, to achieve efficiency; and
- integrating ownership of major yards with large industrial groups operating allied businesses such as steel, machinery, electrical machinery, and trading.

Part of the reason for Japan's success in shipbuilding is that a large base of demand has come from Japanese ship operators who purchase their ships from Japanese shipyards. Thus, the yards have had consistent, long-term contracts and have often been able to offer incremental prices to buyers from the rest of the world.

While there is no Japanese law that requires ship operators to build in Japan, a review of world ships on order in 1983 shows that all those under construction for Japanese owners are being built in Japanese yards.

Volume is the prime factor in a highly productive shipbuilding industry. Without large numbers of ships to build, it is not possible to hone the productive process to a sufficient degree to reduce costs.

'See "Fairplay Shipping Weekly—World Ships on Order, April 1983—Japan has under construction for Japanese owners 4,7 million deadweight tons (dwt), which is more than for any other flag except Liberia, and represents about 9 percent of world orders

This is why the Japanese and Korean strategies of concentrating on building large numbers of relatively simple bulk vessels were so important to their success.

Many other factors have played a role in the high productivity of Japanese and more recently Korean shipbuilding. These yards have developed their technology to an advanced degree, beyond that found elsewhere in the world. The investment-per-worker in Japanese and Korean yards surpasses that of almost all other nations, Their technology is broad-based, and they have adopted technologies that complement each other; i.e., they have purchased machinery and adopted production processes that are carefully interrelated to achieve a smooth and highly efficient work flow.

In comparison to many other major shipbuilding nations, the United States has not installed the level of modern shipbuilding technology necessary for high productivity in the construction of today's major merchant ships.

In contrast to the Japanese and Korean model, some major problems with U.S. shipbuilding technology have been:

- long delays in introducing new technologies;
- a reluctance to adopt foreign technology, and a reluctance to enter into-joint ventures, licensing, purchasing, or other arrangements for the speedy, effective transfer of technology;
- a minimal exchange of technology among U.S. shipyards; and
- minimal evaluation of technologies in other areas (aerospace, electronics, etc.) that have potential applications to shipbuilding.

It is noteworthy that the problem of low output of labor from U.S. yards cannot be traced in any part to worker skill. U.S. shipyard workers are as skilled as their Japanese or Korean counterparts. Rather, the problem is related to work organization and the production tools available. Briefly stated, U.S. yards have never had sufficient volume of merchant ship orders to specialize, to become truly expert, or to develop high efficiency. Flexibility to build many different varieties of ships and other marine equipment has been maintained in U.S. shipyards. Thus, the economies of mass production have seldom been adopted.

The U.S. shipbuilding industry is facing a severe decline in potential new buildings of major merchant ships, primarily caused by the elimination of Federal funds for construction subsidy programs. While the U.S. Navy has embarked on an expanded building progam, it will not require much additional shipyard capacity until the mid-1980's, and only the few yards that specialize in warships will benefit substantially. The trends in the industry are thus toward more U.S. Navy work, more concentration in fewer large firms, and hard times for those firms that have, in the past, depended on commercial shipbuilding subsidies. Although U.S. yards have made recent strides in improving productivity in the construction of merchant vessels, the primary focus of the industry is still on U.S. Navy work where high-technology, custom work is the rule.

Two different approaches to improving U.S. shipbuilding productivity appear possible. One would concentrate primarily on Federal support or assistance to the industry combined with incentives to enhance productivity. Several other maritime countries appear to be adopting such an approach.

Another approach would focus on developing other emerging markets for U.S. shipyards, assuming that there is little chance that the U.S. industry can reduce costs of conventional merchant ships below the level of the low-wage countries. The U.S. shipbuilding industry is geared to custom work and the integration of highly technical with conventional systems. Markets for such skills may develop in fields like Arctic- or deepwater-resource extraction. A challenge for industry and the Federal Government would be to cooperate to identify and develop the most promising markets.

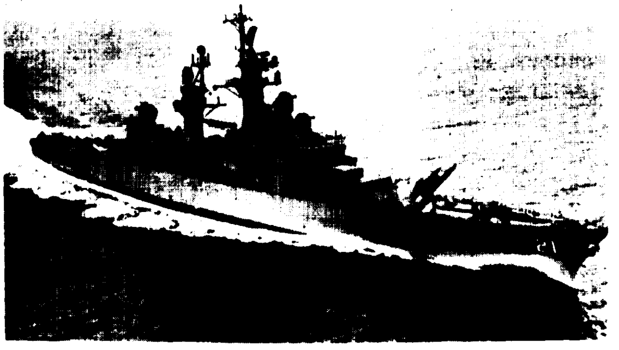


Photo credt: Lockheed Shlpbulldlng Co.

Construction of U.S. Navy warships such as the above is expected to dominate the U.S. shipyard orders over the next several years

CHARACTERISTICS OF THE SHIPBUILDING INDUSTRY

General

World shipbuilding is a cyclical industry with fluctuating demand. It has experienced over nine major cycles, each with more than a 40-percent reduction in demand, since 1896. Three of these cycles have occurred since World War II alone.

From 1930 to 1933, for example, there was a decline of 84 percent in shipbuilding output. Again, at the end of World War II, between 1944 and 1947 a decline of 85 percent was experienced because of the glut of ships built for the war. More recently, a worldwide decline of 60 percent occurred from 1975 to 1979. In addition, smaller fluctuations of 10 to 20 percent every 7 to 10 years have become quite common.

The shipbuilding industry is an assembly industry that is both capital- and labor-intensive. Large capital facilities are required, and major components usually are purchased from man y sources. The assembly process itself, using a mixture of large and small, and single and complex components, is very labor-intensive. As an assembly industry, shipbuilding has major and significant linkages to many other industries, such as iron and steel, machinery, electrical, and electronic manufacturing. Its assembly process can be expanded to include component, and even machinery, manufacture or contracted to include only ship assembly processes. As a result, integrated shipbuilders with close relations to linkage industries can often more effectively weather large cyclical fluctuations than shipbuilders who lack integration with their major supplier industries. The latter is the case with most U.S. shipbuilders.

Investment in shipbuilding equipment on a per-employee basis has mushroomed in recent years. Although many foreign shipbuilders have recently cut back and consolidated facilities, certain foreign shipbuilders are gearing up for a revival of the industry by the introduction of more automation, robotics, modern measurement and control techniques, computerized management methods, and facilities that provide for greater product flexibility. Because shipbuilding is considered an important economic and defense asset, and also because it affects many related or interrelated industries and employment, many governments support their shipbuilding industries directly or indirectly. Furthermore, governments in many countries now take an active part in the ownership of commercial shipyards (i. e., the United Kingdom, Sweden, Italy Spain, Portugal, Netherlands, Taiwan, Malaysia, India, Israel, and the Communist bloc nations). Other types of government shipbuilding support, include:[2]

- export credits ('Japan, Korea, Brazil);
- shipbuilding subsidies (United Kingdom, United States, Brazil);
- new orders financed by the government for expansion of the domestic fleet or investment ('Japan, Taiwan, Korea); and
- exemption of import and other duties (Spain, Korea, India).

These government interventions have made it increasingly difficult to compare shipbuilding productivity between various countries.

Definition of the U.S. Shipbuilding Industry

The majority of the approximately 500 U.S. shipbuilding and repair firms have fewer than 100 employees and correspondingly limited building and repair facilities. Over 200 of the U.S. shipbuilding or ship repair facilities are surveyed annually by the U.S. Maritime Administration (MarAd). Of these, 30 are "major" (i.e., have at least one large building berth) and 26 (as of March 1983) are considered to comprise the ''Active Shipbuilding Industrial Base" (ASIB).

The ASIB list changes (although only slightly in recent years) as yards open, close, or turn to other business. Criteria for inclusion in ASIB include not

[2]See "Maritime Subsidies" (Washington, D. C.: U.S. Department of Transportation, Maritime Administration, February 1983); and ' 'Financing and Subsidizing the Marine Industries" (Copenhagen, Denmark: MAN-B&W Diesel, November 1982).

only facilities but also active conduct or pursuit of shipbuilding work. ASIB yards must be ''engaged in seeking contracts for construction of naval ships or major oceangoing or Great Lakes merchant ships. *

Table 27 is the list, as of March 26, 1983, of the ASIB. Defense planners consider these ASIB yards to be the core of the Nation's shipbuilding capability and a principal measure of the United States' ability to respond to a national emergency. The U.S. Navy keeps a current tabulation of these yards and notes their capability of building major combatant, amphibious, auxiliary, and merchant ships. At present, 7 of the 26 yards are considered capable of U.S. Navy combatant construction. The U.S. Navy also periodically develops shipbuilding mobilization plans (one is under development in mid-1983) and surveys about 100 other shipyards to determine which could be considered as extensions of the ASIB in a national emergency.

* NlarAd definition, used consistently in publications concerning shipbuilding, e.g., "Relative Cost of Shipbuilding. "

Table 27.—U.S. Shipyards Comprising the Active Shipbuilding industrial Base (ASiB)

Alabama Dry Dook & Shipbuilding Co., Mobile, Aia
The American Ship Building Co., Lorain, Ohio
Avondale Shipyards, Inc., New Orleans, La.
Sath Iron Works Corp., Bath, Maine
Bay Shipbuilding Co., Sturgeon Bay, Wis.
Bethlehem Steel Corp., Sparrows Point Yard, Baltimore, Md.
General Dynamics/Electric Boat Division, Groton, Conn.
General Dynamics/Quincy Shipbuilding Division, Quincy, Mass.
Halter Marine, New Orleans, La
Ingalls Shipbuilding Division of Litton industries, Pascagoula, Miss.
Levingston Shipbuilding Co., Orange, Tex.
Lockheed Shipbuilding & Construction Co., Seattle, Wash.
Marinette Marine Corp., Marinette, Wis.
Maryland Shipbuilding & Drydock Co., Baltimore, Md.
National Steel & Shipbuihg Co., San Diego, Calif.
Newport News Shipbuilding, Newport News, Va.
Norfolk Shipbuilding & Drydock Corp., Norfolk, Va.
Pennsylvania Shipbuilding Co., Chester, Pa.
Peterson Builders, Inc., Sturgeon Bay, Wis.
Tacoma Boatbuilding Co., Inc., Tacoma, Wm.
Tampa Shipyards, Inc., Tampa, Fla. (subsidiary of American S. B., 00.)
Todd Shipyards Corp., Galveston, Tex.
Todd Shipyards Corp., Houston, Tex.
Todd Pacific Shipyards Corp., Los Angeles, Calif.
Todd Pacific Shipyards Corp., San Francisco, Calif.
Todd Pacific Shipyards Corp., Seattle, Wash.

SOURCE: Naval Sea Systems Command, March 19S3.

The 26 shipyards comprising the ASIB represent over one-half of the total U.S. shipyard employment and an even larger proportion of total value of work done. The so-called ' 'second-tier' shipyards also represent a viable U.S. industrial sector. These shipyards mainly build and repair barges, tugboats, towboats, supply boats, crewboats, and offshore drill rigs. The industry group, American Waterways Shipyard Conference, periodically surveys this sector of over 300 shipyards. In 1981, about 75 of these yards reported a total employment of 22,000 and gross revenues of almost $2 billion, 95 percent of which was from the private (nongovernment) sector.

The second-tier shipyards have been hit severely by the recent recession resulting in many yard closings and a significant reduction in the labor force (about 50 percent from 1981 to 1983). Even so, some of these U.S. yards still build for and compete in foreign markets.

The shipbuilding supplier base has never been compiled. The Shipbuilders Council of America (SCA) has distributed a questionnaire to its members, asking them to identify all subcontractors or firms supplying at least $300,000 worth of goods or services annually. The resultant tabulation of the supplier base will not be available until late 1983.[3]

The supplier base has a key role in the improvement of U.S. shipbuilding productivity. Shipyards, particularly in the building of sophisticated naval vessels, may funnel up to 60 percent of the total vessel cost to equipment suppliers and program support functions. For some suppliers, the yard is a key customer whose needs take priority; for others the yard is almost a nuisance customer in terms of volume and dollar value of order and technology required. Leadtimes may pose a scheduling constraint, and problems in supporting industries may govern ship delivery schedules.[4]

[3]Telephone conversation with Shipbuilders Council of America, March 1983.

[4]"Building a 600-Ship Navy: Costs, Timing, and Alternative Approaches" (Washington, D. C.: Congressional Budget Office, 1982), p. 37.

The Markets of the U.S. Shipbuilding Industry

The U.S. shipbuilding industry builds or has built for many markets, including U.S.-flag ship operators in both foreign and domestic offshore trades, the offshore oil industry, the U.S. inland water transport industry, fishing and tugboat operators, and the U.S. Government—Navy, Coast Guard, and other seagoing agencies.

The recent cessation of construction subsidies has probably ended the prospect of orders from U. S.-flag ship operators active in the foreign trades, while the so-called ''captive market' of Jones Act and Government vessels, at present, is inadequate to sustain the U.S. shipbuilding industry at 1982 work levels. U.S. shipbuilders' share of world commercial orders also has averaged less than 5 percent over the past decade.

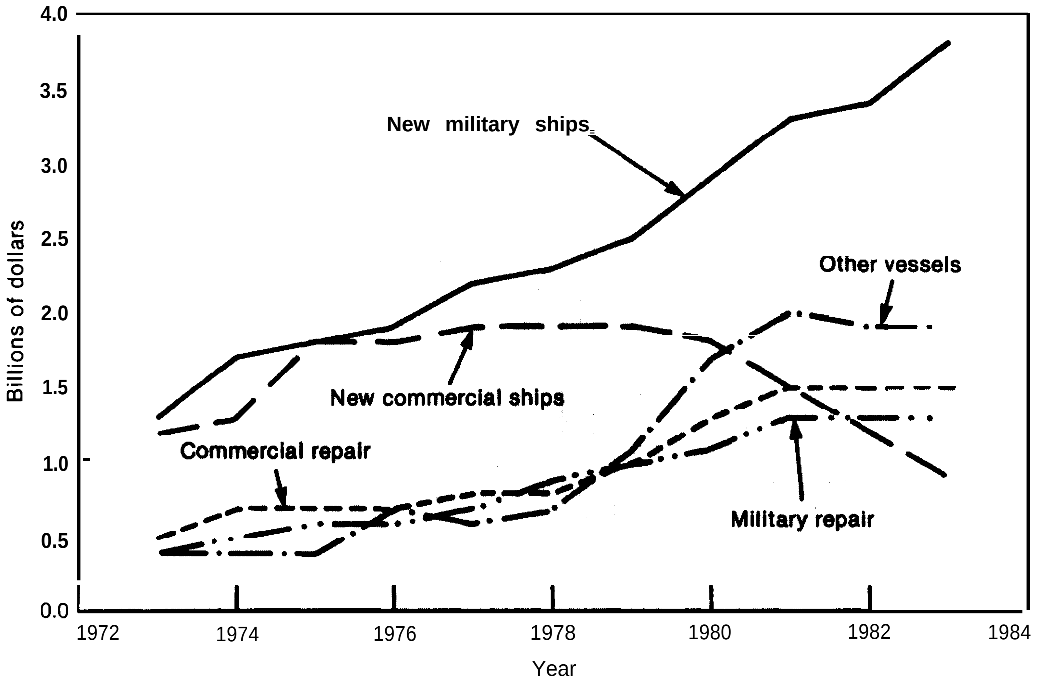
It is naval building and repair that presently supports the U.S. shipbuilding industry. The naval share of ASIB shipbuilding output has hovered around 60 percent in recent years and is projected to exceed 80 percent by 1987.[5] In the past decade, 40 percent of new contracts and 45 percent of annual deliveries have consisted of naval vessels. The commercial workload also reflected Government support. Of the 229 merchant ships contracted for by U.S. shipyards during 1972-82, 37 percent were built with construction differential subsidy (CDS), and virtually all of the remainder were constructed for the domestic fleet which, by law ('Jones Act), must be built in U.S. shipyards. [G]

Self-propelled new military ships in recent years have comprised between 33 and 40 percent of shipyards' revenues. When the repair of military ships is included, the percentage rises to an average of 47 percent. Approximately 33 percent of all naval repairs, alterations, and conversions are performed in private yards—a proportion that has been steady and probably will continue. Figure 29 illustrates the trends in the value of work performed in all private shipyards between 1972 and 1982, divided

[5]Defense Economic Research Report, Data Resources Inc., June 1982, p. 3.

[6]Shipbuilders Council of America, Washington, D. C., 1982.

Figure 29.—Shipbuilding and Repair, Trends in Value of Work Done



SOURCE. SCA annual report 1982.

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into major military and nonmilitary categories. It should be noted that military (U.S. Navy) construction and nonpropelled (barge and rig) construction have shown the most significant growth over this period. The 5-year naval shipbuilding program (fiscal years 1984-88), involving 124 new vessels (51 of which are major combatants), and 21 conversions, promises to increase the significance of naval work for private yards (see table 28).

In contrast to the 124 new naval warships to be contracted for over the next 5 years, the Maritime Administration projects that about 25 new merchant ships (20 tankers, 3 bulk ships, and 2 cargo ships) will be contracted—mostly to replace older vessels in the domestic fleet. In terms of value, the U.S. Navy orders are expected to represent about 90 percent of shipyard revenues.[7]

Naval work is unevenly distributed among the ASIB yards: seven yards are considered "combatant capable' (i. e., capable of building at least conventionally powered combatant vessels), six are considered capable of building ' 'amphibious/auxiliary vessels, and the rest are classified as ' 'capable of building seagoing merchant ships. " Based on the latest 5-year naval shipbuilding plans, it appears that the large concentration of major combatants will place even greater emphasis on those yards capable of complex warship construction.

One effect of the present high proportion of naval work and repair is to focus U.S. yard attention on customized rather than serial design and production. While this disadvantaged the U.S. shipbuilding industry in the 1970's, when series production> of large merchant vessels was at its height, its future impact may not be the same. Economic conditions may bring a return to low-unit demand for more complex ships, with a corollary tendency to maintain labor-intensive production methods in shipyards. Cargo reservation/sharing, on the other hand (if adopted on a broader scale), could produce a growth of conversion or upgrading orders, or even new building contracts.

An outgrowth of U.S. yards' naval experience could be an ability to capture orders for foreign naval vessels. An increasing number of U.S. shipyards are eyeing the international warship market, which has grown rapidly in the last decade. Many countries have begun to replace their aging fleets, and several countries (in ' 'strategically active areas' have begun to build new navies. New generations of weapon systems have caused technical changes that mandate design and construction changes. The development of advanced weapon systems has changed naval tactics and resultant ship design and construction.

[7]Data Resources, Inc., *The Economic Impact of the U.S. Shipbuilding Industry,* August 1982.

Table 28.—Proposed 5-Year Navy Shipbuilding Program (as of April 1933)

Type of ship	Number of ships planned in each fiscal year 1984	1985	1986	1987	1988
Trident missile submarines	1	1	1		1
Nuclear attack submarines	3	4	4	:	5
Nuclear aircraft carrier	—	—	—	—	1
Guided missile cruisers	3	3	3	3	2
Guided missile destroyers	—	I	–	3	5
Destroyer	—	—	—	—	1
Landing ship dock	1	2	2	2	2
Amphibious assault ship	1	—	1	—	1
Landing platform dock	—	—	—	—	1
Mine countermeasures ship	4	4	4	—	—
Mine hunter-sweeper	1	—	4	4	4
Stores and ammo ships and tenders	—	—	2	4	3
Oilers	3	4	4	4	4
Cable ship	–	–	I	–	–
Ocean surveillance ships	–	2	2	2	–
Total of new construction	**17**	**21**	**28**	**28**	**30**
Conversions and reactivation	**6**	**5**	**3**	**4**	**3**

SOURCE: Admiral Fowler, Commander, Naval Sea Systema Command, testimony before the House Armed Servicea Committee, Apr. 5, 1983.

In the 1970's, worldwide naval shipbuilding export orders totaled about 460 combatant units, plus some 40 auxiliaries (logistics ships, landing ships, patrol craft). Compared to the 1960's, when export orders totaled only 17 vessels, this is a significant growth market.[8]

Prices of naval vessels have risen sharply to reflect the increased complexity of electronic ship systems, particularly weaponry. While the United States has garnered the majority of worldwide orders for military aircraft, it lags in ship construction. In recent years, European yards have built 80 percent of naval ship export orders, sometimes with heavy government support. The United States may be disadvantaged by lack of suitable designs for export naval vessels. However, in 1982, the orders of 4 U.S. shipyards included 10 foreign military ships with a total value of almost $1 billion.[9]

[8] *Maritime Reporter, Nov.* 15, 1982.

[9] U.S. Navy, ***Annual Report on the Status** of the Shipbuilding and Ship Repair **Industry** of the United States, 1980.*

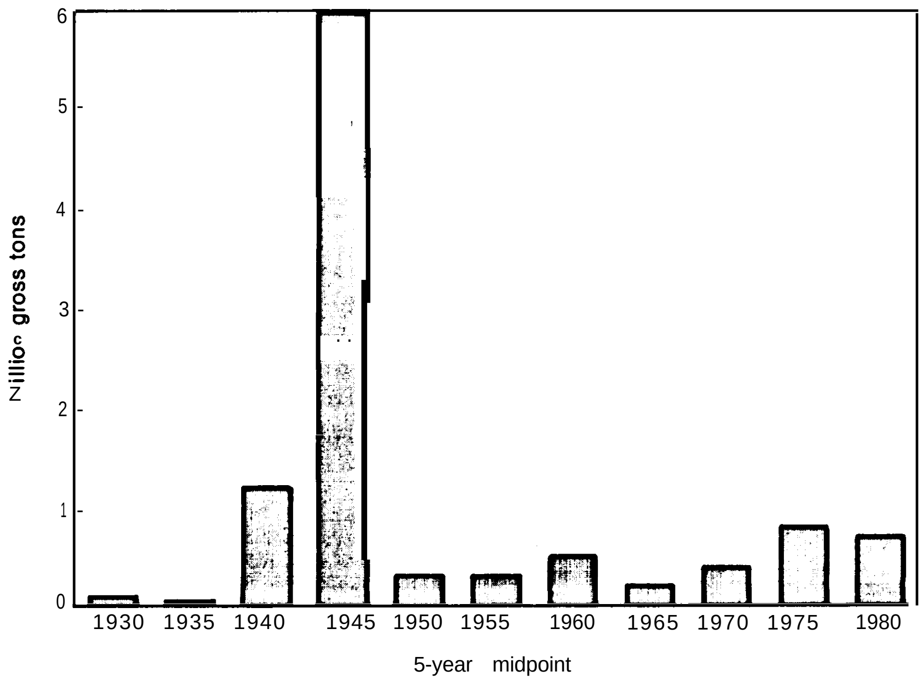
U.S. Shipbuilding Industry Orders

Both the long- and short-term variation in U.S. merchant shipbuilding over the previous 50- and 10-year periods are indicated by figures 30 and 31. Since 1980, a steady decline in orders, particularly for deep-sea vessels, has occurred with only three new merchant ship contracts awarded in **1982.** Since 1960, the trend shown in figure **32** confirms that the **U.S.** shipbuilding industry shared only briefly in the profitability of the worldwide building boom of the 1970's and reverted, in the mid-1970's, to a level of output insignificant in world terms. This is clear from an analysis of the total numbers of merchant ship contracts awarded since the Merchant Shipping Act of 1970. A study by SCA found that the volume of tonnage of commercial building closely correlated with the availability of construction subsidy funds each year and fell far short of the goals of the 1970 Act.

From 1957 through 1982, only 8 to 10 of the ASIB yards shared in naval shipbuilding orders on a regular basis.[10] The indication is that those yards

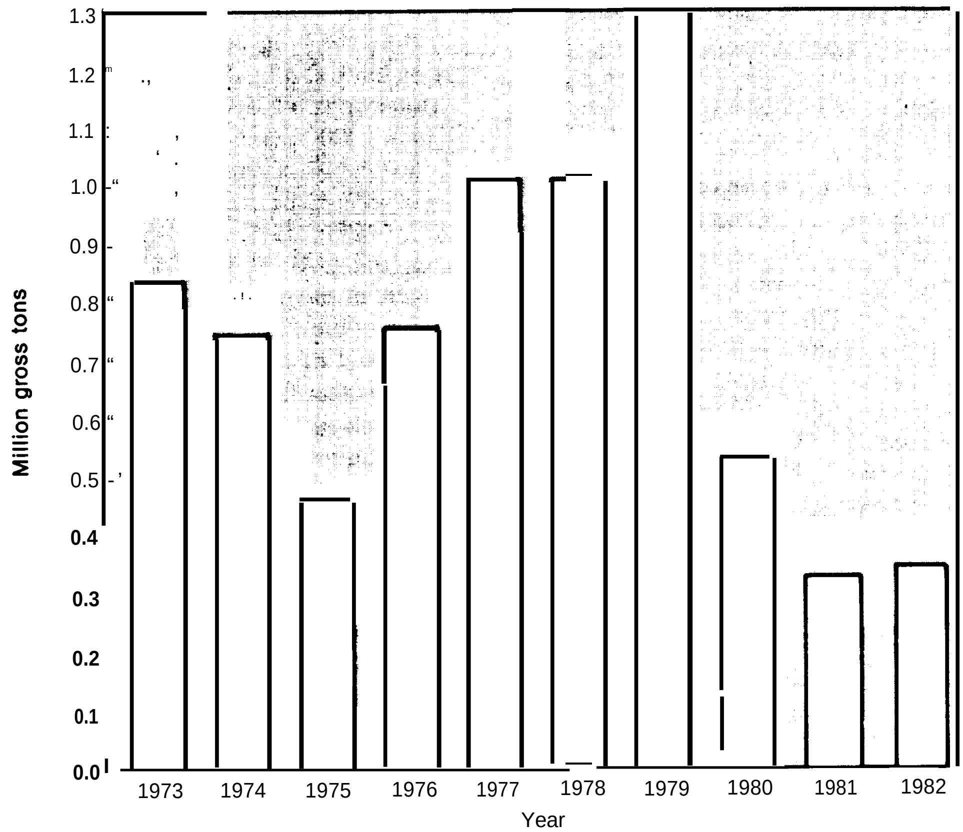
[10] Ibid.

Figure 30.–Merchant Ship Construction in U.S. Yards 5-Year Average, 1930-80



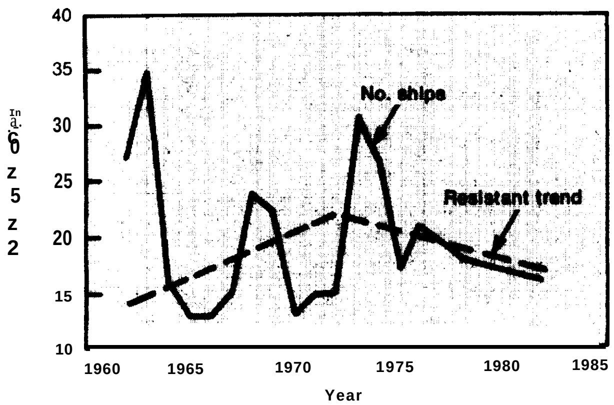
SOURCE: Marine Engieerlng/Log, 1982 annual.

Figure 31.—Merchant Ship Construction in U.S. Yards, 1973=82



SOURCE: Marine Englneerlng/Log, 19S2 annual.

Figure 32.—Historical Trends in Ship Deliveries From U.S. Shipyards



SOURCE: Office of Technology Assessment with data from Shipbuilder's Council of America.

will continue to receive the overwhelming share of new naval ship orders and that, of these, four major private shipbuilders will continue to receive about three-quarters of the total value of naval orders. *

Recent employment trends also indicate a growing concentration of ship construction in the few large yards building complex warships. Table 35 shows production employment of about 79,000 at 14 ASIB yards at the end of 1982. Compared with just 1 year earlier, total production employment increased by 2,000; several of the smaller yards lost

"According to U.S. Navy Annual Report, 75 percent of fiscal year 1983 naval shipbuilding funding of over $18 billion will go to General Dynamics/Electric Boat, Newport News, Bath, and Ingalls.

up to two-thirds of their work force while the larger ones added more than enough to keep the total growing.

The current orders of U.S. yards for naval ships, commercial ships, and drilling rigs is given in table 29. Figure 33 illustrates the locations and orders for the private shipyards engaged in U.S. Navy shipbuilding. Figure 34 illustrates the historical changes in value of commercial and naval shipbuilding work from 1970 to 1982.

Yards not capable of winning U.S. Navy contracts will have to diversify or rely on repair work for their near-term survival. Repair work is presently highly concentrated, with 15 percent of the yards performing 80 percent of the dollar volume of business. This is further confirmation of the existence of an underutilized capacity in the industry.

Table 29.—Orderbook (Vessels Under Contract) in Major U.S. Shipyards (as of March/April 1983)

	Number of ships
U.S. Navy new construction:	
Trident fleet ballistic missile submarines	8
Nuclear attack submarines	20
Nuclear aircraft carriers	3
Guided missile cruisers	6
Patrol frigates	24
Destroyer	1
Dock landing ships	3
Ocean surveillance ships	12
Other auxiliaries and support ships	17
Landing craft	6
Cable ship	1
Mine countermeasure ships	2
Total	103
Commercial merchant ships:	
Containerships	1
Roll-on/roll-off ships	3
Product tankers	8
Bulk carrier	1
Tug/barges	4
Total	17
Other vessels:	
U.S. Army dredge	1
Geophysical research vessel	
Incinerator vessels	:
U.S. Coast Guard cutters	9
Offshore drilling rigs	12
Total	25

NOTE: In addition to the above. U.S. Navv reDair and overhaul contracts on over 40 warships total almost $1.7 bil~ion" in value as of March 1983

SOURCE: Marine Engineering/Log, March 19S3. U.S. Navy, April 1983.

In addition to the recent concentration in U.S. Navy markets, another problem for U.S. shipyards has been the fluctuating size and diverse character of the orders. First, the fluctuating orders force management to seek maximum flexibility in their mix of capital and labor. This results in labor-intensive methods, restrictions on the levels and type of capital investment, a high turnover in the labor force, and an adversarial climate of labor relations.

Second, the diverse character of the output of U.S. yards forces frequent changes in workload and resultant labor requirements, which are superimposed on the normal variations in labor requirements during the building cycle. Even yards heavily involved in naval work are subject to these pressures. Changes in naval procurement methods and cycles add further uncertainty. The labor turnover in the shipbuilding industry has been estimated at 40 to 50 percent per year, and up to 95 percent after 5 years. Since shipbuilding processes are assumed by the industry itself to continue to be relatively labor-intensive,[11] the problem of managing the labor force obviously is acute.

These problems are reflected in Pugh-Roberts Associates' findings regarding the factors perceived by the industry to determine competitiveness.[12] The survey respondents felt that U.S. shipyard productivity was determined more by its external environment than by its investment and marketing program. A 1980 report by the National Academy of Sciences summarized the problems vividly:

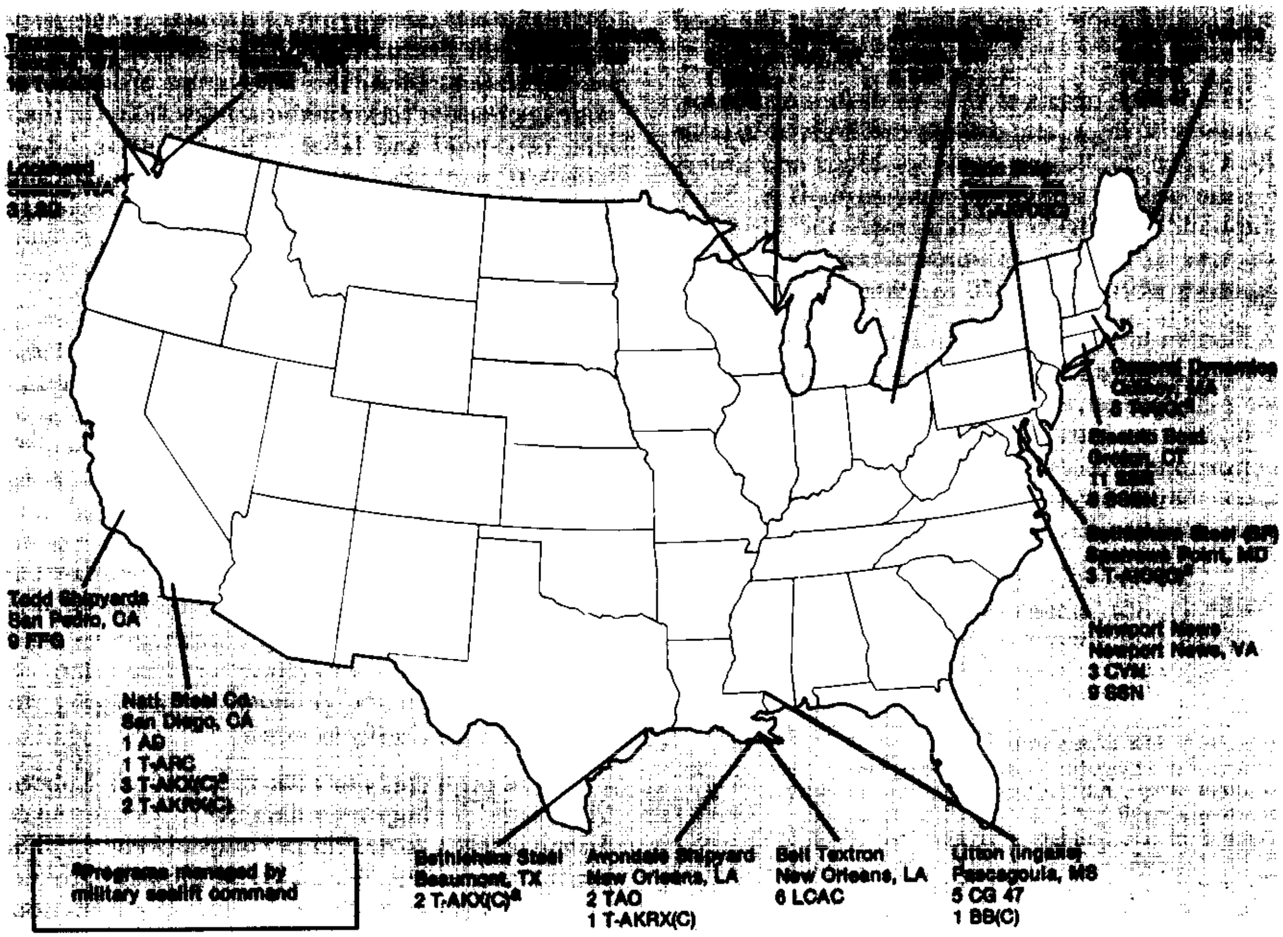
> In summary, the indefinite nature of the market inhibits prudent capital investment, with few exceptions. This ties shipbuilders to a job-shop trade environment that is whipsawed between demands of military programs and those of alternative commercial programs. As shipyard management sees it, this further inhibits capital investment and

[11] Institute for Research and Engineering Automation and Productivity in Shipbuilding, *5-Year National Shipbuilding Productivity Improvement Plan*, Report of the Second Task Group Sessions.

[12] Kenneth G, Cooper and Henry Birdseye Weil, "Ocean Shipping System Dynamics, December 1981 (for MarAd Office of Research and Development) hereafter referred to as Pugh-Roberts Associates' report.

[13] Maritime Transportation Research Board, "personnel Requirements for an Advanced Shipyard Technology' (Washington, D. C.: National Academy of Sciences, 1980), p. 106.

Figure 33.—Major Private Shipyards and Navy Programs (Apr. 1, 1933)



SOURCE: U.S. Navy, April 19S3, updated by the Office of Technology Assessment.

creates hiring and training problems; and that further limits the availability of capital and brings into question the wisdom of investment.

The Capabilities of U.S. Shipyards

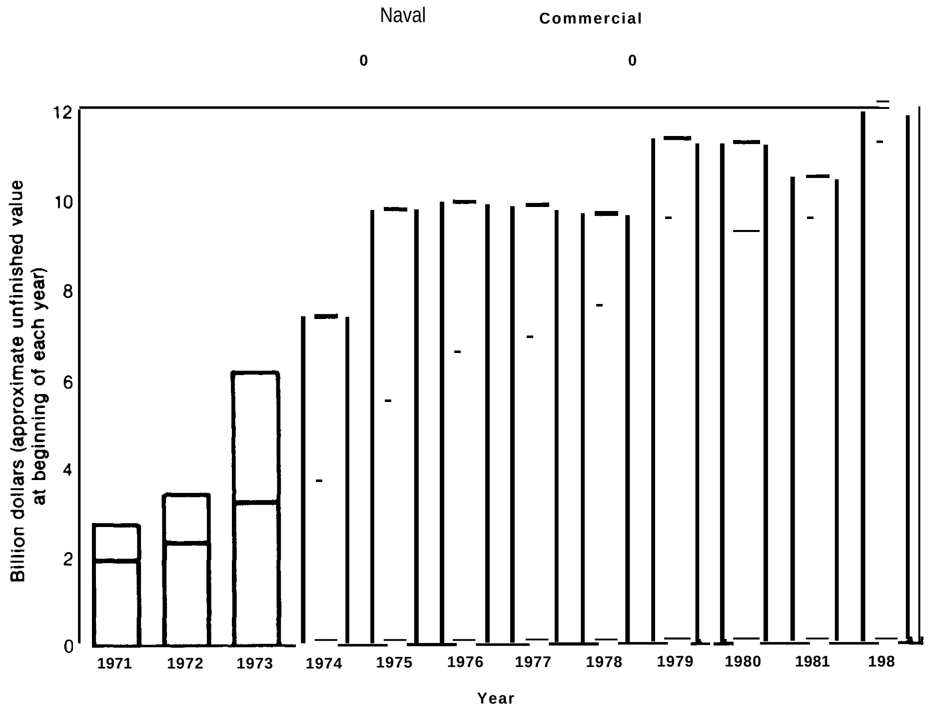
Table 30 summarizes the past experience and current work of the ASIB yards by vessel type. It is immediately apparent that U.S. yards have built a wide variety of ship types in the past, and in many cases are presently making a serious effort to build other types of industrial structures. Diversification is necessary for all yards if they are to keep their work forces intact and their facilities fully occupied. The naval building programs will take some time to gear up and will not help ail ASIB yards .14 The push toward diversification also reflects the yards' belief that naval work is much less profitable than subsidized commercial work and that naval procurement policies may work to the disadvantage of commercial yards. *

It is also important to recognize that not only did the United States pioneer series production in

14"'Because of long leadtime associated with the construction of sophisticated warships, the full impact on shipbuilders of the expected U.S. Navy program is at least 3 years away, and ultimately less than two-thirds of the present production base will be potentially utilized. *SCA Annual Report,* 1981, p. 1.

"This was cited in many articles in the general and trade press. See, for example, the ***Forbes*** article of 9/28/81, p. 114. Gilbride, of Todd, is quoted as saying: (after Vietnam) "the military was viewed so adversely that we lost a decade of shipbuilding.

Figure 34.—Value of Shipyard Work on Order, U.S. Private Shipyards



SOURCE. Seatrade (U.S. Yearbook, 1982).

Table 30.-U.S. Shipyard Work Experience

	Past	Current
Alabama Dry Dock &Shipbuilding Co., Mobile, Ala.	AE	E
American Shipbuilding Co., Lorain, Ohio	ABC	Repair
Avondale Shipyard, Inc., New Orleans, La.	A B D	A B C
Bath Iron Works Corp., Bath, Maine	A B D	B D F
Bay Shipbuilding Co., Sturgeon Bay, Wis.	B	A
Bethlehem Steel Corp.—Beaumont, Tex.	E	E
Sparrows Point, Md.	A C	A C E
Equitable Equipment, New Orleans, La.	C	A C
General Dynamics/Quincy Shipbuilding Division, Quincy, Mass.	B C	A B F
General Dynamics/Electric Boat Division, Groton, Corm.	D	D
Halter Marine, New Orleans, La.	A	A C
Ingalls Shipbuilding Division of Litton Industries, Pascagoula, Miss.	B D	D E F
Livingston Shipbuilding Co., Orange, Tex.	A B	A B E F
Lockheed Shipbuilding & Construction Co., Seattle, Wash.	A B C	C F
Marinette Marine Corp., Marinette, Wis.	A B	A B
Maryland Shipbuilding & Dry Dock Co., Baltimore, Md.	A B	Repair
National Steel & Shipbuilding Co., San Diego, Calif.	A B C	B C
Newport News Shipbuilding, Newport News, Va.	A B D	A B D F
Norfolk Shipbuilding & Drydock Corp., Norfolk, Va..	B D	A
Pennsylvania Shipbuilding Co., Chester, Pa.	A B	Repair, F
Peterson Builders, Inc., Sturgeon Bay, Wis.	A	A C
Tacoma Boatbuilding Co., Tacoma, Wash.	A B	B C
Tampa Shipyards, Inc., Tampa, Fla..	Repair	Conversion
Todd Shipyards Corp., Galveston, Tex.	A B	A F
Houston, Tex.	A	A F
Todd Pacific Shipyards Corp., Los Angeles, Calif.	A D	D
San Francisco, Calif.	A C	A
Seattle, Wash.	A B D	D

Legerid: A–simple commercial vessels; B–complex vessels; C–simple naval vessels; D–naval combatant vessels; E–rigs; F—other industrial fabrications.

SOURCE: E, G, Frankel Report to the Office of Technology Assessment, 1983.

World War II, but that there has also been recent U.S. experience with merchant and naval series production. Some merchant series (e. g., barge carriers such as LASH) predate the 1970 Act, which was intended to stimulate a major new construction program; others (liquefied gas carriers and tankers) were a response to its provisions.

Some of the major U.S. ship series have been divided among several shipyards, and programs have not necessarily run continuously. Swedish experience, by contrast, typically included continuous runs of 10 to 20 ships of one design. Series production in the United States has tended to focus on tanker construction. Apart from the expected duration of tanker overcapacity, it may be that specialized foreign yards have a strong advantage that may be very difficult to overcome, diminishing the value of some of this U.S. experience.

In merchant vessel construction, U.S. shipyards have the capability of building almost any type of ship in the world today and have built at least a few of each principal type, including supertankers up to 390,000 dwt. For example, the ASIB yards have collective and concurrent shipway capacity for over 60 large containerships 610 ft by 90 ft or twenty-three 100,000-dwt bulk carriers. U.S. shipyards possess 17 shipway equivalents capable of building 1,000 ft and longer vessels and over 60 shipways capable of constructing vessels between 500 and 1,000 ft in length. At present, six of the ASIB yards are capable of building tankers or bulk ships over 100,000 dwt or of building super containerships of up to 1,000 ft in length. Twenty of these yards can build cargo ships up to 475 ft in length.

It should be noted that modern shipbuilding methods minimize time on a building dock. Many of the world's most competitive yards use only one building position. The physical capacity of U.S. yards, therefore, does not pose a constraint on the productivity of the industry, although the age and layout of the yards most certainly do.

The Technology Level of the U.S. Shipbuilding Industry

Three or more decades ago, the major yards constructed the entire ship themselves, with minimal use of purchased components. Where ship components were brought in, the supplier tended to be virtually an extension of the shipbuilding industry. This has changed markedly since World War II. Shipbuilders have attempted to reduce the labor costs of their manufacturing technology through standardization and automation. The use of purchased equipment and subassemblies has increased exponentially, with shipbuilding increasingly becoming an assembly and erection industry.

Modern shipbuilding technology is characterized by modular construction techniques, a high degree of preoutfitting, and integration of design and production considerations. * The technology is based on carefully designed materials-handling systems, and is frequently accompanied by a high degree of specialization of output. Edwin Hood, past President of SCA, remarked recently that there is a marked "correlation between shipbuilding market opportunities and incremental progress in shipbuilding technology. The rapid advance in shipbuilding of the early 1970's was based on the explosive growth in demand for tanker and containership fleets and has declined markedly in recent years. U.S. shipyards did not capture very much of the huge market for merchant ships in the 1970's and, as a result, did not match the technological advances made by European and Japanese yards, which built for the world market.

A review of the technology of U.S. shipyards including comparisons with high-technology foreign yards was completed in 1978 by Marine Equipment Leasing, Inc. (MEL) for MarAd. MEL used A & P Appledore's methodology for this study, assigning each of several technology elements to one of four levels of sophistication. The study gave rankings to U.S. and foreign shipyards in eight major areas of technological development. MEL's findings were as follows:

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*A ship is divided into convenient sections (or modules), and each section is completely "outfitted" with machinery, piping, wiring, and other equipment and components that make it a finished section (including painting). The modules are then fitted together into larger assemblies that are themselves joined together to build the ship. In this way, work can be accomplished on each module inside a building that has materials-handling gear, easy access, good lighting and ventilation, and a host of automated tools at fixed workstations, rather than aboard a partially finished ship. This work process has been shown to improve shipbuilding productivity markedly.

[5] "Technology Survey of Major U.S. Shipyards, " Department of Commerce, Maritime Administration, contract No. DO-ADI-78-OO-3037, prepared by Marine Equipment Leasing, Inc., 1978.

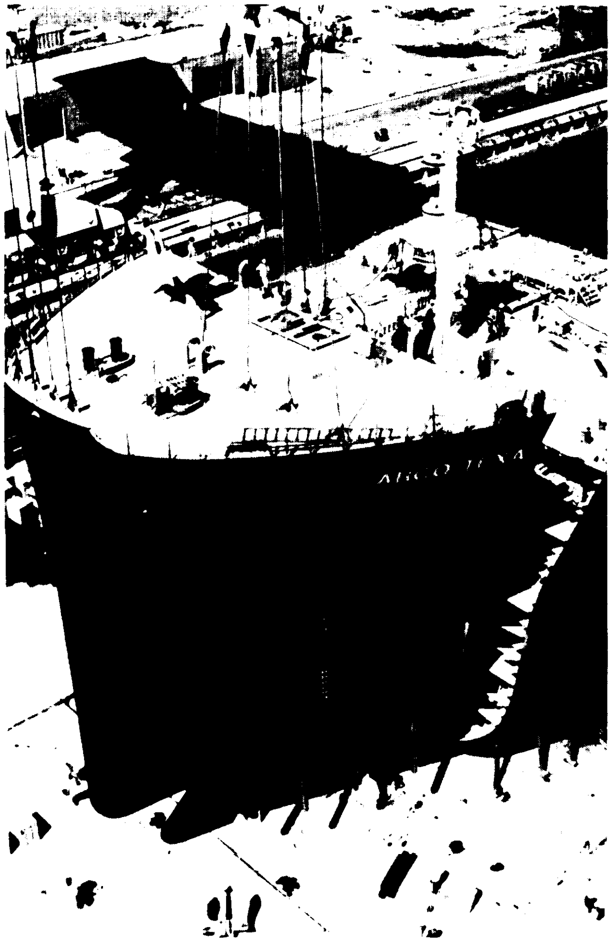


Photo credit: Atlantic Richfield Co.

Modular construction of a 90,000-dwt tanker

- U.S. shipyards generally employed lower levels of technology than foreign shipyards;
- low technology was found in some critical areas in U.S. shipyards; these were primarily management- and systems-oriented; and
- U.S. shipyards were found to be excellent in some areas, particularly those related to steel work and production control.

Between 1978 and 1981, a further $851 million was invested by U.S. shipyards to enlarge their facilities to handle supertankers, to complete specific building programs, and to extend subassembly fabrication capabilities.[16] This has not necessarily reduced the labor intensity of the shipbuilding process. To do that, further investment would probably be required.

At present, the technological status of U.S. shipyards is generally lower than that of comparable Japanese and Korean shipyards in terms of technological investment, research and development (R&D) investment, use of labor, tooling, degree of automation and use of robotics, and application of modern automated management and control techniques, as well as in the methods of processing, joining, and assembly.

The curious fact is that many of the technologies used in Japanese and Korean shipyards are the result of basic research performed in the United States. The United States lags in the application of its own research and the effective introduction of innovations based on scientific and technological discoveries. In the Orient, basic scientific and technological developments are often reviewed for applicability to improving shipbuilding technology, productivity, and cost, yet no such process is evident in the United States. When it occurs, it appears to be more through chance than by design. Thus, U.S. technological shortcomings are usually not due to a lack of basic scientific or technological development but to a lack of effective organization of or commitment to applications research. One reason may be that in the United States no effective mechanisms exist for collaboration in both basic and applications research or for dissemination of the results of such research.

Many believe that U.S. shipyards made a strategic error, following the example of modern foreign yards in the 1970's and investing primarily in advance steel preparation, fabrication, and assembly methods. These areas are traditionally labor-intensive, and the payoff is most pronounced in the serial construction of large, simple ships such as tankers and bulk carriers. However, this has never been a significant market for U.S. shipbuilders. Another more practical reason for such investments was that many U.S. yards have serious space limitations in existing facilities and could not justify the much larger capital requirements to move to a new site.

The U.S. shipbuilding industry's market, product mix, labor costs, and labor-management environment are quite different from those of other major shipbuilding countries such as Japan, Korea,

[16] Annual Survey of Manufactures, 1978-1980; MarAd 1981 figures.

and Spain, most of whom introduced these modern steel-fabrication and building facilities in time for use in the massive tanker/bulk carrier-building programs of the early 1970's. U.S. shipyards introduced many of these technological advances only during the last 8 to 10 years, at a time when large tanker/bulk carrier orders started to decline, when U.S. shipbuilding participation in the world market was negligible, and when U.S. Government support for upgrading and rebuilding the domestic fleet started to wane. At the same time, U.S. shipbuilding labor productivity continued to decline. It was not recognized that the decision by foreign yards to invest in steel fabrication and related technology was primarily driven not by a desire for improved labor productivity—the main U.S. objective—but by the goal to speed the shipbuilding process. They thereby achieved a greater utilization of capital-intensive facilities, such as building docks and heavy-lift cranes, as well as a decrease in production times and the associated costs of holding construction materials.

It should be noted that the difference in the cost of interest charges on material and work in progess for a ship built in 2 years instead of 6 months, is 4 to 1. With interest charges for construction loans at 12 percent, the difference in final cost of interest would be at least 9 percent. Even considering only simple interest and constant dollars, a ship built in 6 months at a cost of $100 million, including $3 million in carrying charges, would cost $109 million to $110 million if built in 2 years, excluding the additional cost of use (or lost opportunity) of shipyard facilities.

Large Japanese and Korean shipyards also assume that opportunity costs of major shipyard facilities add to the actual differential costs for time extensions in the construction of ships. Such costs have been estimated to add about 25 percent to costs of ships built in 2 years v. 6 months, assuming that about 50 percent of the building time is spent in the building dock or on a building way/platform. Therefore, introduction of modern steel fabrication and assembly technology is advantageous in Japan primarily when it leads to a substantial reduction in construction time. Of course, without substantial orders, opportunity costs are of little concern to most U.S. shipyards.

The technology level in major U.S. shipyards in steel fabrication is nearly on par with that of modern shipyards in Europe, but lags behind those in the Orient. This is due in part to a difference in technological approach to subassembly, such as flat-panel v. curved-panel fabrication. The U.S. (and European) approach was to use largely automated flat-stiffened panel-fabrication lines; while Japanese and Korean shipyards use a so-called eggcrate approach, which is more flexible, less automated, and combines the use of several parallel semiautomated fabrication lines. Welding robots are extensively used now in the Orient, while U.S. yards use less fully automatic processes in assembly fitting and erection. Other differences can be seen in the size of blocks and modules and the degree of block and module outfitting, both of which are appreciably greater in the Orient.

U.S. shipyards lag in subassembly and assembly fabrication, and in the installation of preassembled outfit systems in modules. Automated pipeshops, large block-machinery module-assembly plants, etc.; are in common use in modern shipyards in Japan and Korea. U.S. yards have, with some exceptions, made few modifications to the traditional labor-intensive approach to ship outfitting. One reason may be that until recently few ships designed for construction in U.S. yards were configured for efficient, large-scale preoutfitting or system outfitting. In part this may be due to the fact that many ships constructed in U.S. yards were designed with more attention to Government specification than to cost-effective commercial production techniques.

Most foreign yards build mainly from their own designs, which obviously permits consideration of- the most efficient fabrication, assembly, and outfitting approach in the design of the ships. It also permits design for more balanced utilization of the different facilities and other resources of the yard.

Another area of U.S. technological lag is in materials handling. While many large U.S. yards have invested in large erection-crane capacity, rarely is consideration given to improvements in methods and capacities for subassembly and assembly handling and manipulation. This is due often to the fact that many U.S. yards use old converted buildings with limited headroom, support capacity, and other constraints, Materials handling is only one operational aspect of shipbuilding which is constrained by the layout and various other physical characteristics of U.S. shipyards. The age of all but one major shipyard exceeds 65 years, and more than a third are well over 100 years old. They have reached their present configuration, layout, and facilities as the result of many changes and additions over the years. Most of those were compromises to permit the needed addition or expansion to be accommodated in the old yard.

Unfortunately, the area, water depth, access, flow, and other shipbuilding requirements have changed radically with ship size, type, and technology, as well as with developments in shipbuilding techniques. A modified 65-year-old yard can never achieve the efficiency of a modern yard configured and designed to build modern ships using modern shipbuilding techniques.

With a few exceptions, U.S. yards generally do not use modern, integrated computer-aided design/manufacturing systems (CAD/CAM) in which design and manufacturing processes are integrated (i.e., manufacturing inputs and controls, including materials and tooling specifications, are developed as an integral part of the design process). In welding, U.S. use of automatic numerically controlled cutting has lagged behind foreign applications by several years. Except for one experimental machine, welding robotics are not used in U.S. yards at present, nor is laser cutting. Lasers are used in many foreign yards for alignment, forming and cutting control. marking, and interference control. It is interesting to note that most foreign shipbuilding applications of laser techniques are based on U.S. scientific developments.

In summary, major drawbacks in U.S. shipbuilding technology development include:

- the time lag between identification of a technological need and its development;
- the reluctance (and consequent time loss) to adopt foreign technology, including joint venturing, licensing, purchasing, or other arrangements used for the speedy, effective transfer of technology;
- lack of effective exchange of technology among U.S. shipyards;
- lack of transfer of technology from other areas (aerospace, electronics) for use in ship design and construction; and
- lack of recognition of technological voids in U.S. shipbuilding.

It is interesting to note that the most advanced and most competitive shipbuilding industries devote a tremendous effort to inter- and intra-industry technology exchange as well as to the identification of technological voids and the acquisition of new technology. All major Korean and Japanese shipyards have large numbers of licensing, technology transfer, and similar agreements and continuously exchange information with their own competitors within and without their country. Table 31 illustrates the range of projects and sources of technology transferred to four major Korean shipyards from 1971 to 1982.

It should be noted that in the past **2** years, several U.S. shipyards have made substantial efforts to learn from and adopt some of the Japanese shipbuilding techniques that have led to high productivity. These yards have surveyed the Japanese shipbuilding industry, employed Japanese consultants, and participated in MarAd shipbuilding research programs that covered such subjects as accuracy control, block construction, and zone outfitting. Several yards have begun to integrate these techniques into their building programs and practices with an apparent improvement in productivity. It also appears that the U.S. Navy building program, in turn, may benefit from these advancements. *

● Ch. 5 describes the MarAd shipbuilding R&D program status and plans. For a review of recent advancements in adopting productivity-improving technologies see, "Shipbuilding Productivity-Something is Being Done, " by L. Chirillo, January 1983. For a private industry anatysis of foreign shipbuilding technology that could offer benefits to U.S. shipyards, see Lockheed Shipbuilding and Construction Co. Reports—(a) "A Survey of Modular Construction and Preoutfitting Practices in the United States and Europe, " 1982; and (b) "A Survey in Japan and Korea, 1982. For an overview of shipbuilding productivity improvements that could benefit the U.S. Navy building program, see the National Academy of Sciences, Marine Board report "Productivity Improvement in U.S. Naval Shipbuilding, " January 1983.

Table 31.-Examples of Projects That Transferred Technologies to Korean Shipyards, 1971=82

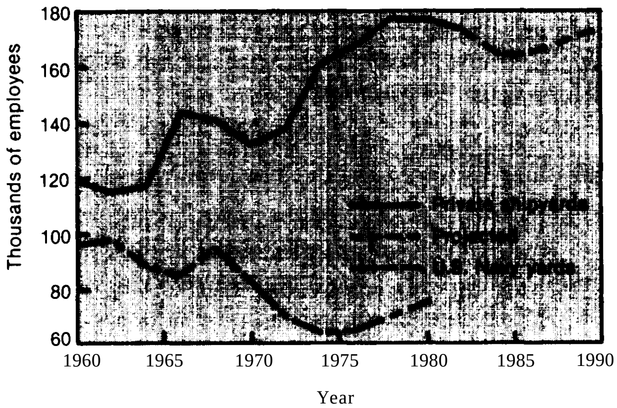
Project type and year	Transferee country and company	Transferee (Korean shipyard)
Tanker design-1971	United Kingdom-A &P Appledore	Hyundai
Tanker design-1971/72	West Germany-KDW	Korea S.B.
Tanker design-1975/77	Norway-DNV	Korea S.B.
Tanker design-1979	Switzerland-Maierform	Hyundai
Tanker design-1979	Denmark-B&W	Sore-Sung
Tanker design-1981	Japan-Hitachi	DaeWoo
Tanker design-1981	Norway-SRS	DaeWoo
Cargo ship design 1974	United Kingdom-Govan	Hyundai
Cargo ship design 1975	Canada-GAMAT	Hyundai &Korea S.B.
Cargo sh(p design 1977	West GermanY-Eurolo~	Hyundai
Ore/bulk design 1977	West Germany-CR Cu~hing	Hyundai
Ore/bulk design 1981/82	Denmark-B&W	Sore-Sung
Ore/bulk design 1981	United Kingdom-Y-ARD	DaeWoo
Ore/bulk design 1981	Norway-SRS	DaeWoo
Ore/bulk design 1976/77	Norway-SRS	Korea S.B.
Containership design 1977	United Kingdom-Y-ARD	Hyundai
Containership design 1978	Switzerland-Maierform	Hyundai
LNG/LPG design 1975/77/78/82	France-Gas-Transport	Hyundai &Korea S.B.
LNG/LPG design 1974	United States-MMC	Korea S.B.
Drilirigdesign 1979	United States	Hyundai
Drill rigdesign 1981	Norway-AKER	Hyundai
Drill rig design 1981	United States-Carrel/Ingails/Santa Fe	DaeWoo
Derrick/platform 1978	Sweden-Ventel	Hyundai
Derrick/platform 1979	Japan-McGregor	Hyundai
Derrick/platform 1980	United States-FOS	Hyundai
Derrick/platform 1981	United States-FOS	Hyundai
Computer programs 1973/76/81	Sweden-Swedeish	Korea S.B.
Computer programs 1975	Sweden-VOC	Hyundai
Computer programs 1976/81	Norway-SRS	Korea S.B.
Computer programs 1977	Spain-SENER	Hyundai
Computer programs 1977	Japan-Hitachi	Hyundai
Computer programs 1980/81	Norway-SRS	Hyundai/Dae Woo/Sore-Sung
Computer programs 1980	United Kingdom-A &P Appledore	DaeWoo
Computer programs 1980	Japan-IKENAI	Sore-Sung

SOURCE: "Status of the Korean Shlpbuildlng industry;'ChungMong Joon, lntwnational Forum onlndustrial Plannlng and Trade Policies, June 1902.

The Labor Force of the U.S. Shipbuilding Industry

Total private shipyard employment increased from about 120,000 in 1960 to almost 180,000 in 1980 as shown in figure 35. During the same period, employment in naval shipyards decreased from almost 100,000 to about 75,000. Annual fluctuations of 20 to 30 percent in the totals mask even larger fluctuations in the skilled labor force of the ASIB yards. Up to 75 percent of the work force has been laid off in the period since 1960 inmost of the major ASIB yards. Since these account for over 75 percent of total private shipyard employmerit, we can conclude that the majority of the work force has first-hand experience- of the cyclical

Figure 35.—Private and U.S. Navai Shipyard Employment Leveis, 1960-80, and Projected Through 1990



SOURCE:U.S. Navy.

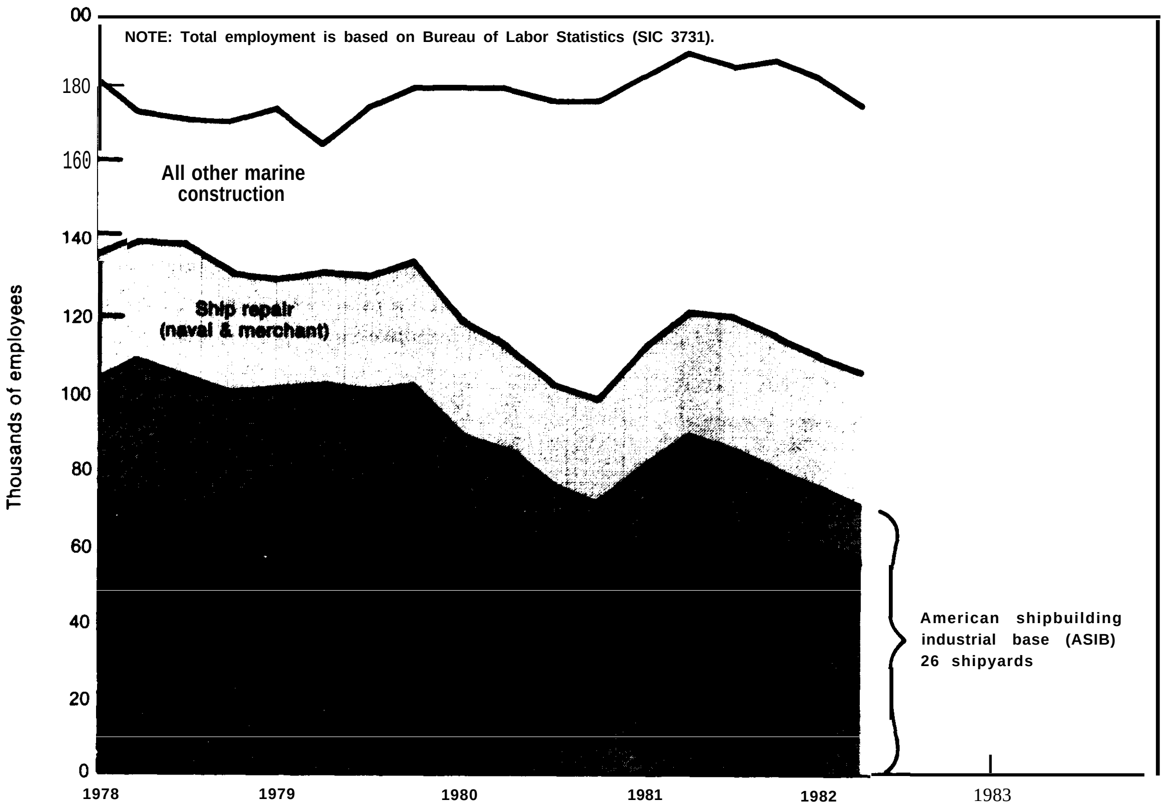
''casualized' nature of shipbuilding employment (i.e., workers with little or no previous experience are regularly hired for only short periods of time).

Figure 36 illustrates employment levels in private U.S. shipyards over the past 5 years. It can be seen that employment in the ASIB yards (new construction only) decreased from about 100,000 in 1978 to about 70,000 in 1982. It is, therefore, this segment of the total industry that has experienced the most significant recent decline, and it is this same segment that represents the U.S. potential for participation in the construction of major merchant ships. It should also be noted that over the same 5-year period, the ''other marine construction' shipyard segment experienced a compensating growth in employment so that total employment from 1978 to 1982 remained about level. This ''other' group includes the builders of tugs, barges, service vessels, drilling rigs, and numerous other small craft. Some of this group have substantial capabilities and could be future candidates for inclusion in a listing of ASIB-capable facilities, especially as technology changes are made.

The proportion of **production** employees in the total work force in the ASIB yards—a commonly used capacity measure—has been reasonably constant—75 to 80 percent in the last decade. The 2- to 5-percent fluctuations that have been experienced do not appear to be systematically related to trends in production techniques, although technological advances increase the requirement for planners, quality assurance personnel, and other specialists. It is much more likely that the fluctuation reflects cyclical layoff of production workers.

Current employment may be compared to an optimum employment to assess the utilization of human resources of an industry with some accu-

Figure 36.—Shipbuiiding and Repairing Employment in Private U.S. Shipyards, 1978-82



SOURCE: Shipbuilders Council of America.

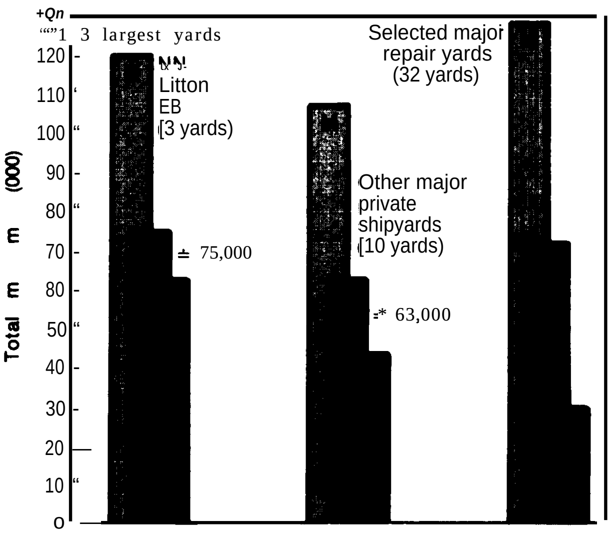
racy, depending on how well optimum employment can be estimated. Figure 37 shows the 1981 employment levels plotted against optimum levels cited in the Lowry study .[17] Utilization for the various groups ranges from 83 percent (for the three largest building yards, Newport News, Litton, Electric Boat), to 68 percent (for other major building yards) to 49 percent (selected major repair shipyards). These levels are not changed significantly from 1979. It should be noted that the data are only reliable enough to form ' 'very approximate estimates of industry utilization . . . ''[18]

Projections of the shipyard work force are necessarily uncertain; however, a recent U.S. Navy projection for private shipyards through 1990 is shown in figure 38. The expectation is that overall employment will be sustained at approximately present levels for the near term with some modest growth past 1986 if the present building program proceeds as scheduled.

[17] "U.S. Shipyard Program Planning" (Washington, D. C.: Lowry & **Hoffmann Associates,** Inc., September 1980).

[18] Ibid.

Figure 37.—Mobilization and Optimum Employment Estimates and Current Employment Leveis in the Major Private Shipyards



= Mobilization
t = Optimum
c = Current (6/81)

SOURCE: "U.S. Shipyard Program Plennlno," a atudy by Lowry and Hoffmenn, A8aoelates, Inc., for Navel **Sea Systems** Command, Septembr 1980.

Demographic Characteristics of the Shipyard Work Force

The shipyard labor force is fairly mobile, partly as a result of the known instability of employment in the industry. The turnover rate has been higher than in most other basic industries, but has declined recently to roughly the same level as durable-goods manufacturing. The decrease in turnover undoubtedly reflects many factors, including lower levels of hiring in recent years, lack of employment opportunities outside the industry, and a reversal in the aging trend of the work force. Like the marine operating industries, shipbuilding has a high turnover among new (less than 1 year's service) entrants, who seldom reenter the industry. Many firms have used high turnover rates as a reason to minimize worker training. However, such actions could be an additional factor in employee turnover.

The shipbuilding labor force is overwhelmingly male,[19] and there are distinct groups in private and naval shipyards. Civil service naval shipyard workers are older and generally have a higher educational level than private shipyard employees, or indeed than employees in most comparable industries. * Although a high proportion (40 percent) of naval shipyard workers are over 45-years-old, the educational distinction is likely to be perpetuated by Civil Service entry requirements and craft orientation of U.S. naval yards. Entry-level educational requirements in private yards have never been demanding and are unlikely to become so, given the shift toward a fabrication-and-erection technology and the availability of specialized vendor personnel.

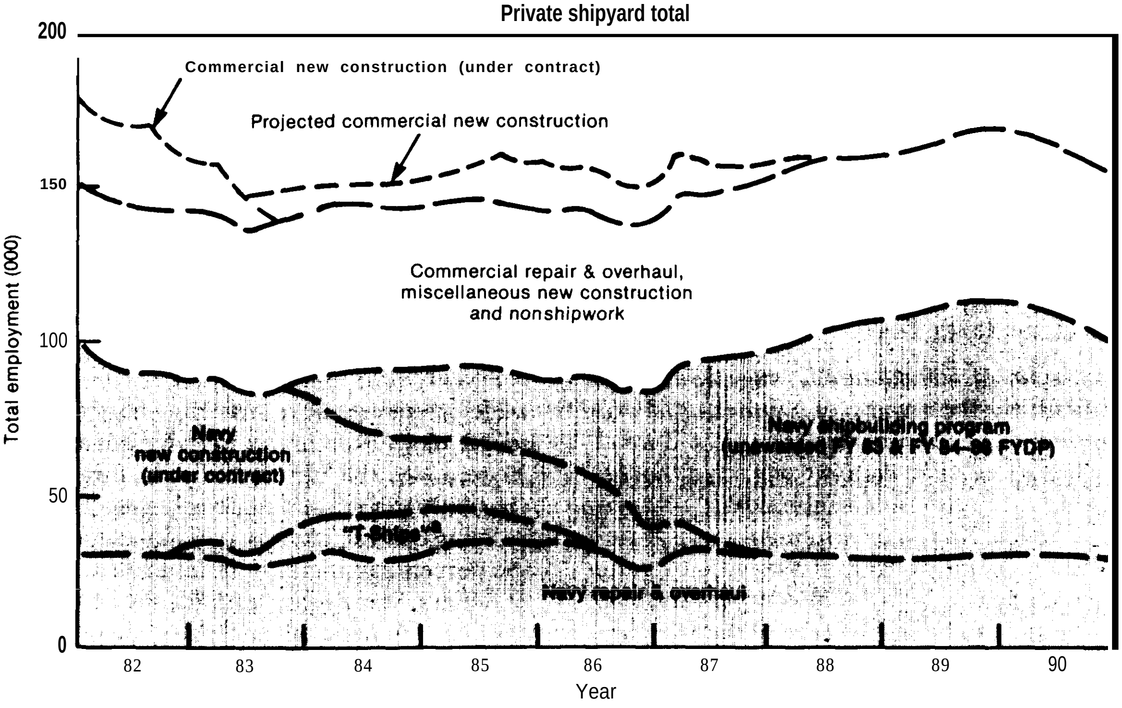
Shipyard Workers' Hours and Earnings

The earnings of shipyard workers compare favorably with those of operatives in durable-goods manufacturing. They compare less well (on an hourly basis) with construction workers, a comparable group in many significant respects. Conversations with the Offices of Maritime Labor and

[19] **Maritime Transportation** Research Board, op. cit., p. 56.

"Forty percent of apprentices have at least 2 years of college. Hartigan, Director of Shipyard Training, Naval Sea Systems Command—cited in Gaffney, "Worker Participation and Organizational Change in Shipbuilding: An International Review, September 1982, p.6.

Figure 38.—Shipbuilding Industry Workload Forecast



[a]Includes awarded/unawarded "T-Ships" TAKRX, TAKX, TAKX(C), T-5, TAH, TAGS, TAGM.

NOTE: The above portrays the U.S. Navy's forecast of employment in the private sector shipyards through 1990. Included In the workload curve Is the current firm work and projected work of commercial, Navy, and other nonshlp work. The projected new construction work Is derived from the unawarded Fiscal Year S3, the U.S. Navy's Fiscal Year & 5-Year Shipbuilding Program, and MarAd estimates of commercial new construction requirements.

SOURCE: U.S. Navy, ASN (S&L) RPE 19S3.

Training (MarAd) and Maritime Affairs and Shipbuilding Technology (NAVSEA) indicate that the shipyard workers consider that their pay is lower than that obtained in comparable skilled jobs and involve far more risk and discomfort. Despite a trend toward covered worksites, the level of amenities in many shipyards remains low.

The 10-year growth in earnings for shipbuilding workers v. durable-goods workers is 8.4 and 8.1 percent, respectively, v. 7.2 percent in the total private sector. Average hours have fluctuated, but U.S. shipbuilding as a whole has been characterized traditionally by a comparatively short (less than 40-hour) week. The 8.4-percent growth in shipyard workers' earnings can be contrasted with the 8.2-percent growth of the Consumer Price Index (CPI) over the same period.

Wages are almost universally time-rated in shipbuilding, and, as table 32 shows, only a minority of yards have a range of pay rates for various jobs.

Table 32.—Method of Wage Payment

	Percent
Time-rated pay systems	
Formal plans	%
Single rate	69
Range of rates	28
Individual rates	1
Incentive pay systems	2
Individual piecework	1
Group piecework	1
Individual bonuses	—
Group bonuses	—
	100
Note: Scheduled weekly hours:	
40.0	94
44.0	4
45.0	1
47.5	1
	100

SOURCE: *Industry* Wage Survey, U.S. Bureau of Labor Statlstlcs, 1977.

These pay ranges, even where they exist, generally are considered by workers to be too narrow to reflect the range of skill levels, resulting in a disincentive effect. The use of an individual, time-rated pay system, rather than a group result-oriented incentive system, may perpetuate current problems; i.e., the ''greatest complaint of production workers about working conditions (involves) inadequate scheduling, planning coordination, and communications among crafts, shifts, and working groups in the shipyard. Improvement of incentive systems or a complete change in the basis of administration and payment may focus workers' concerns on productivity and ease the transitional character of the labor force.

Comparisons of international wage levels are made difficult by the variety of payment systems and the limitations of statistical reports. The Bureau of Labor Statistics (BLS) data in table 33, although biased by the strengthening of the dollar vis-a-vis national currencies in major shipbuilding countries such as Japan, is interesting in that it shows the U.S. "percentage of additional compensation to hourly earnings' to be the average of the 16 countries' figures but growing at a rate of 6.9 percent per year, six times faster than the Japanese rate. Greek, Korean, and Taiwanese benefits have not increased at all in the last 4 years; Italian and Spanish benefits have declined by about 3 percent per year; and the Association of Western European Shipbuilders (AWES) countries' benefits have grown by only 1 percent per year on average.

Table 33 also shows absolute U.S. wage rates to be among the highest. The United States ranks fifth among the 16 shipbuilding countries listed, with estimated hourly compensation 32 percent higher than the average and growing at over 10 percent per year. The indexed comparison makes U.S. wage rates even more striking—and highlights one source of the Korean competitive advantage. Table 34 removes the upward bias in foreign rates by calculating labor and material components of shipbuilding cost increases in national currencies. While the percentage increase in labor prices, expressed in dollars, was higher abroad, the same increases, calculated in national currencies, show the U.S. rate of increase to be higher than that in any country except the United Kingdom.

Organization of Shipyard Labor

The U.S. shipyard industry is over 90 percent unionized. Avondale Shipyard is the one exception among the ASIB yards. The shipbuilding unions

● "The second greatest source of complaints involved inadequate machines, equipment, and materials. Unsatisfactory aspects of the physical working environment proved the next major source of worker irritation. Work safety was the physical factor most often mentioned. Maritime Transportation Research Board, op. cit., p. 96, citing G. A. Muench, *Study for the Improvement of Motivation in the Shipbuilding Industry,* Phase I, San Jose, Calif., June 1976.

Table 33.—Estimated Hourly Compensation of Shipbuilding Production Workers in 16 Countries

	Percent of additional compensation to hourly earnings				Estimated compensation per hour worked in U.S. dollars				Estimated compensation index U.S. = 100			
	1977	1978	1979	1980	1977	1978	1979	1980	1977	1978	1979	1980
West Germany ., ...	69,1	73.2	73.5	76.8	*8.88*	**11.16**	12.83	**14.25**	**110**	**124**	**128**	**119**
Sweden	54.2	56.9	62.4	63.0	*9.76*	**10.47**	12.21	**13.22**	**121**	**116**	**121**	**111**
Netherlands	71.1	73.0	75.8	75.2	*8.63*	**10.50**	12.02	**12.69**	**107**	**116**	**119**	**106**
Norway	38.2	40.2	40.0	40.0	*9.20*	**10.27**	10.91	**11.97**	**114**	**114**	**108**	**100**
United States	34.9	37.5	38.8	45.6	*8.08*	**9.03**	10.06	**11.94**	**100**	**100**	**100**	**100**
Denmark	18.7	19.1	19.1	20.1	*8.01*	**9.45**	10.68	**11.33**	**99**	**105**	**106**	**95**
Canada	20.3	24.7	26.8	27.8	*8.48*	**8.89**	9.81	**10.76**	—	—	—	—
France	65.6	65.9	68.5	69.9	*6.44*	**8.70**	9.35	**10.73**	**80**	**96**	**93**	**90**
Italy	101.9	90.7	91.2	89.7	*5,55*	**6.61**	7.77	**9.10**	**69**	**73**	**77**	**76**
Finland	51.5	57.5	52.5	54,6	*6.42*	**6.89**	8.17	**8.75**	**79**	**76**	**81**	**73**
United Kingdom	25.6	28.9	30,4	33.0	*3.64*	**4.60**	5.76	**7.58**	**45**	**51**	**57**	**63**
Spain	45.0	40.0	40.0	40.0	*4.41*	**5.05**	6.61	**7.13**	—	—	—	—
Japan	14.9	17.9	18.5	15.6	*5.11*	**6.70**	6.46	**6.77**	*63*	*74*	*64*	*57*
Greece	30.0	30.0	30.0	30.0	*2.58*	**3.33**	3.84	**4.29**	—	—	—	—
Taiwan ... , ...	17.5	17.5	17.5	17.5	*.91*	**1.16**	1.44	**1.66**	11		**14**	**16**
South Korea	17.5	17.5	17.5	17.5	1.40	**1.83**	1.87	**1.72**	**17**	**4;**	**19**	**14**

NOTE: Hourly compensation is converted to U.S. dollars using the average daily exchange rate for the reference period. Changes In hourty compensation In U.S. dollars are, therefore, affected by changes in currency exchange rates as well as by changes in compensation.

SOURCE: US. Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, Divlslon of Foreign Labor Statistics and Trade.

Table 34.–Shipbuilding Cost Increases, 1975-80

	U.S. dollars—hourly labor cost			Percent change from 1975-80 national currencies	
	1975	1980	Percent of change	Labor	Material
United States	$5.47	$8.59	57%	57 "/0	52%
Japan.	3.57	5.76	61	26	29
West Germany	4.34	8.26	90	38	23
Netherlands	4.21	7.43	76	37	89
Sweden	5.62	7.81	39	41	55
United Kingdom	3.12	5.86	88	81	48

SOURCE: BLS/SEA 017.

are characteristically craft unions, and, consequently, multiunion yards are the industry norm. Their influence has been considered largely prejudicial to maximizing productivity: the craft orientation has produced numerous demarcation disputes. More important, it prevents flexible use of labor, complicates planning and scheduling, and discourages career changes.

It is notable that technological development in "Organization and Operating Systems, " where U.S. yards otherwise compare well with foreign yards, has lagged substantially in a subset entitled "Organization of Work. " This pertains to flexibility in assigning and supervising craftsmen's work, and the gap was the second largest found by the MEL study .20

There have been several attempts to upgrade practice in this area, While the first programs were tried in naval shipyards, the interest in human resource management has spread to civilian shipyards, where there are a number of successes, including Lockheed Shipbuilding Co. well-established Quality Circles program and Bethlehem Shipbuilding Co. comparatively new program at the Sparrows Point, Md., plant. These programs address flexible organization as one of many aims, in conjunction with revised work practices. However, the overall craft form of U. S. shipyard organization is still the most common.

Table 35 lists the number of production workers and the union affiliations and memberships in most of the largest ASIB yards. Data from the 1980 census on the makeup of the shipbuilding work force will not be published until late 1983—if then—but the dominance of craftsmen as a worker category is expected to persist. The 1970 breakdown, below, appears to remain broadly accurate.

Worker category	*All industry*	*Shipbuilding*
Laborers, service workers . . .	21.0 percent	6.9 percent
Operatives	23.5 percent	24.8 percent
Craftsmen, foremen, etc.	18.5 percent	52.6 percent
Manager, administrators, technical professions	30.9 percent	15.7 percent

These proportions indicate the predominantly blue-collar character of the existing labor force and suggest the rather flat organizational structure of shipyards. Craft dominance of the shipyard labor force means that technological change must be negotiated, which is time-consuming and can be extremely difficult.

[20] 'Technology Survey of Major U.S. Shipyards, op. cit.,

Table 35.-Unions In U.S. Shipbuilding Yards

Yard	Total production workers as of November 1982	Union
Avondaie Shipyards, Inc.	5,547	Nonunion
Bath Iron Works Corp.	7,293	IUMSWA
Bethlehem Steel Corp., Sparrows Point	496	IUMSWA
Bethlehem Steel Corp., Beaumont	482	Metal Trades
General Dynamics/Quincy Shipbuilding Division	1,491	IUMSWA
General Dynamics/Electric Boat Division	21,130	Metal Trades
Ingails Shipbuilding Division of Litton industries	8,705	Metai Trades
Lockheed Shipbuilding & Construction Co.	2,611	Metai Trades
Nationai Steel & Shipbuilding Co.	3,781	iron Workers
Newport News Shipbuilding Co.	19,668	Usw
Todd Pacific Shipyards, Los Angeles	3,691	iUMSWA
Todd Pacific Shipyards, Seattle	3,337	Metai Trades
Bay Shipbuilding Co.	519	Boilermakers
Livingston Shipbuilding Co.	462	Metal Trades
Total	79,213	
(Total of 27 ASIB Yards = 90,492)		
Totals		
iUMSWA (industrial Union of Marine and Shipbuilding Workers)	12,971	
Metal Trades Council, AFUCiO	36,727	
USW (United Steelworkers of America)	19,668	
iron Workers (international Association of Bridge, Structural, and Ornamental ironworkers)	3,781	
Boilermakers (international Brotherhood of Boilermakers, iron Shipbuilders, Blacksmiths, Forgers, and Heipers)	519	
Nonunion	5,547	

SOURCE: Off Ice of Maritime Labor end Training Report, Feb. 10, 19S3 (Form MA-S1).

SHIPBUILDING PRODUCTIVITY

Shipbuilding productivity is the eficiency with which the industry transforms its raw and semifinished inputs into ships, using the classical factors of production—land, labor, and capital. The physical sites, fixed capital, and labor force of U.S. shipyards have a major impact on their productivity. It is accepted generally that the productivity of U.S. yards is in many cases constrained by their sites and by the yards' inability to effect comprehensive replacement of often obsolete physical facilities. However, in many cases, phased facilities development plans are in place and low-cost, high-return pilot human resources programs are being applied. The productivity of U.S. shipyards is definitely increasing. The rate of increase, however, must be improved in order to compete internationally.

The Determinants of Productivity

Shipbuilding productivity is clearly a function of the interaction of:

- the length of the shipbuilding cycle;
- c the number of man-hours required; and
- the extent of nonproductive peripheral costs.

The following sections discuss each factor as related to U.S. v. foreign experience.

The Length of the Shipbuilding Cycle

Between 1975 and 1980, over 60 commercial and 80 naval ships were under construction in U.S. yards at any one time. However, only about 20 commercial and 15 naval ships actually are delivered per year. This ship-under-construction-to-delivery ratio, furthermore, has not changed appreciably over the past three decades. It indicates that a commercial ship may take 3 years to construct, while a naval ship averages 5 to 6 years. This conclusion admittedly is simplified because many other factors contribute to the large discrepancies between the number of ships under construction and those delivered during any period of time. However, ship flowrates (a ratio of deliveries to ships under construction) in the United States historically have been about one-half those of European shipyards and less than one-third those of Japan.[21] This means that the average modern merchant ship spends over twice as much time in a U.S. shipyard as a comparable ship in modern foreign shipyard. Considering the capital invested per ship, it is evident that the additional construction residence time adds at least 5 to 6 percent to the cost of the ship. If this figure is augmented to reflect the complementary cost of inventory—which amounts to 4 to 6 months of supplies for the average U.S. shipyard compared to 1 to 8 weeks in an equivalent foreign yard—the total capital cost of excess ship and material inventory time increases U.S. shipbuilding costs by 8 to 9 percent. Similar comparisons of the cost of construction of naval ships are not possible; combatant and warships vary extensively in detail.

Because there has not been extensive U.S. experience with continuous series production, learning curves for the U. S, shipbuilding industry have not been established. Results from naval building programs are misleading because of the extent of changes expressly allowed in the production of the series and the frequent splitting of lead ship and series production between distant yards. It appears that the industry is capable of realizing substantial time savings in series production, with associated reductions in inventory costs. This requires customer acceptance of standardized designs, as noted earlier, but the extent of customization by U.S. shipyards is incompatible with maximum production efficiency.

The Number of Man-Hours Required

In a recent study by the Maritime Transportation Research Board of the National Academy of Sciences it was noted that, despite increasing mechanization,

> . . . direct labor costs in U.S. shipyards are between 40 and 50 percent of the finished product cost, depending on type of ship . . . (the) ratio (between labor and material costs) has remained relatively constant since 1961, increases in labor efficiency being largely offset by rising wages.
>
> High as these figures are, they tend to underemphasize the total labor component in shipbuilding. For a ship, labor costs constitute 70 to 85 percent of the value added. . . . In the 15-year period from 1958 to 1972, the share of added value received by labor in U.S. shipbuilding averaged 77 percent, never falling below 71 percent and rising as high as 84 percent. . . . The labor-intensiveness of the industry is underscored by noting that, among 22 industries, U.S. shipbuilding ranks 15th in assets per employee and 3rd in sales per invested dollar.[22]

A basic source of data on the scope of productivity improvement through reduction of man-hours is the MarAd-sponsored IHI-Livingston project. This has been characterized as a ''unique contract for transfer of Japanese technology, " but the project also established valid cost data on the comparative man-hour requirements and average length of shipbuilding cycle. It showed that the length of the U.S. shipbuilding cycle, in theory, could be reduced by 50 percent, from 24 months to 12. Similarly, the man-hour requirement could be reduced by 60 to 70 percent However, there are social and institutional barriers to the measures that would be required to effect these changes; these will be discussed as they relate to specific productivity -enhancing measures.

The Extent of Nonproductive Peripheral Costs

Workplace Safety and Health Costs .—Zosen's annual statistical summary of Japanese shipyards' safety record is frequently compared with the U.S. shipyards' record.[23] The U.S. accident-frequency-rate per thousand workers per year is 269; the same Japanese rate is 2. While these statistics may not

[21] Shipbuilders Council of America, Association of Western European Shipbuilders, and Zosen, annual reports, 1980, 1981, 1982.

[22] Maritime Transportation Research Board, op. cit.

[23] BLS and Zosen figures, 1979 and 1980.

be comparable directly due to differences in accident-reporting practices between the United States and Japan, it appears that the accident rate in U.S. yards is considerably higher. Since benefit payments under the 1972 amendments to the Longshoremen's and Harbor Worker's Compensation Act (LHWCA) have increased by an estimated 600 percent, this is one obvious area of concern.[24] The five shipyards responding to an SCA 1978 study estimated these costs at 2.4 to 4.7 percent of the price of the hypothetical ship and suggested that the foreign equivalent requirements were ' 'less stringent and (had) a lesser cost impact than those of the United States. '[25]

"Buy America" Policy .—The U.S. supplier base is comparatively independent of the shipyards, and many shipbuilders argue that it does not make economic sense to hinder the shipbuilding industry's development to provide marginal support to the supplier base. Existing ' 'buy America' policies (i. e., requirements that 50 percent of machinery and materials for subsidized ships be of U.S. manufacture) are difficult to supervise and define, With more and more U.S. firms taking advantage of lower foreign labor rates—and higher standards of productivity and industrial discipline —it probably will become harder to follow this policy and more disruptive of production. This is particularly true given the trend toward increased buying of components in lieu of fabrication by the yard itself.

Productivity Trends in the U.S. Shipbuilding Industry

Many measures of production have been used in the shipbuilding industry. Each has shortcomings, and the assessment of shipbuilding productivity remains difficult, particularly in the United States. Comparing labor and production is particularly difficult because collected production figures often relate only to larger vessels or larger yards, but labor statistics typically are inclusive of the entire industry. Other problems with productivity measures include:

- lack of accepted skills classification schemes;
- a multiplicity y of ways of quantifying ship production;
- difficulty in quantifying compensation and fringe benefits on a comparable basis for international comparisons;
- differing proportions of subcontracting in the shipbuilding process, both intra- and internationally; and
- too high a level of aggregation in statistics, e.g. , assimilation of repair to shipbuilding.

Although there are many possible measures of output/productivity, the two most satisfactory measures of output are compensated gross registered tonnage **(CGRT)** and value-added.

CGRT, unlike gross tonnage, lightweight tonnage, or deadweight tonnage, attempts to allow for the differing levels of complexity of ships, which is particularly desirable where naval vessels figure in many yards' workload. However, the adjustment coefficients are approximate, judgmental, and vary over time and between studies. The present coefficients used by West European shipyards, for example, will be revised shortly to reflect changes in the Organization for Economic Cooperation and Development (OECD) system for calculating gross tonnage. The OECD system is being aligned with the 1969 International Convention on Tonnage Measurement of Ships, which changes gross and net tonnages for several vessel types. Table 36 shows the trend in the labor required to produce

Table 36.—CGRT Measure of Productivity Gains in Private U.S. ASIB Shipyards

Year	CGRT (000s)	Employment[a] (000s)	CRGTI employee/year	Manhours/ CGRT
1980 . . .	393.3	40.9	9.6	200
1979 . . .	545.3	39.9	13.7	140
1978 . . .	289.5	39.6	7.3	263
1977 . . .	446.6	40.0	11.2	172
1976 . . .	373.0	38.7	9.6	196
1975 . . .	276.7	35.4	7.8	243
1970 . . .	199.6	30.4	6.6	292
Growth in productivity per year			3.5°/0	

[a]Derived number: proportion of total labor force in private yards (70 Percent) x proportion of private yard labor in ASIB yards (88 percent) x proportion directly engaged in shipbuilding (50 percent), i.e., 23 percent of total employees are shipbuilding production workers in ASIB yards.

NOTE: The CGRT output understates U.S. yards' potential productivity, given a stable workload, because it does not really reduce varying ship types to equivalent tonnage. Only the direction of the trend and its average magnitude are significant.

SOURCE: E. G. Frankel Report to the Office of Technology Assessment, 1983

[24] "Longshoremen's and Harbor Workers' Compensation Act Needs Amending' (Washington, D. C.: General Accounting Office', 1982).

[25] 'Study of Cost of Federal Government Regulation on Shipbuilding Prices' (Washington, DC.: Shipbuilders Council of America, 1978), p. 4,

one **CGRT** of output in U.S. shipyards. This measure indicates that the output per employee has increased by 45 percent in the past 11 years, a gain of approximately 3.5 percent per year.

Value-added is the difference between total revenues and the cost of purchased intermediate goods and services and, as such, may be affected by market imperfections. Value measures of productivity also are less useful in international comparisons and where different technologies, or levels of technology, may be employed. Value-added is superior to sales, however, because the latter reflects widely disparate levels of Government support to shipbuilding. Table 37 measures the ratio of value-added to the capital and labor inputs and shows that the U.S. shipbuilding industry has made a 12-percent absolute gain in productivity in the past decade, a rate of 1 percent per year.

The ratios of CGRT and value-added to input measures such as man-hours or dollar value of assets may be crude absolute measures of productivity, but they do indicate its trend. From 1960 to 1980, the value-added-per-employee productivity measure for U.S. yards increased by about 27 percent while the payroll-per-employee measure increased 15 percent (in current dollars).

These real but modest productivity gains of the U.S. shipbuilding industry have lagged the gains of its Japanese, Korean, and European counterparts. In 1973, the Commission on American Shipbuilding compared some historic statistics on the productivity of major shipbuilding nations over a 6-year period and found U.S. productivity to be only 50 percent of Swedish and 43 percent of Japanese. U.S. man-hours per delivered-ton averaged 30 percent higher than Japanese and Northern European yards. These figures have increased at a rate that reflects the small productivity gain computed above; but in 1980, A & P Appledore concluded that U.S. shipbuilding productivity is still generally only half that of Scandinavia and Japan.

It is difficult to compare U.S. and Japanese and Korean shipbuilding productivity because the type, size, series, and complexity of ships built vary so much. Japan and Korea largely have built series of standard tankers, bulk carriers, and other types of ships, usually designed by the yard itself for construction by the yard. U.S. yards, by comparison, built small numbers of often custom-designed and comparatively complex ships. Few of these ships are built in series of three or more.

Comparing the productivity of U.S. shipyards with those of Japan and Korea, it is possible only to evaluate their respective performance in the building of comparable vessels such as medium-sized tankers or dry-bulk carriers. The limited information available shows that:

- U.S. shipyards require 38 to 65 percent more man-hours to build the same or similar ship; and
- labor productivity in terms of output-per-man-hour for basic measurable jobs such as stick welding, is comparable and, in fact, often shows U.S. workers to be more productive.

While U.S. shipyard workers appear to perform equally well in the performance of comparable jobs under identical conditions using similar equipment, the percentage of time in which U.S. workers perform actual work is appreciably lower than that of their counterparts in Korea and Japan.

The lower comparative productivity of U.S. shipyards is considered to be explicable largely in terms

Table 37.—Value-Added Measure of Productivity Gains in U.S. Shipyards (millions of current dollars)

Year	Value added ÷	(Payroll +	Depreciation) =	Productivity ratio (PR)	Index of PR
1980 . . .	5,338	3,360.4	163.3	1.51	1.12
1979 . . .	4,587	2,927.6	152.7	1.49	1.10
1978 . . .	4,107	2,647.5	138.7	1.47	1.09
1977 . . .	3,823	2,494.0	139.9	1.45	1.08
1976 . . .	3,287	2,219.5	1 lo.5a	1.41	1.04
1975 . . .	2,923	1,995.6	96.5[a]	1.40	1.03
1970 . . .	1,610	1,161.2	36.0[a]	1.35	1.00

[a]Estimated as 0.033 percent of gross fixed assets: depreciation figures not collected before 1977 Census of Manufactures.

SOURCE: J.A. Gribbin.

of: 1) the military market demand for excessive customization, 2) restricted opportunity for learning from series construction, 3) older facilities and specific technological weaknesses, 4) materials availability and origin constraints, and finally, 5) a fluctuating and less effectively utilized work force, with skill deficiencies arising from insufficient training and inflexible union practices, which do not facilitate redirection of careers and expansion of skills. The Appledore study attributed 30 to 35 percent of the productivity difference to the latter cause alone-foreign yards are said to have "superior organization and systems and a more effective work force. '[26]

Improving U.S. Shipbuilding Productivity

Many U.S. shipyard facilities were laid out during World War II and have not been redeveloped since. To enhance productivity in these yards, greater attention is needed to integrate production planning and engineering functions. Many believe that the scope for improving the productivity of U.S. shipyards is significant and that, in many cases, only limited capital improvements are needed. While the prevailing U.S. wage rates probably will make it impossible for U.S. shipbuilding costs to be as low as foreign competitors such as Korea, it would appear possible to get much closer than today's price differentials indicate. In a report to OTA by E. G. Frankel, Inc., the following actions were suggested :27

- impose serial construction of ships in sets of not less than 12, all built in one yard;
- allow material to be bought without reference to national origin, with no import restrictions, and no duty on imported materials used in the construction of foreign-going ships;
- reduce inventory size and cost to no more than 1- to 2-month supply needs;
- Utilize lower U.S. capital costs when available;
- employ modern production, production engineering, planning, and management methods; and
- incorporate latest methods of design and production through effective research-and analysis.

Many of these factors have been applied in U.S. shipyards specializing in the construction of offshore vessels, barges, tugs, and workboats with marked success in achieving high productivity.

To make substantial productivity improvements, most U.S. shipyards would need to concentrate on production-oriented designs accompanied by industrial engineering applications such as simplified materials flow, mechanization, use of three-dimensional subassemblies, and preoutfitting. Productivity-enhancing measures also would include introduction of integrated computer systems for outfitting, manufacturing, and assembly. Perhaps most importantly, improving productivity would require modernization of management, planning processes, and organization of work.

The flexibility required by U.S. yards to respond to changing product and output demands in the past has led to the following problems:

- delay, deferral, or elimination of introduction of new technology;
- concentration on investment in basic processes such as steel preprocessing, fabrication, and subassembly, activities that are not among the most labor-intensive in any yard;
- large fluctuations in shipyard manning with huge manpower turnovers of as much as 67 percent per year among blue-collar workers;
- large expenditures for training, retraining, and lost posthiring and prefiring time;
- lack of medium- and long-term (strategic) planning and management preoccupation with short-run, even daily operational problems that should be delegated to production management;
- use of outside ship designers with the result that designs usually have to be modified to accommodate the particular production/assembly needs of the yard. This results not only in added costs, but also lost time and compromised designs;

[26] A & P Appledore, *Development of a Standardized U.S.-Flag@-Bulk Carrier: Innovative Analysis of Cost-Cutting Opportunities* (Washington, D. C.: Maritime Administration, U.S. Department of Commerce, 1980).

[27] "Status and Trends of U.S. Shipbuilding Technology and Productive Capacity," written for the Office of Technology Assessment by E. G. Frankel, Inc., December 1982.

- lack of effective marketing strategies;
- lack of standardization in procedures, as well as product parts and manufacturing and assembly standards;
- insufficient R&D in methods, production aids, basic processes, materials research, etc.; and
- lack of coordination among the industry.

It is difficult to determine if this last factor is due to concern with regard to antitrust actions or simple competitive posture. Yet countries like Japan and Korea, where yards compete much more for the same markets, have found more effective ways to cooperate and coordinate their R&D in basic processes, procedures, and standards. They rely on the maintenance of competitive positions through management efficiency, labor-management collaboration, marketing, and product design. This approach appears to result in efficient, effective technology development.

American shipbuilders have attempted to improve the industry's productivity through:

- improvements in facilities and equipment;
- introduction of CAD/CAM; and
- increasing adoption of national shipbuilding standards.

While facility and equipment improvements were introduced starting in 1966, practical adoption of CAD/CAM (described in ch. 5) was begun only in 1972-74, and shipbuilding standards are under development only now. U.S. shipbuilding lags behind foreign shipbuilding in shipbuilding standards and even more so in standards for suppliers and equipment manufacturers. Shipbuilding productivity is greatly affected by CAD/CAM and standardization. Japanese shipbuilders, for example, use more than twice the amount of automatic welding as U.S. shipbuilders. In Japan, computers are used increasingly not only to assist in welding automation but also in welding quality control, This in turn has led to a large increase in the use of welding robots. In U.S. shipyards, only one welding robot is in use as a pilot operation.

Standards

While 13 U.S. national shipbuilding standards have now been published, and 100 are in various stages of development, Japan has established 7,750 industrial standards with 518 shipbuilding standards that cover all types of components, equipments, materials, fabrication methods, and more. It must be recognized, though, that Japanese industrial and shipbuilding standards are enforced by an industrial standardization law enacted in 1949. U.S. shipbuilding-standard development and adoption are completely voluntary. At present, a panel of the American Society of Testing Materials is developing U.S. shipbuilding standards.

Shipbuilding Management

American shipbuilding management and planning has become a topic of increasing discussion in recent years, and various proposals for change have been advanced. Many of these propose adoption of certain techniques and approaches successfully used in other major shipbuilding countries such as Japan and Korea, where shipbuilding management is based on organizational, decision-making, and operating structures and procedures founded on quite different cultural backgrounds, human relations, and traditions than those found in the United States. While some of the techniques and approaches found successful in those countries may be transferable, it must be recognized that the environment in the United States cannot be changed in the short run. This makes successful application of some of these methods difficult.

Factors that make Japanese and Korean shipbuilding competitive include the use of cost controls in engineering, quality circles, labor incentives, high-productivity manufacturing processes, standardized ship design and production, labor flexibility, good supplier and customer relations, and effective production-planning management and control. There are some factors that are distinctly unique, such as the lack of adversarial relations between shipbuilder and client, and management and labor. There is a general agreement in these countries that adversarial relations and potential litigation hinder efficiency and timely, low-cost delivery. Similarly, most supplier, client, and labor issues with shipbuilding management are resolved by various informal approaches resulting in little if any delay. This is quite different from the generally formal approach used in the United States, where procedure, documentation, and even conflict resolution methods are often defined.

SUMMARY

Federal assistance to U.S. shipyards through construction subsidies over the past two decades appears to have discouraged independent attempts to reach and maintain commercial viability. At present there is uncertainty about the implementation and scope of overall maritime policy and naval procurement policy. Since subsidies for commercial construction have been terminated, one policy alternative would be to replace subsidies with a form of support that directly enhances productivity and competitiveness, and at the same time put naval procurement on a less cyclical basis. In addition, the Federal Government could enhance industry efforts to improve productivity by coordinating those efforts or funding their coordination.

Some of the more innovative technical approaches to improving productivity employ a man-machine system perspective. It is considered more cost effective to reduce the labor component of shipbuilding by using electronic assistance in easily mechanized areas such as precision control, than by making larger—often inflexible-investments in capital equipment that attempt to emulate human flexibility and pattern-recognition capabilities. In addition, current social philosophies and the trend toward increasing stability in the industry work force require from employers a complementary effort to stabilize employment opportunities and improve the quality of industrial life. There is great scope for productivity improvement through better use of human resources.

Possible directions for productivity improvements in U.S. shipbuilding have been discussed throughout this chapter. It should be recognized, though, that technological improvements will not necessarily pay off unless accompanied by improvements in the structure, organization, and management approach used in the industry. Product development, client relationships, and marketing are other important areas where improvements are needed if the industry is to achieve a more competitive position in world shipbuilding.

Many of the deficiencies and opportunities identified in this report have been identified previously, particularly in the MEL survey (1978) and the MTRB's *Shipbuilding Research and Development: A Recommended Program (1973)*. Comparatively few of their suggestions were implemented. Some in the industry have claimed that the reason is institutional barriers to transfer of foreign technologies for productivity improvement. Others claim that the reason for lack of progress is the tendency of the industry to identify a Government-sponsored ''stable increasing (sic) ship construction program' '[28] as the solution to the problem of lack of international competitiveness, rather than to develop a program based on the industry's own resources and planning.

A larger volume of business could allow U.S. shipbuilders to realize economies of scale and increase productivity through higher utilization of facilities, but only at realistic prices. Perceptive marketing might enable U.S. yards to overcome their cost disadvantage to some degree, particularly if a new product were developed and offered. While volume is important, it appears that facilities, management, and labor are the principal areas where improvement can be most readily effected by joint actions of industry and the Federal Government. These are discussed below.

The Physical Facilities Problem

The work and material flow is severely compromised in a converted old yard, as is the method of fabrication, assembly, weight handling, and ship erection.

Most major shipbuilding countries have found that it is cheaper and more effective to replace old shipyards with new yards specially designed and located for the production of modern ships. It is interesting to note that the United States and Britain resorted to the modernization of existing yards on a piecemeal basis, while most other major shipbuilding countries replaced many of their yards with completely new yards because they found that in the long run it was a cheaper and better approach. The primary reasons for this difference appears to be that U.S. shipbuilding management generally

[28] Maritime Transportation Research Board, "Shipbuilding Research and Development: A Recommended Program' (Washington, D. C.: National Academy of Sciences, 1973), p. vii.

plans only for the short term, while Korean, Japanese, etc. , shipbuilding management is organized to plan for the medium to long term.

Possible policy approaches are to:

- make investment funds available to yards for development and implementation of viable long-term plans;
- guarantee loans for technology transfer by purchase, where other means—e. g., joint venturing—are demonstrably infeasible; and
- devise a capacity reduction plan that could convert some shipyards to other uses and ease the closure of worst affected yards.

The Management Problem

It has been argued that the dominance of subsidized and naval shipbuilding has stifled U.S. managerial innovations. In fact, subsidy has failed to develop the U.S. shipbuilding industry and may well be a cause of the failure to resolve fundamental problems, such as the excessive customization of vessel designs. Many believe that the shipbuilding industry needs to extend its investment horizons, especially since most U.S. yards are subsidiaries of financially robust companies and have provided poor return on investment for years.

Management must develop mechanisms for identification of technological voids and evaluation of solutions. This requires diagnostic skills and an alertness to developments in other industries, reinforcing the perceived need for a higher ratio of technically skilled managers at all levels in the industry and higher qualifications for these professionals.

Possible policy approaches are to:

- facilitate intra-industry information exchange, technology transfer, and problem diagnoses by sponsoring regular conferences, reporting, and other means;
- review the content and administration of joint Federal/industry R&D and fund only high priority work;
- improve the Federal R&D structure and encourage the industry to implement its efforts;
- support a Government/industry management training center;
- ensure that any Government support stabilizes the workload, which in turn allows the retention and training of the work force and the development of better operational planning techniques; and
- provide Federal support to development of industry standards, even to the extent of legally mandating their adoption.

The Labor Force Problem

The casualized employment system in U.S. shipbuilding is one of the largest barriers to improved productivity. Since many of the theoretical foundations that underpin high foreign productivity are of U. S. origins, there is logically substantial scope for a program of institutional changes. This area is one where the rate of progress is difficult to predict but could be surprisingly fast.

Possible policy approaches are to:

- disseminate information on the use of ' 'social technologies, such as quality circles and (semi-) autonomous working groups in U.S. yards, both for their beneficial effects on productivity and for their effect in creating openness to new technologies;
- implement technology transfer in areas of production skills and management methods by training and fellowship programs and translation and dissemination of foreign references;
- develop a cross-trained labor force to provide better responses to fluctuations in the need for various craftsmen (multiskilling);
- require shipyards to attack excessive turnover directly and set up interim programs for limited ' 'outplacement' of redundant employees; and
- support an industrywide training program.

The above approaches are some detailed actions that could be used to enhance U.S. shipbuilding productivity. OTA analysis suggests that U.S. shipyards can improve their competitive position in the world but only with a concerted effort on the part of both industry and the Federal Government. However, productivity improvements alone will probably never close the very large foreign merchant ship price differentials that are partly the result of lower wage rates and the direct and indirect subsidies of other governments. Federal policy, therefore, must acknowledge that the future viability of U.S. commercial shipbuilding will depend on some form of Federal support. Such support may be minimal where the United States has some market or technological advantage (e. g., LNG ships, offshore drill rigs a few years ago, or possibly Arctic tankers in the future) but will need to be substantial where other nations now have technology, experience, and market advantages (e. g., large tankers and bulk carriers).

At present, the U.S. Navy is supporting the U.S. shipbuilding industry with massive orders. It would be useful for policymakers now to look beyond the U.S. Navy building program and devise a plan for U.S. shipyards at least 5 years hence. The existing U.S. Navy program can be helpful for encouraging productivity improvement in the near term. After the U.S. Navy program slows, either new markets must be developed or Federal support must be increased or U.S. shipyards will probably contract to a much smaller base.