Shipbuilding Process – Challenges and Opportunities

An IBM Product Lifecycle Management Resource Paper

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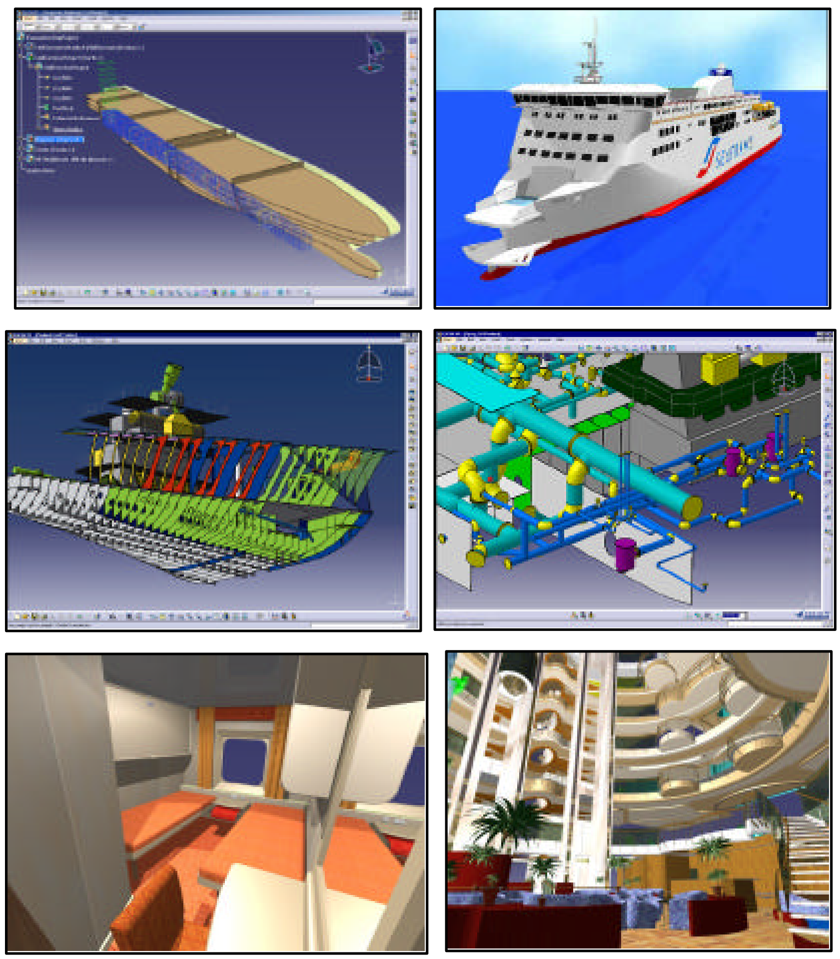

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This white paper was prepared by Deltamarin Ltd for IBM Product Lifecycle Management as a marketing, sales and support resource.   It provides essential background on the business environment and trends in design-production being implemented at yards worldwide. While there are considerable differences between yards, most face common economic conditions in a global market. As a result, yards are putting in place new information systems to support greator design flexibility and more efficient production processes. Their goal is to improve their competitive position through innovative design, increased quality, faster time-to-market and tighter cost controls. These goals create I/T requirements for collaboration, digital mockup, simulation, change control, shop floor assistance and production control – for PLM Solutions.

Although this paper draws most of its examples from passenger and ferry builders, the processes described here are also applicable to military and commercial yards.   We hope you find this paper useful in identifying marketing, sales and support opportunities. This is the first edition and we welcome your comments and suggestions for future updates. Please address them to:

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SHIPBUILDING PROCESS - CHALLENGES AND OPPORTUNITIES

1. SHIPPING AND SHIPBUILDING - MARKET AND ECONOMIC SITUATION

1.1 General Market Situation in Shipping

Shipping has experienced good times since 1997. Most shipping sectors have been going through an expansion rarely seen before, especially in the segments of container, LNG and cruise shipping.

At the same time, order books have been well filled for most of the shipyards worldwide and an expansion of shipbuilding capacity has been ongoing, first in Korea and now in China. Even major European cruise shipbuilders have nearly doubled their capacity during the past few years.

Shipping and shipbuilding cycles, of course, depend very much on the world economic situation and consumer behavior, but also on more specific developments such as oil consumption in the Western world, automobile industry production patterns, paper consumption, leisure market and holiday spending, etc.

But shipping and shipbuilding tend to accelerate these cycles. In the wake of a good shipping market and higher rates, owners in many shipping sectors over-ordered in 1999 and 2000. At the same time, scrapping increased only marginally, meaning that older vessels were kept to take advantage of the possibility of quick returns.

Yards still have a reasonable workload for 2002, but order books are drying up. Together with increased yard capacity, competition for newbuilding orders will be fierce. Newbuilding prices recovered in late 2000 and early 2001, but it appears that over-capacity already is leading to price cutting by some desperate yards. The big question: Are the very low yard prices going to be irresistible for owners once more? A general prediction on the market is that shipbuilding prices may continue to fall, leaving any major recovery to take place in autumn 2002, at the earliest.

Long-term predictions for scrapping show an improvement of 30-35% compared to levels of the late 1990s, up to 17-18 million gross tons per year. If this materializes, significant over-capacity will be removed from the market and an upturn in the newbuilding market could start as early as 2003 instead of 2005, as assumed in the most pessimistic predictions. New safety regulations for ferries and passenger ships and double hull requirements for tankers, which will pave the way for at least some part of the projected scrapping volume, offer support for projections of an earlier recovery. In addition, the International Association of Classification Societies (IACS) also is introducing new safety requirements for bulk carriers.

Newbuilding activity is estimated to be about 25 million gross tons annually through 2005, a drop to only 54% of the contracts in 2000. By historical standards, however, this is not as poor a market as persisted throughout most of the 1990s, and is double the typical level of the 1980s.

It is, however, important to understand that shipbuilding capacity has increased markedly during the 1990s. 2002 and 2003 are going to be difficult years for the industry. The only market sector showing increased activity is offshore building, including floating production units and service vessels. But general economic recovery will play an important role and shipping is always one of the first areas to quickly feel a recovery.

1.2 Impact on Shipbuilding

The shipbuilding price recovery during 1999-2001 was, in general, modest and unevenly distributed. An average price increase, according to Fairplay statistics, was 8% during 2000, but prices weakened towards the end of 2001.

Shipbuilding capacity is typically managed to maximize throughput, i.e. to run at maximum load, which decreases unit costs and improves efficiency. To maintain employment, generally is considered more important than the final contract price.

Global shipbuilding capacity will continue to rise in the short term, as much as 15% by 2003, mainly due to productivity improvements and new capacity in China. In the past decade shipbuilding capacity more than doubled.

The only sectors still improving their order books in 2001 were builders of tankers and LNG carriers. All other sectors decreased their order intake. This year will be extremely difficult as many of the tanker and container orders placed in 2000 will be delivered in the middle of the depressed market.

The typical European market sectors -- cruise ships, ferries, ro-paxes and ro-ros -- have boomed during the past two years. The Far East yards tried to enter the cruise ship market throughout the ‘90s, with a major push in 1999. This prompted European yards to increase their capacity for building cruise ships to defend their market, though some of the ferry orders slipped to the Far East between 1998 and 2000.

Today the cruise ship order book remains high, even though some options have been postponed in the aftermath of September 11th. Year 1999 was a record in terms of new orders and the deliveries will extend into 2006. Capacity increase for the coming years is high: 9% in 2002, close to 14% in 2003, 7.5% for 2004 and 2% in 2005. Although the growth rate in passenger numbers in North America was as high as 17% in 2000, the average rate has been 8.4% since 1980. The industry is recovering well at the moment from the initial drop in passenger numbers after the September 11 terrorist attacks on the U.S., but prices are still well below the level of previous years. Cost cutting is the key word in cruise operations at the moment and it appears that serious newbuilding discussions will not start before the latter part of 2002, with deliveries in beginning in 2005 and beyond.

The ferry market has been very active during the past five years. The Mediterranean and especially the Greek market have experienced a flow of newbuildings unlike any seen before. Public financing has been the main feature in the growth, but unfortunately that is over for now. Meanwhile, some heavy investors have been forced to change direction, selling out even recent deliveries. The phasing out of tax-free sales has postponed some new projects in Northern and Western Europe, while the investment rate for new ferries is projected to be low in the coming two years.

LNG carriers, container vessels and ro-ros traditionally were built almost exclusively in Europe, but now Far East shipbuilders have conquered most of these markets as well. That leaves Europe with only two markets where the outlook is promising and the competition is limited: luxury yachts and navy projects. Some European shipbuilders already have secured additional work through these two sectors. Meanwhile, some of the navy yards are reconsidering their planned entrance into commercial shipbuilding in the wake of damaging early experiences. Therefore, they are likely to remain concentrated in their core business.

The market perspective for many shipyards is short at the moment. At the same time, shipbuilding subsidies are being withdrawn in Europe, making it even more difficult for the region's shipbuilders to compete. Year 2002 will be difficult for all shipbuilders, but especially in Europe. Political decisions may be rethought, but some of the yards may have to reduce their capacity or even close down newbuilding activity.

It is, however, obvious that the market situation is driving forward new, more efficient solutions, procedures and business practices for shipbuilding.

1.3 Safety and environmental issues

Safety standards typically are being driven in response to accidents, especially in the case of rules developed after accidents sustained by the ferry and cruise industry. Groundings, collisions and fires in the late '80s and '90s have contributed to significantly improved safety standards and requirements for passenger vessels and especially for ro-ro passenger ferries.

Tanker double-hull requirements in the U.S. came into force a long time ago, but the phasing-out period for non-conforming vessels has been extremely long and has contributed to the fact that only a few U.S. ship owners continue to operate in international trade.

Bulk carriers are going through the same process at the moment, with several accidents leading to rule and design changes. The European Union has taken an active role in putting local requirements in force much more quickly than would be possible through the IMO.

There are, however, two major issues bubbling in the safety environment at the moment. The introduction of very large cruise ships has led to widespread discussions about their safety, especially regarding evacuation procedures and lifesaving systems, and ship owners have responded proactively. Rather than waiting for new regulations to come out of the long process of IMO, ship owners are actively working to independently improve the safety standards and level of their ships. Simple, straightforward practical methods are being applied in conjunction with theoretical risk assessment methods. Classification societies and specialized companies are supporting this work.

In addition, for the first time in shipbuilding history, equivalent design soon will be approved, assuming the level of safety is at least the same as for existing ships built to the latest rules. This would release ship designers from following the strict rule requirements concerning issues like arrangements, and would give them an opportunity for better commercial design. However, the designer will become responsible for proving the safety level of his design is equivalent to that of vessels designed to the latest rule requirements. Still, for the first time, rules are not just an additional burden driving designers to search out loopholes that will make design and building easier and cheaper. Now, designers have been given the challenge and opportunity to create real functional and safety optimization. Recent advances in the development of numerical design tools arte leading the way to simulation and risk-based designs.

Environmental issues are developing in the same way as safety issues. Basic requirements are being set by IMO but local requirements and proactive owners are leading the development much faster than expected a few years ago. Investment in new technology is prevalent.

New safety and environmental requirements only turn into additional costs if the industry is not prepared. For those who are prepared, the requirements are a challenge but also an opportunity.

Simulation and risk-based design methods will represent the first steps toward a real revolution in ship design. However, the bulk of the benefits will only be realized by those yards that implement an efficient 3D conceptual design system linked to an all-inclusive product model and handled with knowledge management systems linking all related parties.

1.4 Shipbuilding environment

Shipbuilding is a basic metal industry, which requires typically heavy investments. It is not easy to move the production facilities to places where the workforce is cheapest, as is possible with textiles, consumer goods or electronics.

At the beginning of the 1980s, European shipyards produced and built 70-80% of the value of each ship by themselves. They produced diesel engines, steering gears, watertight doors, interior paneling, cabins, etc.

The steep fluctuations in shipbuilding, coupled with heavy investment by Japan and Korea in shipbuilding, led to two major developments in the early 1980s: the closing of shipyards, as seen in Sweden and the UK, or specialization and outsourcing, as observed in Finland and Germany. At the moment, outsourcing in Europe is prevalent. Typically, the yards produce and build only 20-30% of the value of each ship by themselves, with the rest being produced and installed by suppliers, subcontractors and turnkey suppliers.

Suppliers have always played an important role in the shipbuilding industry, taking part in the technical and technology development in specific areas while helping to smooth out major capacity and load variations. Outsourcing was accelerated by the second oil crisis in the early 1980s. Yards sold all of their remaining supplier parts and concentrated on their core competencies. The market depression led to the need for further cost savings and outsourcing was a prime opportunity.

There were major differences in the way major European shipyards went through the process. Some included design and engineering in this first phase of outsourcing, while some went so far as to outsource the whole process, including engineering, supplies, installation and even commissioning. The presence of a local supplier industry and infrastructure has had a major impact on the course followed by individual yards.

In Italy, small- and medium-sized yards have relied on their own small workforce, concentrating on structural, machinery and piping work while hiring subcontractors to deliver and install outfitting, interiors, air conditioning and similar systems. In Finland, yards built specialized vessels for the Soviet Union, requiring substantial supporting infrastructure and suppliers. UK, Norway, Holland and, to some extent, Germany benefited from the big boom in North Sea offshore building in the 1980s and early 1990s.

The shipbuilding supplier and subcontractor industry was developed in North and Central Europe. Germany, Norway, Holland, UK, Finland and Sweden dominate the world's shipbuilding supplier industry. Germany's supplier and subcontractor industry ranks Number One worldwide, with an invoicing level double that of the German yards. Yards have been closed in Europe, reducing capacity, but the supplier industry has been growing even faster than yard capacity has been declining. In Finland, 18,000 more people worked in shipbuilding in the early 1980s, most of them at shipyards, than are employed today. Current shipbuilding employment is 35,000, of which only 6,000 work at shipyards.

The first phase of outsourcing and building big North Sea platforms was not very successful. Cost overruns and delays were typical. The industry responded by finding even cheaper suppliers and workforces, but achieved little improvement. This led to further analysis of project management, project coordination and working procedures. The industry learned that it had not been prepared to achieve massive outsourcing and cost cutting simultaneously. The technical coordination between the different parties involved was difficult to manage, while scheduling and installation management and coordination added further complexity.

Design and engineering subcontracting is still carried out by many yards on a per discipline basis (steel, piping, machinery, outfitting, electricity, etc.), but the actual installation phase should be concurrent with engineering. Design and project coordination have become new imperatives.

It is obvious that in the Far East, shipbuilding conglomerates need to follow the European industry's lead. These companies must break down into smaller units by industry and by industry branch, a process that began in Korea after the Far Eastern monetary crisis of 1998. Once that is accomplished, the industry probably needs to look at achieving consolidation between yards and between suppliers. The pressure from Chinese shipbuilders on the Korean and Japanese home markets will accelerate this development. U.S. shipbuilding, after stumbling years in the commercial market, obviously will continue to concentrate on navy vessels.

Therefore, Europe continues to have a major advantage in its infrastructure and supplier and subcontractor industry, a benefit that the other regions generally lack. This provides Europe with a substantial buffer in the extremely cyclical shipbuilding and offshore industry. Although the yards may experience difficult years, the supplier industry will keep the business, investments, R&D and related universities running. The region's knowledge management systems, product modeling techniques and systems enabling concurrent engineering create additional opportunities to further develop efficient work sharing, reducing lead times and costs.

1.5 Trends in shipbuilding

Technical development in the shipbuilding industry was faster during the 1990s than ever before. New materials, equipment, systems and arrangements were introduced at a rapid pace. This process once was driven by the yards, and they continue to have an important role. As the industry has struggled, however, the suppliers have clearly taken a central role. Typically, they have been first in introducing new technology, along with ship owners. Independent consulting offices have had an important role as well. This has been especially true of conceptual thinking in a variety of areas -- for example, developing better and more efficient overall ship configurations by combining new technology and systems in unconventional ways.

Diesel and gas turbine machineries are typical for several ship types today. Podded propulsion became a standard for cruise ships during the 1990s. Waterjets deliver power up to 10 times more power today than was available in the late 1980s. Many ship service and safety systems have experienced similar advances. In cruise ships, automation and machinery control systems have developed from rather simple systems with a few hundred alarm points into complicated, multilevel systems with more than 10,000 alarm points.

The development has been technology driven, however, and the shipyards have seen this development as a threat rather than a challenge or opportunity. This is based on two simple realities: responsibility and statistics. Shipyard cost estimates are based on statistics, especially concerning production and installation man-hours. If new systems or technology are introduced, shipyards instinctively estimate higher man-hour requirements to accommodate the learning curve, even though much new technology actually reduces man-hour requirements.

Three successive, prosperous years have given the yards some freedom to invest in new technologies in production, engineering and design systems, however. 3D modeling techniques capable of covering a complete ship, even a cruise ship, have become a fact of everyday life, at least for the detail engineering phase. Contract and basic design remain primarily 2D. However, several ongoing projects, such as those funded by the European Union emphasize 3D, virtual reality design tools and product modeling.

During the lean years of the early 1980s, many of the privately owned European yards were taken over by government organizations. Governments also implemented yard subsidy systems to avoid high unemployment and to counter Japanese and Korean investments in shipbuilding. Today, most of these shipyards are scheduled to be privatized but the task is difficult, especially when the shipyard is unprofitable. For example, Kvaerner was built on shipbuilding, the oil and gas industry and the construction industry. When the formula failed, however, Kvaerner tried to sell its yards without success.

It may be that consolidation and mergers are the future for the market's bigger players such as Aker-Kvaerner, Northrop-Grumman, General Dynamics, and Bazan-AESA. Takeovers are another possibility, such as the case of HDW in European navy shipbuilding. Fincantieri is on the privatization list this year, and IZAR in Spain was expected to be, but is postponed into 2004-2005.

Consolidation, takeovers and mergers on the supplier market have been ongoing since the late 1970s, and major conglomerates were created in the 1990s. ABB, Rolls Royce and Wärtsilä are typical of this trend, yet unique in that they concentrate on certain areas and systems in ships.

Consolidation is obvious, especially among suppliers as the yards concentrate more on their core business and seek bigger partners. However, this should ease the required heavy investment in design and knowledge management systems and IT technology.

Competition in the coming two to three years will be tough as most of the yards look for new contracts. China has taken a share of Korean markets and some Japanese business as well, while China's medium-size yards have conquered typical European ro-ro, product and chemical carrier markets. This has been created difficulties for Europe's small-and medium-size yards.

Although the smaller shipping companies traditionally have been unwilling to go outside their own geography for newbuildings, this is changing. Now several

Central and South European yards are losing their home markets and are trying to compensate through cooperation, with East European yards for example. Korean and Japanese yards will obviously try to win all possible LNG tanker and offshore vessel contracts and will be more aggressive for ferry orders as well.

Navy orders may save some of the European shipbuilders, but that market depends on economic growth. With the weakening economy, many governments are unwilling to increase military spending substantially, although the market is experiencing a mini-boom at the moment.

Competition among shipbuilders has always concentrated primarily on basic shipbuilding elements, regardless of the market and competition. Technology transfer has been an area of cooperation, especially when direct sales have not been possible. China's LNG program is a typical example: Two to three Chinese owners will order one vessel from an experienced, non-Chinese builder, with a requirement for a short delivery time. The remaining vessels will then be built in China through a technology transfer program included in the import contract.

In the future, the shipbuilding market will be governed by three equal parties: ship owners, suppliers and yards. Consolidation of ship owners will lead to bigger companies able to arrange financing, utilizing economies of scale in newbuilding orders, and pushing through requirements for product lifecycle management. New ship concepts and configurations will be developed by owners using the latest supplier technology.

Suppliers will seek bigger markets through standardization, modularization and through a broader scope as functional providers rather than as mere equipment suppliers. Suppliers will have an important role in lifecycle management as service and maintenance become growing markets.

At the moment, yards do not seem to have any role or interest in product lifecycle management. For the yard, the product lives only from the contract through the end of the warranty period. After that, yards lose interest because they have no involvement in long-term service and maintenance.

1.6 Future opportunities

Future opportunities for shipbuilding could come from many different directions -- from other industries, from IT technology, from safety requirements, and from a bigger share of the supplier industry, to name a few.

Standardization has always been a problem for shipping and shipbuilding. Being a technology-driven industry, a substantial number of newbuildings are more or less prototypes, both in terms of equipment selection and in terms of systems and arrangements. Building prototype ships based on standardized modules and parts is a challenge and an opportunity, a lesson the shipbuilding industry could learn from the automotive industry.

However, there is one major prerequisite to taking this step. The yards must come to understand that while standardization for their specific requirements represents an additional cost, standardization for a worldwide market represents an opportunity, especially for the supplier market. The individual requirements of the yards should be swept away and standardization should take place for a wider market.

Rule revision may help this. Navigation bridges are a good example. At the moment, these are always prototypes requiring thousands of design man-hours and long lead times. As such, they are always the last item completed, which delays the start-up of system commissioning. Standardized bridge arrangement is a safety issue driven by IMO, but also presents an opportunity for workshop-produced, standardized bridges with short delivery times and plug-in type connections, which will shorten installation times and accelerate final commissioning.

Building prototypes with extremely short delivery times puts substantial pressure on project management and coordination, both in terms of technical product and process coordination. The number of parties throughout the process is significant, especially when point-to-point, uncoordinated communication is typical. Centralized knowledge management with a good, easy-to-use product model would eliminate significant communication problems and subsequent modifications, saving time. But by developing a partnership-style relationship between the yards and their design, equipment and system suppliers, it would become possible to invest in the systems required for fluent, centralized information handling.

2. SHIPBUILDING PROCESS TODAY

2.1 Background

Today, most of the world's shipbuilding is based on principles such as structural building in blocks, block outfitting to a maximum degree, modularization of outfitting into units, utilization of prefabrication in pipe work, ducting and cable trays, pre-assembly of pipe packages, and outfitting of units such as cabins, cold rooms, etc. All this requires concurrent design, engineering and installation. Coordination of design and procurement has become a central and demanding task. Delivery of equipment in the correct phase for outfitting is crucial. Even more important is that the information be received in time for the design, which means that procurement handling is driven by design. Some shipyards therefore have moved the procurement of major design-dependent items to their design and engineering office, rather than having them procured by a separate purchasing office. E-commerce is starting to play a role in this and could have a more centralized role when combined with a product model and database.

Class and authority approvals play an important role, though less central than that of suppliers and subcontractors. This is the case for both design and installation phases. Delivery of important and essential information throughout the process remains the biggest stumbling block. The number of parties involved in one area or system often reaches six to nine, with some overlapping and others following one another. The total number of parties involved in a cruise ship can easily approach 300-400. Therefore, the role of information management is crucial.

2.2 Shipbuilding process

The shipbuilding process is a complex interaction among the shipyard organization, owner, partners, suppliers, class and authorities. The ship is in most cases a one-off product and is handled as a distinct project. The processes are recognizable, but vary slightly from shipyard to shipyard and based on the ship type involved.

Usually the shipbuilding process is described against the timeline of the actual building process. The main milestones are:

- Investment decision
- Contract date
- Start of manufacturing
- Keel laying
- Launching
- Delivery
-

These milestones may be important for financing and payments, but the process itself is far more involved and complex. In fact, traditional milestones have lost some of their relevance, making planning even more important.

All shipbuilding activities can be placed in a schedule relative to these milestones, and the duration and timing of each step can be estimated with reasonably good accuracy. The shipyard's role is to maintain total control of the schedule and adjust it according to the available production facilities and resources.

If we look at the shipbuilding process, it is typical that all the parties and stakeholders are more or less involved throughout the entire process. The amount of exchanged information varies naturally as the building of the ship advances, but communication between the yard and all the other parties is ongoing.

The active parties in this process are:

- The owner

- The shipyard
- The classification society
- National authorities
- Consulting and engineering offices
- Equipment suppliers
- Subcontractors
- Turnkey suppliers.

The owner and the shipyard are the key players. The roles of other groups vary depending on the stage of the project, but continuous involvement throughout the whole period is standard.

The interests of these stakeholders are different. The owner is interested in receiving a high-standard ship according to the contract specifications and delivered on time. Authorities and classification societies want all rules and regulations to be met. Suppliers and subcontractors are looking for good business opportunities. In many situations, this leads to contradictory interests and problem situations, which must be managed successfully to maintain the fluency of the building process. The shipyard and its management take the lead role in organizing these matters. In the end, the yard is responsible for building the ship in a technically and economically sound way.

The shipyard management must have access to the information necessary to make the right decisions. Good planning and an efficient ERP system should give the management the decision-making tools it needs. Once the ship contract has been made based on the developed master schedule, shipyard management has few additional opportunities to influence the success of the project. Therefore, a good planning organization and planning tools are even more important than top management. Even mediocre managers can run a successful business with good support, but even top managers are lost if the information they work from is wrong or misleading. A series of bad decisions can often cloud the original starting point, causing one to lose sight of the last valid point of reference. Unfortunately, when the original starting point is lost, and a new, revised plan is taken as a new starting point.

Usually, the shipyard handles a newbuilding as a project. This means setting up a full project organization, supported by the line organization. The project manager and his project team are in charge of the project. The project manager, who generally reports to the managing director, should have considerable decision power inside the project. The reality in a matrixed organization, however, is that the line managers will not necessarily concur with the priorities of the project manager, especially if several projects are running simultaneously. Generally, the project manager should be aware of all communication with the owner and authorities so that he can accommodate any change in the project.

After the contract, the owner has a supervising role. Owners monitor that everything is designed and built according to the technical specifications. They also have approval authority for suppliers and turnkey contractors as specified in the maker's list. In passenger vessel projects, the owner normally provides his own architects for the interior design. The shipyard, however, provides inspection material, such as drawing copies and equipment data, and arranges the inspections during production.

The authorities have a supervisory role similar to that of the owners. They monitor adherence to rules and regulations by inspecting the design and verifying that everything is being installed according to the approved plans. The authorities also deal with the equipment suppliers. However, certification of equipment generally is beyond the control of the yard. It must, therefore, assume that the suppliers delivered the goods with the necessary certificates and approvals.

Suppliers, whether they are equipment suppliers, work subcontractors or turnkey suppliers, provide goods and services. In most cases, these goods and services are provided directly to the shipyard. This means that the yard has full responsibility. Every change of information must be coordinated through the shipyard, including schedules, cost control and weight control. However, the line of communication can become lengthy, which contributes to the loss of pieces of information.

2.3 Typical shipbuilding process

A typical shipbuilding process can be presented as clearly separated chronological phases:

1. Pre-contract stage
2. Contract - Start of manufacturing
3. Start of manufacturing - Delivery
4. Guarantee period

As previously mentioned, these phases are linked to the main milestones and scheduled accordingly. Each of the phases includes typical activities.

2.3.1 Pre- contract stage:

During the pre-contract stage, the shipyard must create the contract specification according to the requirements of the owner, set the contract price and set the vessel delivery date. This requires close cooperation among the project development team, calculation team, planning team and procurement. Competing on the basis of superior product performance is possible and always worth trying. However, price consistently is the single most important parameter for final selection of a builder. Of course, the builder's track record is important, too.

Concept design, at least to some extent, is typically driven by the owner, although the yard often is involved. Today, owners typically use their own experts and outside consulting companies to develop contract aspect, leaving less space for yards to develop their own approaches. This makes it easier for the owners to receive comparable proposals. Contract design is a very important documentation because it explicitly defines the ship project, both technically and economically. Decisions made during this stage dictate a major portion of the possible variables, making them difficult or costly to change afterwards.

Calculation of price must advance along with contract design. The prices of equipment must be established quickly after choices have been specified. This requires the seamless participation of the procurement department. The procurement team strives to handle major equipment technically and commercially, making it possible to place orders as soon as a ship contract is signed. However, the quality of technical specification and of the other contract material has a big impact on this process. A well-defined product model and database helps, and e-commerce is speeding up the process, creating the potential for more reliable data.

At this point, the production planning team creates a preliminary build strategy, providing the necessary construction guidelines for the project development team. The build strategy becomes the basis for work-hour estimations and a preliminary production schedule. The planning team's role is key; they define the possible delivery time and work hour estimates.

Authorities become involved during the contract design phase as special interpretations of the rules are required. Generally, the classification society is already selected by the project phase. It is involved in special areas and questions from the initial stage of the project, especially concerning alternative and equivalent designs. Classification societies may have a dual role, for in many cases they represent the authority as well.

Practice varies from yard to yard, but typically the project engineer and the sales manager are responsible for ensuring that the contract material is complete and that calculations are made correctly. Cost estimation is always performed as precisely as possible. This information is provided to sales management and the managing director, who are responsible for setting the actual price of the contract.

Teams and persons with an active role during the pre-contract stage include:

- the owner and his representatives, such as consultants
- the managing director
- sales manager
- project engineer
- planning team
- calculation team
- material manager
- procurement team

- financial director

The amount of documentation is not yet very extensive (commercial projects):

- contract documents
- production planning documents
- calculation documents
- preliminary schedules and build strategy
- correspondence with the owner
- correspondence with the class and authorities
- limited equipment data and correspondence with suppliers
- contract documentation

Navy projects typically already include a complete basic design at contract signing.

2.3.2 Contract – Start of manufacturing

After the contract is signed, the ship specification and price are fixed; in most cases, delivery time also is largely fixed at this point. However, the signing of the contract is often delayed, cutting into valuable design and production time. Without the contract, it is dangerous for the yard to start any major activities, especially purchasing. Therefore it is extremely important that all activities scheduled to start immediately after the contract signing are well planned and that all the necessary resources are available to enable a head start.

Basic engineering and procurement go into full swing at this point. The goal is to prepare documentation for approval of authorities, of the owner and for the basis of detail (production document) engineering. Time is usually very short and success depends heavily on the shipyard's ability to coordinate and steer the owner, architect, classification societies, authorities and suppliers to make quick, prompt decisions and meet schedules.

Usually, these stakeholders have little incentive to cooperate, however. They generally take the attitude that time schedules are the shipyard's responsibility, not theirs. They often fail to understand and accommodate the shipyard's pressure for a decision on equipment that won't be installed for a year or more. However, they forget that the design being created today requires knowledge of data for equipment that won't be installed for a year.

Basic engineering needs accurate information about equipment and systems specified in the contract material. Technical handlers give the technical data to the procurement team and they are responsible for buying the equipment as efficiently as possible. Sometimes, however, they concentrate too much on price and forget about schedule. The procurement schedule is naturally tied to the production schedule, but in many cases the critical path is determined by the need for design information. 80% of the cost of the vessel is defined and decided within the basic design period. For this reason, basic design and procurement organizations should work together closely and with the same goal.

The basic design schemes, calculations and arrangements are inspected and approved by the owner, class and authorities. The approval schedule is somewhat beyond the shipyard's control and is a wild card in the project. For passenger ships, this process is even more complicated because the owner's architects have a big role to play and they may generate significant modifications throughout the process. Good project management tools, a well-organized project and the ability to respond to rapid changes in information can reduce the risks involved.

The start of detail engineering is linked to the start of manufacturing. By estimating the required lead times and design hours, it becomes possible to set the detail design start date. In an ideal situation, basic engineering would be finished before the start of detail engineering, but this rarely happens and these design periods generally overlap. Careful planning of basic engineering helps to control this problem. Coordination between the different disciplines also is essential; it is imperative that the structural phase not advance too far without necessary piping and equipment data.

Planning is responsible for preparing the detailed build strategy and master plan. The build strategy is absolutely necessary for the detail engineering, because most of the design solutions are based on knowledge of how a particular element is going to be built and installed. This build strategy, together with the master plan, sets the need dates for the major equipment. This information is necessary to allow procurement to time the deliveries.

Design schedules are created using the master plan and a drawing list. The production schedule is the 'bible;' the design documentation must be available prior the start of production.

Planning begins to refine the master plan to lower level production schedules, which are necessary for correct resourcing, including turnkey deliveries, subcontracting and managing of the yard's own resources. (Supplier and subcontractor follow-up systems also are essential because these players generally are not linked directly into the yard's system.) The shipyard loading schedule will be revised accordingly. The work hours will be distributed and budgeted to the production activities used in the follow-up system.

The active teams and persons during this period are:

- project manager
- engineering manager
- basic design project manager
- basic design discipline managers
- basic design teams
- detail design project manager
- detail design discipline managers
- detail design teams

- production manager
- planning manager
- planning team
- procurement team
- owner (design inspection team)
- class
- national authorities
- architect(s)
- subcontractor and supplier coordinator(s)

2.3.3 Start of manufacturing – Delivery

Initiation of production is a major step in the process. After this the costs start to accumulate rapidly and it becomes extremely difficult to make additional changes to schedules or to the technology of the ship.

The detail engineering continues for a long period, concurrent with production. This is especially true of the electrical design, which continues almost until the delivery of the ship. Virtually every piece of equipment and every onboard system contains electronic elements and the data on these components often arrives extremely late.

The purpose of the detail design is to provide sufficient documents to enable efficient manufacturing and installation work. Equally important are the material and parts lists attached to the drawings. Normally, the design team creates these directly in the shipyard's material management system, together with the timetables to ensure availability of the material at the right point in production. During work planning, planners disburse material from the warehouse, sending it to the corresponding work place. If the material is not available or it is incorrectly timed, the work phase in question must be rescheduled, often causing delays in other work in a critical path. Timing is extremely important in areas where subcontractors are involved.

Production basically requires three elements to finish the job: resources, materials and production facilities. Maintaining this balance is a joint effort of the design staff, planning team and material department.

Production begins with steel parts fabrication and block manufacturing. Steel production is a well-defined process and is relatively easy to follow and control. If calculated in terms of work hours and material costs, the amount of steel is not significant even in a complicated ship like a passenger vessel. However, the steel blocks and complete hull become the basis for all the outfitting work, and any failures in steel production can cause massive problems for the project.

During the various block and grand block assembly stages, outfitting work starts with installation of piping, steel outfitting, equipment, cabling, insulation, etc. Achieving an early start to outfitting while maximizing the number of blocks outfitted is the target. Subcontractors generally are involved at this phase.

Efficient change management is one of the key elements in production. Changes in production documentation are guaranteed to occur for a wide variety of reasons, including:

- owner's requirements
- architect changes
- requirements from classification societies and authorities
- changed or late equipment data
- errors in design
- delayed design
- delayed equipment deliveries

If the design period is very short and overlaps significantly with the production period, the risk of significant impacts due to changes grows and the role of change management increases. Quick and fluent communication between the design and production functions is vital. If the yard can reduce the required production lead times, the chances of tackling the changes improves.

The planning department is normally responsible for creating the follow-up system for every project. The follow-up is based on the estimated hours, used hours and the evaluation of work progress. The accuracy of follow-up is highly dependent on the evaluation of work progress. This evaluation usually is conducted by experienced foremen or production engineers. Evaluation often is somewhat subjective due to a lack of proper estimation tools. In the worst cases, progress is evaluated by comparing used and estimated hours. Although this process is technically simple, it can be highly misleading.

Follow-up reports are the single most important medium allowing shipyard management to understand what is happening in a project and what should be done to overcome potential problems. Reporting on progress and hours consumed naturally is backed up by a cost calculation from the financial department.

The commissioning of individual systems and of the ship itself is based on a test-and-trial schedule prepared by the planning department. The sale of certain systems starts quite early, because the progress of production can prevent efficient inspection of system components (like piping behind cabins or wall panels). At the time of actual commissioning, certain documentation is required, including operational and service manuals of the equipment in question. Generally, the design department prepares the necessary test protocols. These protocols contain the actual testing program including test values for pressure, rpm, etc., and values to be measured and checked against the specifications.

The commissioning team is responsible for organizing the trials and arranging for all required parties to be present during the tests.

2.3.4 Guarantee time

The guarantee period starts from the delivery of the ship and is normally 12 months. During this period every deviation of the ship systems from the specification is recorded and reported to the yard. If the problem requires immediate resolution, the yard is responsible for scheduling the right repair team onboard for maintenance.

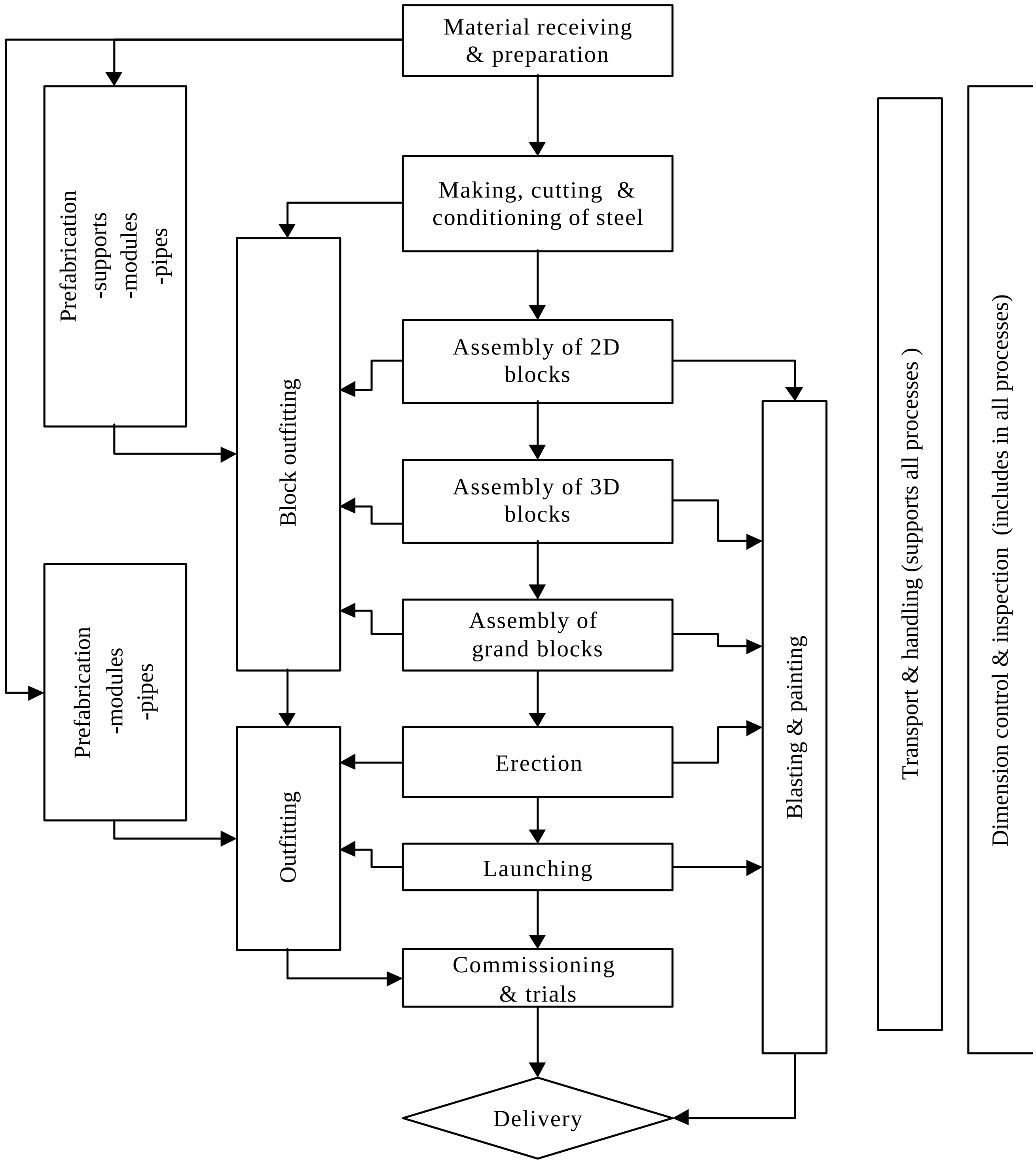
Some of the problems discovered during this phase can wait to the end of the guarantee period, when the ship comes to the yard for guarantee repairs. This is by far the most economical and convenient solution for each party. Unfortunately, it is not always possible.

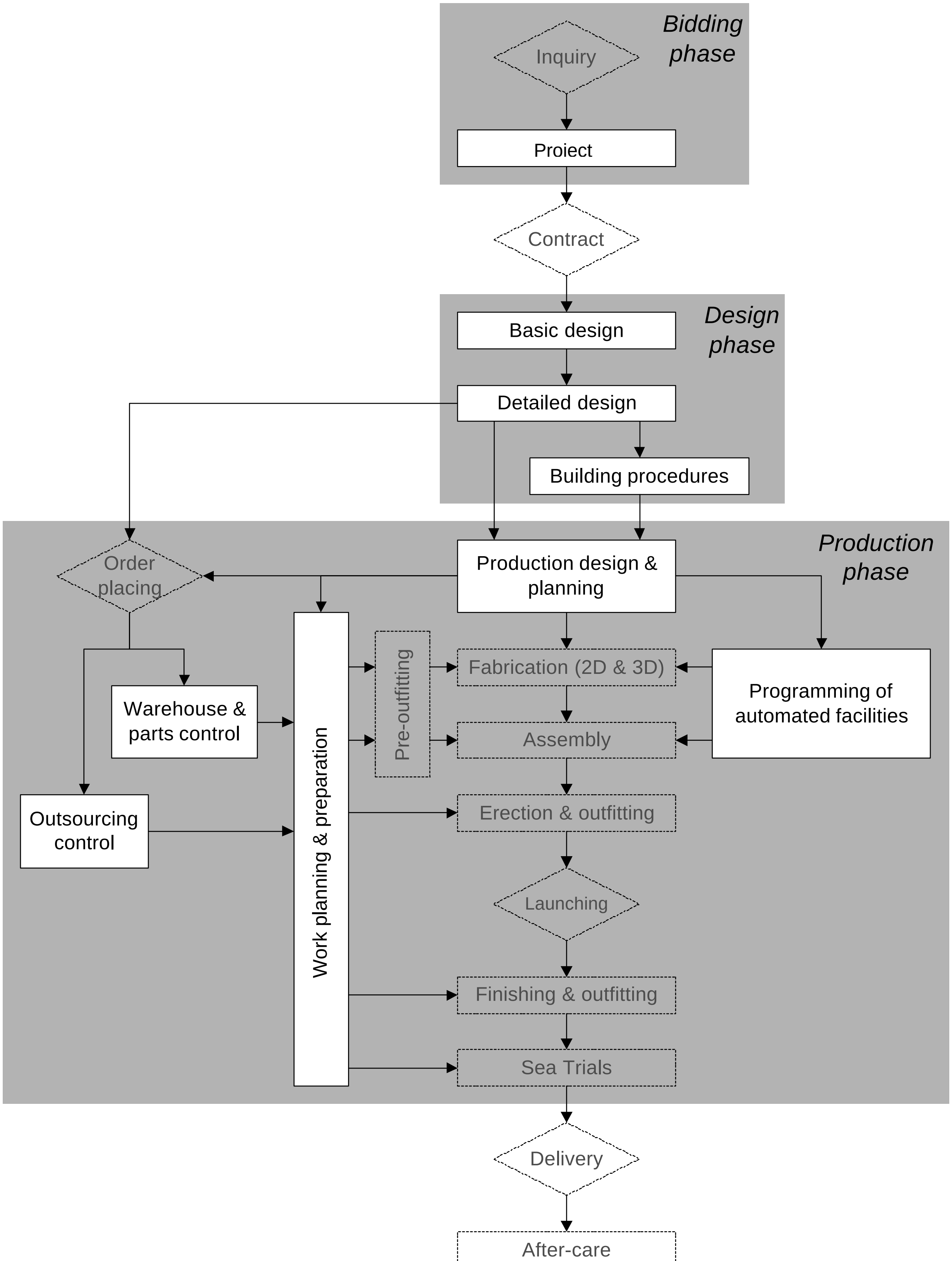
The shipyard usually appoints a guarantee engineer, who acts as a liaison officer for the owner and the equipment suppliers. The guarantee engineer must have a comprehensive database of system information, including all the operational/service manuals and access to the design documents.

To ensure timely responses from equipment suppliers, a certain sum of the equipment price is held back until the end of the guarantee period. The procurement team must ensure that the guarantee times for equipment are extended to cover the entire first year after ship installation, considering some items can be installed more than a year before the delivery.

Guarantee is of particular interest to the owner. He typically negotiates additional guarantees and spare parts directly with the supplier without the shipyard's involvement. For suppliers, this is an opportunity for wider service and maintenance business.

Example of a typical shipbuilding process





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2.3.5 Differences between yards

The basic shipbuilding process varies little from yard to yard. At small yards, it is possible to find all the same activities as at a major yard having 100 times the workforce.

If the master schedules of different yards are compared, it becomes difficult to differentiate one yard from another, because the items in the schedule are very similar. Activities in a building process must occur in a certain order and occupy a pre-determined amount of time, which is not always a function of size or weight. As an example, the outfitting of blocks can take two weeks independent of block size. The limiting factors are workspace -- the number of people that can have enough space to work in a block -- and the fact that installations must be done in a defined sequence.

Although yard processes are similar, how the processes are undertaken in practice can be very different. The automation level varies significantly, as does the amount of work subcontracted. Outfitting levels at panel line and at block stage also vary widely, with some yards reaching as high as 85 -90% outfitting as early as the panel line. This leads to widely different management processes.

The greater the volume of work performed and subcontracted, the more demanding the project management and technical coordination tasks become. Therefore, good tools are required.

2.4 Initial Project Design

Project design extends from first concepts to contract signing. The duration of this period is typically 3-12 months, depending strongly on the type of design and market situation.

This phase includes defining realistic main characteristics, cargo capacities, performance and dimensions, as well as a sufficient amount of design information to calculate the cost of the vessel, its income potential and the feasibility of the project.

2.4.1 Parties involved

In the cases of cruise, ro-pax and special vessels, it is typically the owner who, by himself or using a consultant, develops the first ideas and specifies the technical requirements. Shipyards are involved at the bidding stage and, in many cases, also help develop the initial design according to the owner's technical requirements.

The most important decision-maker at this stage is the owners' newbuilding director, heading the owners' design team. Important role-players in this team typically include a senior marine engineer/naval architect, the marketing executives and, perhaps, a captain. The owners' financial officer, who is responsible for determining the economics of the investment, is of course crucial.

The most important designer at this stage is the project engineer, who may come either from a consultant or the shipyard. He is the person who manages the design work in the initial design phase, and the quality of the design is heavily dependent on his vision, experience and know-how.

Authorities and classification societies typically are not involved at this stage, unless the design features novelties outside the rules.

2.4.2 Scope and hour budget of initial design

Typically, the following material is included:

- Specification
- Definition of main dimensions
- General arrangement
- Main flows, simulations
- Machinery arrangement
- Structural principle (midship section)
- Lightweight calculation
- Hull form
- Tank arrangement
- Intact and damage stability
- Powering
- Electric and heat balance
- Architect design
- 3D models
- special items, if any

The hours budgeted for contract material ranges from 500 hours for a simple ship to as many as 10,000 hours for a complex cruise vessel, including many specific studies beyond the list outlined above.

This is certainly the case when a new prototype design is being developed, especially if a so-called equivalent design is processed. Equivalent design is not based on existing rules, but on the results of safety and simulation studies.

2.4.3 Design tools

The most important design tool is a general-purpose 2D CAD program, the most common being AutoCad. The general arrangement, the machinery arrangement and the midship section are drawn using such a tool.

The hull form, tank arrangement and stability calculations are done using a dedicated naval architecture program, with NAPA-system being the most common for passenger vessels.

The rest of the deliverables are produced using standard office tools such as MS Office.

Use of 3D models, with exterior, interior and cargo spaces, are becoming more common and will soon replace 2D tools. Designs based on simulation as well as on safety are yet to come. Obviously, the future rests on widespread use of parametric 3D models, together with a good product model.

2.5 Basic Engineering

Basic engineering is the design phase where the ship is defined to a functional level. The most important tasks at this stage are:

- Basic design of all disciplines
- Approvals (from the owner, the authorities and the classification society)
- Specifying material needs
- Coordination with procurement and detail design schedule

2.5.1 Parties involved

Basic engineering is typically controlled entirely by the shipyard. Some yards try to do it completely by themselves, while others use capacity subcontracting. In the latter case, however, the management of all individual disciplines is in the hands of the yard. At the yard, basic engineering work is normally distributed to the various design departments. Typically, these are the following:
Theory (naval architect), hull (structure), interior, outfitting, HVAC, machinery, electrical and automation.

In all departments, a so-called discipline manager is typically nominated. This person is responsible for all activities in his design area and reports to the project manager, who is responsible for the overall design.

The role of design offices is typically to sell their design capacity to the yards. In some exceptional cases design offices can provide overall turnkey design packages, including basic and detail engineering.

Approving parties are all-important at this stage. It is crucially important that they follow the approval schedule as mutually agreed upon and respect the ship's specification and shipbuilding contract.

2.5.2 Change control

The basic engineering phase lasts only a few months, depending of course on the type of ship involved. During this short time, large quantities of interdependent information are being generated. Therefore, as almost everything depends on everything else, the design organization's ability to handle changes is crucial. Distributing the information to the right persons at the right time is vital to success, as is the ability to efficiently approve modifications. At worst, the ship can be described with nine different models, none of which may be well coordinated. A knowledge management system is therefore of the essence.

2.5.3 Interaction of design with procurement

Much of the input information needed during the basic design phase depends on the actual choice of equipment. Coordinating design work with procurement is vital; otherwise schedules cannot be met.

Typically, shipyards divide the equipment into groups according to its importance. The most important items – about 40 to 80 items affecting the majority of costs and having the biggest importance in scheduling -- receive the greatest amount of attention. It is important to note that the most important items each represent a multi-million-dollar investment, must be ordered as much as a year before delivery and tie the yard to non-flexible contractual obligations.

By contrast, the purchase of non-costly items, which are easy to purchase but represent perhaps 80% of the item numbers ordered, can be left to the designer level or can be handled through basic annual agreements.

2.6 Planning and Coordination

The planning and coordination process is one of the most important activities in shipbuilding. Failure in planning can lead to dramatic consequences in a ship project. The possible hazard factors are:

- miscalculation of production hours
- miscalculation of design hours
- insufficient turnkey and subcontracting reservations
- incorrect scheduling
- wrong capacity estimations
- wrong estimation of facility usage

Miscalculation of work hours is the most devastating error that can be made in planning. Miscalculation will cause any or all of the other problems in the list to occur. Underestimating the hours yields too low a price for the ship, causes resourcing to be underestimated and generates schedules that will be too tight to follow. On the other hand, overestimation may cause a yard to lose the contract. Even if the contract is won, it will create loose schedules and wasted hours.

Coordination of a project is based solely on the build strategy and on the different level schedules prepared by planning. The schedules, together with the strategy, clearly dictate which activities are taken care of by the yard with its own resources and which must be subcontracted. The follow-up system is built according to this division and the project management is performed through the schedules. In rare cases, subcontractors may be obliged to directly join the shipyard's follow-up system, which is by far the most efficient approach.

However, this is still the exception more than the rule; follow-up generally is coordinated through regular reports provided by the subcontractor in a specified form suitable for the shipyard. This may be a problem because most local subcontractors are small and medium-size companies unfamiliar with scheduling, follow-up and reporting systems.

Production planning can be divided into the following phases:

- Bidding Phase
- Contract Phase
- Design Phase
- Production Phase
- Close-Out Phase

In the following, different phases are described from the planning point of view, including a list of activities:

Bidding phase

The bidding phase is the period before the actual signing of the ship contract and covers preparation of the bid and technical/commercial negotiations in order to achieve the contract. The planning department is heavily involved during this time and is responsible for estimating the production hours and the production times as well as the possible delivery times. The starting point for this estimation work is the shipyard status in terms of capacities, existing production load and available facilities.

The evaluation of production hours and delivery time requires generation of a rough building procedure, including a block scheme and preliminary master plan. The production times in the master plan and estimation of production hours are based on the shipyard's statistical database. Usually it requires the judgement of experienced planners to modify the existing data to suit the project in question.

It is essential to clarify the number of turnkey deliveries and subcontractors, because these have significant impact on the cost structure and schedule. It also must be possible to make the capacity reservations early enough to ensure the availability of these resources.

A reliable promise for the delivery date is the one of the key pieces of information for planning to provide to management and the yard's sales people.

The starting point for planning is:

- Yard's production schedule
- Design hours (usually estimated by the design department)

The planning team prepares the following documents:

- Production hours

- Building strategy:
    - Block split (hull assembly blocks)
    - Hull assembly “serial cartoon”
    - Investment proposals
- Yard loads:
    - Design/discipline
    - Production/discipline
    - Master schedule
    - Timing of main equipment

Contract phase

When the shipyard is in the process of closing the contract, production planning puts the focus on the same items as in the bidding stage, but the intention is to increase the level of estimation accuracy.

The production hours will be broken down to discipline levels and the needed amounts of turnkey and subcontracting will be established as well.

As in the contract stage, the time available for planning can vary considerably depending on the commercial situation. In a typical case, the following documentation is prepared:

- Yard schedule + new contract
- Design hours
- Production hours
- Rough building method
- Turnkey and subcontracting plan
- Yard loads:
    - Design/discipline
    - Production/discipline
    - Master schedule
    - Timing of main equipment.

Design phase

The design team requires various types of information for design work, including data from production planning -- at the same time production scheduling starts on a detail level.

Information produced by planning includes:

- Final building method
- Final subcontractors and turnkey plan
- Target design hours/discipline
- Target production hours/discipline
- Design schedules
- Production schedules
    - Design histograms & S-curves
    - Production histograms & S-curves

- Timing of drawing list
- Timing of material list.

Production phase

During the production phase, production planning takes care of:

- Fixing main items
- Corrections to the planning information
- Updating of previous output
- Follow-up and progress reporting.

The follow-up system must operate without delays because rapid responses to potential problems minimize the potential damage.

Integrating the main turnkey suppliers to the follow-up system is critical.

Close- out phase

In the close-out phase, the post-calculation of the project is performed. All the experiences and lessons learned are analyzed and utilized to improve performance in future projects.

Analyzing the numerical data and determining the final values for key figures is essential for the calculation of new contracts.

Tasks of production planning include:

- Close-out report
  - planned/actual building method
  - planned/actual hours
  - planned/actual schedules
  - planned/actual productivity
  - planned/actual turnkey supply delivery schedules and contacts

2.7 Detail engineering

The main purpose of detail engineering is to provide sufficient information for the production and material department to build the ship. Detail engineering is based on the basic design documentation, build strategy information and shipyard standards.

Very few yards have design departments large enough to handle an entire ship project in house. Usually several design offices are involved, and part of the design is contracted to the turnkey suppliers and subcontractors as a part of their package. This leads to a complicated network of information interfaces among all the parties.

Traditionally, the shipyard has taken the coordinating role. However, this role also can be played by a consulting office, which takes major responsibility for the engineering work, coordinating the subcontractors' design work as well.

Most engineering and design work today is performed in a 3D-design environment. This helps greatly in interfacing design information between design teams, provided everybody is using the same system and database. However, this is sometimes a problem for smaller subcontractors, which typically have only 2D drafting systems.

3D design requires that a complete component database of all the equipment be shown in the model and work drawings. This includes all the items that have physical dimensions affecting the manufacturing and installation – including those that require space and have connections to other components in the system.

Maintaining this component database for one shipyard is not easy; it contains literally thousands of items starting from special pipe clamps and valves to main engines and propulsion units. The shipyard standard outfitting components, like stairs, must be modeled as well.

The design work is usually organized under the engineering project manager to whom the discipline managers report. The discipline distribution in traditional shipyard practice is:

- Steel and structural design
- Machinery design
- HVAC design
- Outfitting design
- Interior design
- Electrical and automation design

The design teams and designers handle considerable amounts of information including:

- Basic design documentation
- Equipment data
- Rules and regulations
- Contract documentation
- Shipyard standards
- Shipyard material system information
- Shipyard production information
- Design manuals
- Architectural documentation

The coordination and distribution of this information, generally, is the responsibility of the discipline managers. They must ensure that every piece of new data is immediately distributed to the right people coordinated among the different disciplines, in order to avoid costly errors in design.

Information management is the biggest challenge to the design organization because huge amounts of basic design and equipment data must be available in a short time and must be distributed to every designer whether they are sitting at the yard or in design offices around the world. This information is constantly changing and requires significant attention within each design discipline, between disciplines, with design suppliers and towards equipment and turnkey suppliers.

However, it is increasingly common for production foremen to have direct access to the design documentation and the ability to convey their comments, requirements and recommendations online.

2.8 Production

Design documentation through production is first handled in the work-planning department. The scope of work for the work planners depends on how the design documents are created. At some yards, the designers create the drawings based on the agreed-upon build description and build methods without a specific workplanning department at production. A dedicated drawing is made for each work phase, including the associated parts lists.

In that case, the work planners need only to take the drawings and parts lists and prepare the corresponding work orders. The work orders contain the sequential work activities in the form of small schedules with durations for each step. Durations are estimated based on the shipyard's statistics and the experience of the planner. At the same time, planners locate and "take out" the necessary materials from the warehouse. If the material is not in stock, the corresponding work order must be postponed.

The planners also are responsible for loading individual workstations. They try to 'even' the load by organizing the work order, demanding more capacity (more shifts for example) or by subcontracting. This is a continuous prioritization and arranging process.

The work order is delivered to the production departments for dissemination to the responsible engineers and foremen, who take care of organizing the actual work.

In a typical shipyard, the following production phases can be clearly separated:

1. Steel preparation
2. Steel parts manufacturing
3. Pipe prefabrication
4. Unit prefabrication
5. Block assembly
6. Block outfitting

7. Grand block assembly
8. Grand block outfitting
9. Hull erection
10. Area outfitting

Steel preparation

Steel preparation includes sandblasting and primer coating. Some yards have outsourced this and the next phase, steel parts manufacturing.

Steel parts manufacturing

During the steel parts manufacturing process, all the steel components needed for assembling the blocks are made. This includes cut plate parts, bent shell plates, cut and bent profiles, etc. Usually, the automatic panel line is part of parts manufacturing. Also, small subassemblies like T- beams and small panels with stiffeners are manufactured in this phase.

Pipe prefabrication

Most of the pipes installed onboard are prefabricated in the pipe workshop; the proportion of prefabs can reach more than 90% of all pipes in a specific space. Compared to fabricating in place abroad the vessel, prefabrication is much easier, yields pipes that are accurate and of good quality and simplifies installation. Without prefabrication, shipbuilders would be required to invest 3-10 times more work hours for pipe manufacturing and installations. Pipe packages combine prefabricated pipes into prefabricated packages, which can be installed as such.

The design department makes the decisions on prefabrication and prepares the pipe spool drawings for the pipe shop, which often is outsourced. In some cases, the pipe shops are controlled entirely digitally, which means paper drawings are no longer required.

Precise timing is very important in prefabrication, because the first pipe spools are needed at the beginning of steel production. The schedules must be correctly defined and there must be enough manufacturing time and lead time before the pipes are needed in production.

Unit prefabrication

In prefabricated units, adjacent system components like pumps, filters, heat exchangers, valves, and electrical installations are built together on a common frame. The unit can be completely assembled and functionally tested in a workshop. The installation of units is easy during the block assembly stages, when the spaces are open and direct lifting is possible.

A subcontracting company often manufactures the units. Sometimes it is a complete turnkey package, in which case the supplier is responsible for design and materials. In some cases, the unit must be designed in a specific way due to space restrictions or other requirements. Therefore, the shipyard provides the design and the major system components.

In that case, coordinating design and materials to be available at the right time is the responsibility of the shipyard. Normally, the timing of materials is done during the design work phase by the designer.

Combining prefabricated pipe packages and units is a very efficient way of building complicated machinery spaces. However, it requires good design documentation, coordination of the work and fitting areas, and pipes that fit.

Block assembly

The ship is divided into grand blocks and these grand blocks are further divided into blocks. The weight of a grand block varies from roughly 100 tons to 1,000 tons depending on the shipyard's lifting capacity. One grand block consists of several blocks, typically 4 to 8 units.

During the block assembly phase, steel parts and small subassemblies from parts manufacturing are assembled into blocks. This normally happens close to the parts manufacturing location -- often in the same hall. The lifting and transportation capacity dictates the maximum dimensions of the block.

Block outfitting

Outfitting work is started during the block assembly stage. Typical outfitting components to be installed include double-bottom pipes, which are very difficult to install in a completed block or grand block. Usually this work is called "hot outfitting," indicating the use of welding equipment that, if used in later stages, would destroy the painting.

The window for outfitting work is narrow -- a few days or a week. The prefabricated components and other materials must be available or the outfitting must be done in later stages. But this increases the cost dramatically, because it is likely that the components will not be usable as built and must therefore be modified.

Grand block assembly

Grand block assembly is nothing more than fitting and welding together the assembled and outfitted blocks. By using grand blocks, the assembly work and outfitting can be brought from the building dock to the assembly halls where the work can be done in sheltered conditions. At the same time, this process reduces the number of lifts to the building berth along with the bed time between the keel laying and launching.

Grand block outfitting

Outfitting work continues during the grand block assembly. Correctly planned, the amount of outfitting can be considerable. It is not unusual for certain spaces located within one grand block to be almost completely finished, including lighting.

Part of the outfitting work is done simultaneously with the grand block assembly work. However, it is normal for the schedule to include a period that is reserved exclusively for this work. This period can be 2-3 weeks, depending on the complexity of the block.

During this outfitting period, the grand block requires a construction space and auxiliary space for stores and equipment. The scheduling of the building space is done in the production planning department. At most yards, it must be done carefully due to the large number of blocks under construction at any given time.

The planning team maintains a daily schedule of block movements in the shipyard area. This schedule is coordinated with material management to ensure that needed materials reach the right places at the right times. During this stage, a large number of subcontracting companies and the shipyard's own personnel are involved.

Hull erection

The hull erection period (also known as "bed time") starts with the keel laying, which involves setting the first grand block on the building berth.

The sequence of lifting and joining the grand blocks is designed to make the bed time as short as possible, because building berths are often the bottle- neck in total production capacity.

In passenger vessels, where the outfitting of public spaces takes a long time, the erection sequence is done in such a way that the work in critical areas can start as early as possible. This means that a tower type of erection procedure is preferred to the normal deck-wise procedure.

Area outfitting

During hull erection, the block concept ceases to exist after the blocks are welded together. Blocks, therefore, cannot be used as a reference for materials, drawings and work beyond this point in time.

Instead, it is necessary to start using areas, which are defined in the very first stages of the project. Production planning prepares an area map, which divides the ship into logical areas according to physical boundaries, type of spaces or turnkey scopes.

All the design documentation and materials are then labeled according to this area definition. The follow-up and schedules are made accordingly and all coordination happens through areas.

The shipyard appoints so-called area managers, who are experienced production engineers responsible for all activities in their assigned areas. This may include communication with several subcontractors, suppliers, the owner, authorities and the yard's own working teams. The area manager is supported by a team comprising a foreman, a design contact person and a planner.

The interior outfitting of accommodation and public spaces generally is turnkey work. When turnkey work is scheduled to start, the area manager must ensure that all outfitting work behind the interior paneling, etc. is installed, tested and approved. Any delay here is directly in the critical path and can lead to postponing delivery, or at least postponing the start of interior outfitting.

Interior turnkey can create situations in which the shipyard has obligations and work in the same area as a subcontractor. To avoid that, it is possible to make so-called steel-to-steel turnkey contracts. This involves the shipyard providing only the space with bare steel walls (penetrations, at least, must be defined), and relying on the subcontractor to design, manufacture and install everything in that space. The shipyard must provide target dates and the subcontractor must handle the scheduling, resource planning and material management for the area. The shipyard basically is only interested in progress reports and through-going systems which may hinder the startup of neighbor spaces.

This is an easy solution for the yard, but sets new thresholds for the turnkey company. Instead of one discipline, they must manage several types of work, from steel outfitting to electrical installations as well as all the design and engineering. The shipyard has actually transferred a major part of its responsibilities to the turnkey supplier.

The kind of infrastructure required for turnkey suppliers can be found only in the most developed shipbuilding countries in Europe. It requires a partnership arrangement and experience in working together. However, it appears to be the wave of the future, and most of the European cruise and ferry builders are moving in that direction.

Varying ways of building cruise ships in Europe

A passenger cruise vessel is one of the most demanding projects for a shipyard. It involves more work hours and more material costs than any other commercial vessel. Today, even the large European shipyards do not have enough workers to build such ships. Even they require varying amounts of subcontracted workers and the support of turnkey and supplier companies, beginning with the design work.

In that sense, large- and medium-size yards are in similar situations, although the medium yards must rely more on subcontracting because of their own limited capacity. On the other hand, this arrangement may give smaller yards the advantage of smaller overhead costs and additional flexibility.

Large shipyards usually have the advantage of bigger lifting and transportation capability. As previously described, this can reduce the bed time and overall production time. If the shipyard has larger production areas, more blocks can be under construction at the same time and the outfitting times of blocks can be longer. If the space is limited, the production flow from steel manufacturing to hull erection must be more straightforward and faster.

There are examples of fairly small yards building fairly large and complicated ships successfully. The secret is a good network of long-term, partnership-style subcontractors who know the yard well, plus an effective project management system to coordinate everything.

The financial risk is bigger for small yards, however, because the project can represent several years of normal turnover.

2.9 Commissioning and guarantee time

Commissioning of the systems and the whole ship is a continuous process extending from the very beginning of steel manufacturing. The approval of the owner, classification societies or authority is needed for almost all of the work done. This is a routine process and is accordingly accommodated in the production schedules.

The commissioning of systems is a multiphase activity, which starts with factory testing and approvals and continues with partial approvals of installations during the outfitting work. It is finalized with system quality testing and sea trials.

The shipyard has people responsible for the most important systems, like air conditioning. Their task is to follow the system installation and take care of necessary actions to ensure the success of installation and commissioning. Area managers are responsible for commissioning other systems.

The equipment manufacturer arranges for factory tests based on the schedule outlined in the purchase contract. The shipyard representative informs the owner and the classification society about the test and provides the opportunity to participate. Test protocols are delivered as a part of the equipment shipment.

The commissioning process involves large numbers of documents, including:

- Installation drawings
- Test program
- Test protocols
- Technical specifications of the equipment
- Operational manuals
- Approvals and certificates of the authorities
- Lifetime management models/documents

The responsibility for collecting and preparing the documents belongs mainly to the design department and procurement. Usually, dedicated designers prepare the test program and protocols and the procurement department checks the availability of documentation belonging to specific equipment.

The collected documents are part of the delivery documentation given to the ship's crew. It is especially important that operational, service, spare parts and safety manuals be available.

Guarantee time

The guarantee time is set by the contract. It is usually 12 months and starts from the delivery of the ship. As in any guarantee, the shipyard is responsible for replacing and repairing any systems that are not functioning according to the specifications.

The shipyard coordinates the activities during the guarantee period, even if the fault is recognized to be in a certain system or piece of equipment covered by a manufacturer’s warranty.

The guarantee engineer therefore must have a database of system information, including all the operational/service manuals and access to the design documents.

Owners, however, typically negotiate additional guarantees for major equipment and systems directly with the suppliers.

3. CHALLENGES AND OPPORTUNITIES

3.1 Economic challenges

After two good shipbuilding years, in terms of capacity, the next two to three years will be difficult. Like so many times before, additional shipbuilding capacity is being introduced in the middle of a downturn in the shipping market. This time, however, it might take some years before the market will recover.

Talks between the EU and Korea, so far, have failed to yield any concrete results concerning shipbuilding subsidies. That means subsidies likely will be reinstated in some form. With the overall market depressed, subsidies will not be the solution. They may even generate speculative orders, further increasing overcapacity on the shipping side. Navy orders may bring work for some of the yards, but for a very limited number and for a limited number of years as well.

Most of the yards implemented cost-cutting and saving projects throughout the ‘90s, and there’s little additional potential in these measures. More radical methods are required. Consolidation and merger of yards is one option, but this does nothing to improve the cost picture. It is difficult to bring a new culture into an old industrial site. It may succeed when the yard is totally rebuilt, as in the case of Kvaerner Warnow. But the consolidation of Aker and Kvaerner merely resulted in two extremely modern and efficient yards working on the same markets and utilizing the same infrastructure.

Consolidations and mergers will take place, but the outcome of that process may be reduced capacity more than improved competitiveness. Each shipyard in a bigger group should find its specialized market and products. Overlapping products will lead to a review to determine the most competitive site to build these products.

Larger shipbuilding groups will, of course, offer a better basis for work sharing, standardization, and prefabrication, and they certainly have bigger buying power. There are, however, basically two obstacles to making use of this potential. One is a cultural issue, and the other is the high variation in capacity loading with prototype products.

Culturally, many countries have already experienced the difficulty of creating deep cooperation and uniform standards between similar yards, even within a single country. The problem is even more challenging for yards located in different countries. Better information flow is, of course, the key. All standards, procedures, systems, etc. should be easily available through a common knowledge management system for all of the yards in a group. With an efficient, group-wide intranet, it might be possible to introduce group-type standardization while allowing for variations in the type of prototypes concentrated at each shipyard. Specialization is another way of building up efficiency within a shipbuilding group.

Financing is, of course, one of the benefits offered by a bigger group. This is especially important for European yards concentrating on cruise ships and ferries. Attractive financing may improve the pricing by at least 5% -- and by as much as 10-12% in the most extreme cases. Some owners are in a position to arrange their own financing, but most need help, especially in the case of smaller companies and newcomers.

Financing for construction also is essential. Although money is relatively cheap now and interest rates are expected to remain low for the foreseeable future, adequate guarantees are still necessary. A good business plan and first mortgage may not be sufficient. Stock markets, leasing arrangements and bonds have been actively used to finance newbuildings. Generally, however, recent poor performance by the stock market and by several bonds have placed these financing options out of reach for the moment.

3.2 Opportunities

3.2.1 Cooperation

Cooperation has been discussed for years between shipyards, but has not really played any important role in shipbuilding. The best examples can be found in cooperation between small- and medium-size yards. For example, in Holland several yards have joined forces in steel preparation. One supplier cuts the steel and delivers prepared steel parts for yard production.

Several West European yards are building hulls at East European yards – in Romania, for example -- where the labor cost is low and relatively good steel production capacity exists. There are actually two kinds of savings here. One for the labor involved in outfitting and another savings resulting from reduced manhours for installation work aboard the vessel. Typically, work aboard the vessel requires two to three times more manhours than carrying out the same work on steel shop panel line.

Euroyards is a rather loose, cooperative organization created mainly to develop new products, such as common tanker design. However, only one such design ultimately was built, and that occurred in Spain. Coredes is a similar loose organization of West European shipyards aimed at common research and development projects funded by the European Union. However, most of these projects are related to new products and/or new technology in products, with only a few related to engineering, production, procurement, infrastructure, systems and their improvement.

Cooperation remains difficult in core areas of shipbuilding. The situation is very much the same in Japan and Korea and probably in China as well, although the system there is very centralized.

Opportunities abound, however, for deeper cooperation in procurement, engineering, prefabrication, standardization and outsourcing. This likely will occur first in Japan, where signs of deeper cooperation can already be seen through the development of common knowledge management systems. Cooperation will require better links between yard systems and better information exchange. Cooperation will create savings when the supplier market of several different shipyards is combined into one single market with standardized equipment and systems installed in all vessels built at those yards.

It is likely that ship owners will embrace cooperation, as it creates savings for them in terms of spare parts, service and maintenance availability.

3.2.2 Prototyping - standardization

Prototypes remain a big problem in shipping and shipbuilding. The whole industry is technology driven. New technical solutions and products are continuously being introduced. And while they may improve the final product in terms of safety, performance or maintainability, prototypes require design and engineering effort, coordination with all the surrounding spaces and systems, additional planning effort, new commissioning programs and training.

Although shipbuilding is considered a conservative industry, suppliers are introducing, and owners are requesting, new technology at a very high rate. Phase-out of existing technology also is quickly resulting in many cases of seven- to 10-year-old vessels with equipment, materials and systems which are no longer produced and for which spare parts are difficult to find. However, building and installation phases and shipyard building procedures typically are not taken into consideration when introducing new solutions. This is a threat that should be converted into an opportunity. Partnership arrangements, good product models and shipbuilding process simulation tools are obvious areas where this opportunity could materialize.

Standardization is a key word for safety, service and maintenance and so should not be difficult to achieve in those areas. Supplier consolidation, in accordance with ship functions, could be one way to accomplish this, i.e. a single power supplier, a safety system supplier, service system supplier, cargo system supplier, etc. At best, a galley on a cruise ship or ferry today is the product of eight companies. Soon, we expect to see this reduced to a maximum of two or three suppliers.

Clearly, prototyping should be limited to the most important and essential features of the vessel, in accordance with owner requirements. Otherwise, the product should be based on standardized parts, systems and modules.

3.2.3 Outsourcing - Supplier chain - Partnership

Outsourcing in shipbuilding began with two areas: workforce and special equipment. Jobs with uneven workload -- mainly for certain outfitting and installation tasks -- were outsourced to specialized companies where special skills were required, or simply to lower costs. Special equipment, like cargo gear and hatch covers, were outsourced because they vary by ship type. Interior outfitting was the next area, including cabins and public space equipment, paneling and installation. Sharing the workload peaks and saving costs have been the main drivers for outsourcing.

Outsourcing allows smaller and specialized companies to work with a smaller fixed organization, reducing overhead costs. The drive has been solely to lower costs. However, even within a series of 5-6 vessels, the same space is being built by as many as three different companies in consecutive ships. Only the direct purchase cost is considered. Some of the shipyards have even taken to reviewing the financial results of suppliers and subcontractors and penalizing them if they have been too profitable. This can be done by raising additional claims and by making it difficult to reach a contract for the next project. This policy has led to bankruptcies and kept all but a few subcontractors from developing their products, procedures and systems.

Lessons have probably been learned, however. Outsourcing was controlled too much by purchase costs, and the yard organizations' procedures and systems were not prepared for heavy outsourcing. Most of the yards have had problems with coordination of subcontractors and suppliers. All of the big cruise ship builders have had their preferred list of suppliers.

Planning of the design, engineering, installation and especially the coordination and follow-up procedures was not properly managed. Requirements for design documentation, taking into account the different subcontractors and their installation timing and procedures, were not carefully considered. Planning and follow-up tools were the same heavy tools used by the yard as a whole. But small subcontractors do not have the resources to use such tools, especially when cost is the only driving force.

Planning, follow-up and even change management information was not trickling down to the lowest levels in the supply chain, resulting in confusion, last-minute changes when costs are highest, and loss of time.

Design and engineering work should take into account all the different work phases, where the work is going to be carried out, who is responsible for it and the phase during which it is to be started and finalized. This allows right-working methods to be applied. It also is essential to follow the progress of the work properly to avoid sticky situations. For example, it is not unusual that outfitting is planned and designed for execution on the panel line. However, due to material delays, typically caused by a purchase not being completed in time, the work is delayed to the ship phase. This means that instead of working from the top down, all installation work must be performed from the bottom up using scaffolding, rendering previous work preparation inaccurate and resulting in execution requiring two to three times more working hours.

A planning and follow-up system must be simple enough to involve all the subcontractors and suppliers. Design documentation and change management must go through the complete supply chain. The same holds for safety issues. Cutting costs in system installation, piping and cabling may inadvertently destroy the intended reliability and safety of the system.

Tight partnership is obviously the solution in outsourcing. The management of most yards understands this, and is slowly building up their supplier networks based on partnership relationships. When suppliers and subcontractors see the possibility for a longstanding customer relationship, they are more receptive to investing in design, engineering and project management and coordination systems.

Product modeling for technical and project coordination is an essential tool to facilitate on-time follow-up and management. A good 3D product model is required for design and project coordination.

Adequate -- and only adequate -- information should be available for all parties in real time. The amount of information should be limited to the essential or efficiency will suffer. Start-up information, version handling, progress status and process changes must be available for all parties involved throughout the process.

3.2.4 Turnkey contracting - Slice ship

To avoid too many interfaces and to concentrate supplier responsibility, turnkey contracting has been introduced. This means, for example, that one space or one complete system is delivered, installed and commissioned by one supplier. Interfaces are then limited to the yard-only or to the yard and those suppliers responsible for through-going systems. Typical turnkey installations are galleys, garbage systems, elevators, cabins, air conditioning systems, public spaces, hatch cover systems, ro-ro systems and the like.

In reality, however, there are few full turnkey installations. For example, a single company typically supplies all galley systems and equipment. However, a second company handles air conditioning and a third handles all basic electric and lighting installations. Therefore, even turnkey installations involve multiple interfaces.

The next step would be a complete package, including the steel structure and everything in it. A full package offers interesting incentives for a ship owner, including:

- integrated system responsibility
- single source interface
- single source for maintenance and lifecycle support
- enhanced training
- increased safety
- reduced operating costs
- standardization

Incentives for a shipyard include:

- integrated system responsibility
- single source supplier for reduced coordination
- shorter lead and installation times
- lower overall costs
- lower overheads

For a supplier, the incentives can be very attractive, especially related to increased volumes, increased market, increased after-sales volume, as well as potentially improved margins.

As a new method in shipbuilding, total packages involve obvious risks. Wider responsibility for one supplier, having typical shipyard parts included in the supplier package, and the definition of interfaces and responsibilities are just a few considerations.

Despite the considerable risks for all parties, it does appear that the package concept is one the industry should actively investigate. Three essential issues are required to succeed in package deliveries: a good product model (specification), efficient project management, and good technical and project coordination.

A slice ship concept is a possible further development of a package. A supplier – perhaps even another shipyard -- delivers a complete, ready-built and commissioned portion of the vessel. Fully outfitted superstructures are a good example of this potential.

Navigation bridges, bow and stern sections with ro-ro equipment, and stern sections with pod-propulsors are all possible examples of the slice ship concept. Shorter lead times can be gained. Better use of modularization, prefabrication and standardization, and reduced installation time are just a few of the potential benefits offered by slice ship concept.

3.2.5 Planning - coordination - information flow

The basis for good project management, in fact for a strong company as a whole, is a quality assurance system built up as a continuously developing process. It forms the steady foundation on which to build the procedures and regulations for project management.

A quality system consists of the following typical parts: quality policy, quality thesis of the company, quality assurance A and B manuals, documentation of quality system, C-manual (project manual), quality plan for each specific project and work procedure, and working procedure descriptions for each specific discipline and task. The quality system should be approved, continuously audited and monitored by an external quality auditor. It also should be developed based on experience.

The first step when starting a new project is to agree upon a project plan with the customer. The project plan then becomes the project manager's tool to supervise his project and to ensure that the customer's requirements are fulfilled according to the contract. Contract review and project evaluation is the first focus of the project team.

Although this is standard procedure for project management, the ways in which newbuilding projects are organized, coordinated and managed present major differences. In many cases, shipyards consider the start-up phase with the customer as a necessary evil. They, therefore, tend to provide the customer with as little information as possible, leaving him largely out of the process. Only when big problems -- typically delays – occur is the customer informed. Even at this point, however, he is not invited to participate in resolving the problems.

Typically, the yard’s team carries out project planning, contract review and project evaluation on its own. Subcontractors and suppliers are not involved and, if involved, they are each dealt with separately. This means that subcontractors and suppliers are handled not as an integrated part of the project. Project planning, coordination, management and the follow-up plan do not directly link in subcontractors and suppliers.

The available tools for project management and coordination also do not support the actual, real nature of shipbuilding projects. Typically, this is a rather complex task. The number and size of the parties involved vary significantly, so the system should be intuitive enough for even a small subcontractor to use.

The project management task for a typical subcontractor includes two major issues: 'real time' follow-up of the work and reliable reporting to the yard. The next level of subcontractor(s) must be tracked as well, using the same tool. Significant information from start-up and proceeding work phases must be made available and ready before the subcontractor can start. But different parties may be responsible for providing the start-up information, including the shipyard and one or more subcontractors.

The project breakdown structure should be similar for all parties. This is necessary to match the planning and follow-up and especially to ensure that all parties understand the reporting requirements and that nothing is overlooked. Subcontractor projects should be split into logical groups and sub-groups so that each set of work content can be identified and checked separately. When defining the work breakdown structure, the following items should be considered: yard's master plan, yard's area subdivision, and different works and work phases of the company and its subcontractors. Works and work phases must be identifiable and measurable.

Required start-up information includes the master schedule, specific requirements for the work, possible critical milestones, the input and requirements of subcontractors, and information, boundaries and connections available concerning neighboring areas.

The main project management document is the project control follow-up sheet, where all the activities are listed either as work phases or as milestones. This is the basic document where all information is registered. The status of each activity and of the overall project is controlled with status lines, which are date oriented. The original, unchanged plan must be maintained even though changes may take place. When this does not occur, the changed plan becomes the starting point, which inflates the original schedule.

Another important document is the S-curve, on which planned work, cumulative progress and cumulative hours are shown. Knowing the background of the curves and how they normally behave, it becomes possible for the management to make a one- to three-month forecast of how the project will develop. If the work breakdown is accurate it is even possible to identify possible deviations before they reflect on the total project. This enables the yard to take corrective action when needed.

This philosophy has been successfully applied in some major turnkey contracts including design, engineering, production, installation and commissioning for ferries and passenger cruise ships. One turnkey contractor had two to four subcontractors for special areas. Some of these subcontractors have never previously had access to any planning or reporting system. It was, therefore, essential for both systems to be easy for workers (down to the level of foremen) to use and understand, if they were to be effective.

One of the key issues is to plan the different work phases of all parties properly to reach the most efficient working methods. Sub-optimization of one work phase may lead to extensive consumption of hours in the next phase. This requires good understanding of all the work phases and the roles of all parties. A subdivision by discipline is no longer possible; more efficient forms of combining multiple disciplines are required. At this point, technical coordination starts to play an important role. Fluent and understandable information flow in both directions is an essential feature. Project planning and follow-up tools must be developed and adapted to fit the current shipbuilding environment.

3.2.6 Assembly yards - Knowledge management

Some of the yards have already made their move towards an assembly type of production facility. Therefore, they are concentrating on their core business, which is steel and hull production, piping and machinery installation and coordination and management of the complete product and project. Large entities are subcontracted either as complete packages, as turnkey contracts or as typical subcontracts.

Assembly yard principles, when properly utilized, minimize the outfitting work at the shipyard phase. The maximum amount of work is removed into workshops with a high degree of prefabrication. Prefabrication yields a remarkable saving in installation hours, but modularization takes the concept even farther and generates additional savings. Modules could be equipment, systems, pipe packages or some combination, including even structures. Functional modules are creating further benefits in commissioning and paving the way for standardization.

However, modularizing an engine room by simply cutting it into modules is not the right solution. This approach typically generates additional pipes, structures and equipment, plus additional weight, which at least partially offsets the benefit gained by modularizing.

Assembly yard principles offer the potential for shorter delivery times, improved building and installation procedures and improved quality. But the approach requires a good planning system incorporating all the suppliers and subcontractors. An efficient information flow and knowledge management system is required as well, tying together all the parties: ship owner, class, authorities, designers, suppliers, subcontractors and the yard. Having all this in place and assembling the prototype ship for the customer's requirements from a maximum number of standardized modules generates a major leap in efficiency and cost saving.

3.3 Summary

World economic development will heavily dictate the recovery of shipbuilding – more specifically, it may dictate the length of the recession following three healthy years. World trade growth is defining the recovery of container shipping and, more slowly, of container shipbuilding. Markets for smaller tankers and bulkers may be the first to recover, beginning as early as the second half of 2002. U.S. consumer behavior will be crucial for a return to pre-September 11 price levels for cruise shipping. Recovery of the stock markets will contribute to accelerated ferry newbuilding business, especially in the areas of biggest demand, including Southern Europe and Greek domestic lines.

Restructuring of shipping and shipbuilding will accelerate within the next two years. Mergers and consolidations will take place and new patterns for cooperation will be sought. If the ‘90s were the decade of new technology in ships, the first decade of the new century will be dedicated to the development of new shipbuilding practices, procedures and technology. We can profit from observing the steps taken by the aviation and automobile industries. But because the basis, procedure and infrastructure of the shipbuilding industry is different, we can't directly copy from these industries.

Trends such as increased prototyping, short series, short lead and delivery times, and the growing importance of the supply chain are all having an affect on specific features for shipbuilding. If we manage to create worldwide markets for standardized, modularized units, parts, systems, etc. in ships or in certain types of ships, we will have taken a major leap. This requires intense cooperation between the different parties and a somewhat wider perspective than is typical. But it is certainly possible, especially in today's world of safety and environmental consciousness and with today's engineering and IT tools.

4. BUSINESS INITIATIVES - INCREASED PRODUCTIVITY

4.1 Changes and opportunities in the product

Development of ship designs and especially of their safety features has been driven by accidents. *Titanic* is one of the best known, of course, but *Exxon Valdez*, *Erika*, *Herald of Free Enterprize*, *Scandinavian Star*, *Estonia*, and *Derbyshire* are all names associated with tragedies. They also are names that have had a major influence on the rules and safety developments of different ship types, from double-hull tankers and fire fighting systems to escape-way arrangements and water-on-deck stability requirements.

The introduction of very large passenger cruise ships in the late 1990s led to concern about vessel size, the large numbers of people aboard and how incidents and accidents would be handled. A proactive approach became imperative. IMO, major shipping companies, classification societies, research institutes, authorities and other parties began to work proactively towards higher safety standards. Safety simulation started to be developed, and numerical simulation and computer fluid dynamics methods are being incorporated into design methods.

The major leap into new designs will be taken when so-called equivalent designs are approved. IMO is working in this direction and authorities are pushing this forward. Equivalent design will be possible for damage and fire safety and for evacuation. With equivalent design, design is no longer rule-based (rule restricted). Instead it is based on simulation and safety (risk). This leaves designers free to propose a totally new type of design, provided the safety level of the design is at least as high as that achieved with a similar rule-based design.

An arrangement of the vessel can then be developed on the basis of the intended purposes, i.e. ro-ro cargo handling efficiency, space allocation efficiency, etc. The problem has been how to prove the equivalency of the improved design. Simulation methods provide this proof. Passenger evacuation simulation tools are perhaps best known and are already well advanced. IMO is, therefore, expected to approve the equivalency principle this year.

Flooding simulations and model tests are being applied to water-on-deck situations for ro-ro passenger vessels. Risk-based design methods are being developed, and the first practical tools will be available within the year. These methods obviously will calculate cost as one parameter, so cost-benefit analysis will be an essential part of the new design tools. It is hoped that this will lead to easier-to-build, cheaper vessels with better earning capacity.

However, all these methods require a quick-modeling tool for the arrangement of the vessel and a highly efficient system for alternative verification and modification handling.

4.2 Increased productivity

When the costs of a ship project are calculated, the formula is actually simple and consists basically of two cost positions: work hours and material costs. The work hours are based on the production planning estimate derived from the shipyard statistics. The material costs are based on quotations and budget prices from suppliers.

If the material calculation and procurement are done correctly, the material cost position is more or less fixed and predictable. The work hours are an unknown factor in the formula, and exceeding the hour budgets during production is not uncommon.

Assembly shipyard concept means moving to extensive subcontracting in the shipbuilding process. The shipyard retains only certain production areas and the rest of the work is subcontracted. In fact, this means moving work hours from the hour budget to the material budget. If this is done correctly and the contract is for a fixed price, the unknown factors in cost calculation are reduced and the financial risk is shifted to the subcontractors.

Subcontracting brings the following advantages:

- Working teams are specialized and skilled for the work
- Subcontracting companies with higher efficiency and smaller overhead costs
- Flexibility in load fluctuations

- Shipyard labor contracts generally make it very difficult to lay off people quickly when there is no work.
- Turnkey subcontracting involves total responsibility for a system or an area
- Savings in material costs

The basic form of subcontracting is work subcontracting. In that case, the yard provides the design documentation, materials and facilities and the supplier takes care of the production work at a fixed contract. This is the simplest form of subcontracting and still involves substantial responsibility for the yard.

In a turnkey contract, major responsibility is moved to the supplier. He creates the design and purchases the materials. The scope of the turnkey can be one system or a complete space like a separator room or a cabin area. The coordination responsibility for the area therefore lies with the subcontractor.

When the amount of turnkey is increased, however, coordination and management becomes more complicated. The master schedule of the shipyard is the basis, but every supplier prepares its own schedules using the milestones from the master plan. Today, this is often very uncontrolled because every participant uses its own project management system, if any. From the coordination point of view, it would be ideal to have all of these suppliers linked to a single project management and follow-up system. Similarly, the material management systems should at least be compatible and capable of exchanging information.

The interfaces in the design and production between different suppliers are critical and the exchange of information is an absolute must. Ideally, using the same design system and database achieves coordination with a high confidence level.

Standardization is a good method of decreasing costs. It reduces the design costs and production costs and minimizes the surprises in installation work. Shipyards are traditionally standardized for minor outfitting items like stairs, door, hatches, bollards, etc. To some extent this is also true of larger units, but that is standardization per yard, not per industry.

It is clear, however, that there is tremendous potential for extending the scope of standardization to bigger units and even to entire parts of the ship, such as engine rooms. Technically, this would not be difficult, but shipbuilding and ship owners,are ruled by tradition. Part of this tradition involves the idea that ships should always be one-off designs, which limits the possibilities for large-scale standardization. Changes in attitude are needed, for the potential economic reward is big and lucrative for all parties.

4.3 Changes and opportunities in the process

While the phases in shipbuilding remain the same - the steel hull has to be built and outfitted, for example – who does it or where it is done is changing. The production place is not necessarily the shipyard any longer, and major parts of the work can be done elsewhere.

The assembly shipyard concept provides the potential to use a large network of companies, allowing production work to be done in a parallel process. Parallel production work shortens the delivery time but requires significantly more in terms of coordination, design and procurement.

For the future shipyard, a newbuilding project will not be a production problem, but more of a procurement and coordination problem. Instead of relying exclusively on its own resources and material management, an efficient information distribution and functional procurement organization supported by technical expertise will change the way shipyards work.

By increasing turnkey subcontracting, supplier companies can take on more of the financial and technical risks from the shipyard, assuming they are able and willing to do so. This may lead to deeper involvement by these companies in the actual contract with the ship owner. If the suppliers carry the risk, they will want to have a place at the negotiation table when the technical specifications, delivery time and price are decided.

4.4 Initial Design

Advances in information technology are creating new possibilities for the initial design phase. With more sophisticated software and powerful computers, it is now possible to develop the design further before signing the contract. This has the following advantages:

- As the product is better defined, the price may be more accurately defined;
- As the design is better defined, surprises at later stages should become less numerous;
- The basic design phase can be shortened due to a better starting point;
- Procurement can proceed more quickly and easily; and
- Ultimately, this will lead to shorter delivery times.

The tools that contribute to a better-defined product in the initial design phase include the following:

- Integrated 3D CAD encompassing hydrostatics, stability, structure, weight calculation and room definitions, purchase specifications, production planning definitions and efficient reporting tools;
- An efficient and easy-to-use CFD program linked to the 3D system, enabling designers to optimize the hull form prior to model testing and to select the right machinery earlier; and
- An FEM-analyzing program linked to the 3D system, and enabling a fast and cost-effective check of the global strength.
- Simulation software for functions aboard the vessel, as well as production and installation.

There are risks, of course, when one considers using an integrated 3D CAD system at the preliminary design phase. At this stage, the design changes very rapidly and even radically. The system, therefore, must be flexible enough to support this kind of evolution, rather than impede it. Advantages, however, include:

- Risk-based design
- Simulation-based design
- The ability to completely define and test a product at contract signing, reducing the design effort and time required afterwards
- First version of product model for design, space allocation and handling, cost estimates, planning, routing, simulations, analysis, CFD, lifetime management, etc.

4.5 Basic Engineering

It would be logical for the total design created in the basic engineering phase to be based on a common product model, which would serve as the medium of coordination. However, such an evolution must be achieved without increasing the amount of work in this phase and certainly without lengthening the duration of this phase.

Another logical step would be for the information generated at this stage to be stored and organized to serve not only the builder and approvers, but also the end user -- the ship owner. He will, after all, need this information daily during the following 25 years!

4.6 Detail design

Detail design, today, is done largely in 3D. Product data starts to accumulate along with the model as the design advances. Every component has material information attached. If it is supplied equipment, it also will have a volume component model. Depending on the shipyard, this information is moved to the material system in either a manual or semiautomatic way. Usually, the timing information must be added at this stage. This process is already a major step forward in product information management. Still, it is clear that the potential is there for much more information to be attached to the design model. This information can be anything from the costs to the operational manuals of the equipment.

The design model is also the mean of coordination when several design offices and turnkey suppliers are working with common interfaces. If all parties can use the same database, interface management will become much easier.

If the basic design and the equipment data can be linked to the design model, yards will achieve better control by ensuring the availability of the latest data.

Ideally, the equipment manufacturer can supply all the necessary information about his product directly to the design model, including the volume component model.

4.7 Production

As already emphasized, production planning is absolutely key. The estimation of production hours and the arrangement of production, today, are done mostly manually based on a combination of personal experience, information on the present situation at the yard, facilities and a statistical database on production efficiency. The planners often need to adapt all this in a limited time frame. It is obvious that opportunities to seek out more attractive alternatives and optimize the process are being lost.

Production simulations provide a new tool to solve these problems. The simulation can be run on a yard level to arrange shipyard loads or it can be run on any individual production process to optimize the throughput and use of facilities.

Steel part manufacturing is a good example. It is not unusual for the panel line to stand still at least 60% of the time waiting for materials, for work orders or for more space to be cleared. On the other hand, the panel line is the biggest investment in steel production and produces good quality with high efficiency. By optimizing parts production, the degree of panel line utilization can be increased, which means shorter production times and, in the best cases, shorter delivery times.

Simulation systems must enable working in the different detail levels. During the contract and basic design stage, the information from the ship is limited. But as the detail design progresses, the production information increases rapidly and the simulations become more detailed.

An important part of production is a clear, continuous process for:
- Material management
- Resource management

4.8 Examples from everyday life at the shipyard

Example 1

Basic design for a passenger vessel was running late by 3 months and the quality was not good. At the same time, procurement was late and equipment data was not available.

This created pressure on the detail design, but the gap was reduced to 2 months. However, the gap was still great enough to force a major portion of the prefabricated pipes and equipment, which were planned for installation during the block stages, to be delayed and installed much later during the area outfitting. This caused excessive costs for the shipyard.

The reason was the yard's inexperience in this type of ship, and in basic engineering.

Example 2

The delivery of propulsion gears for a ro-ro passenger vessel was seven weeks late. The shipyard had to make a large opening in the main deck to install the propulsion gears because the engine room was already closed by the time they arrived. All the outfitting under the deck was left out and installed later.

This was very costly for the shipyard. The gear manufacturer paid only the fee for delay, which reached the maximum after four weeks. Beyond that the supplier was not in a hurry with the delivery.

The follow-up of the supplier was not sufficient and the procurement and basic design processes were not proceeding hand-in-hand, causing disruptions in the purchase specification.

Example 3

The shipyard ordered prefabricated pipes from a new supplier. The bending of pipes was done incorrectly and overall quality was poor. This caused a lot of problems during the pipe installations.

This occurred because the shipyard did not inform the designer that the supplier had been changed to one that had slightly different bending equipment. The yard also did not give bending instructions (information on how to read the drawings) to the supplier.

5. PRODUCT LIFECYCLE MANAGEMENT

Shipyards have been producing the first product lifecycle models for lifecycle management of navy vessels, typically based on models used for detail engineering and workshop drawings. Experience has not been very encouraging, with a lot of detailed information having little or no value for the management of the vessel. The model being prepared for the building of the vessel is not the best starting point and, therefore, does not provide a suitable basis for a lifecycle model. Blocks and grand blocks and cutting and welding instructions are not essential for structural maintenance.

Product lifecycle management is of importance for the owner/user of the vessel, and the suppliers and repair yards participating in the service and maintenance of the vessel. The builder seldom sees the vessel after delivery.

Ship lifecycle management includes all safety issues, operational issues, crew training, maintenance, service, conversions and abnormal incidents.

For a tanker it obviously covers tanks, tank structure and coating, general hull structure, cargo piping systems and machinery systems. For a passenger cruise vessel, passenger comfort-related systems become an important issue, as well as all interior decoration and materials. Systems related to passenger flow also are of importance, as well as electric and propulsion power systems.

Classification societies have produced their first product models, including the basic hull structure, but that is only a starting point. Moreover, these are not yet available for passenger vessels.

It is most likely owners, their consultants and suppliers that will have the responsibility to produce the systems required for successful product lifecycle management. Knowledge management, product database, and 3D product models may be the building blocks for successful product lifecycle management. Obviously, at the end of the basic engineering phase, all necessary information is available, including structures, coating, systems, functions, layouts materials, suppliers and the like. This should only need to be updated with the detail engineering phase data and final commissioning data. It will become reality when a business concept is derived from it. Two areas that may be forerunners are: safety systems/decision support systems and machinery maintenance.

The more the industry moves towards partnership working alliances, turnkey supplies, package deliveries or even slice-ship concepts, the more eager suppliers will be to have a good product database and 3D product model of their part. This will be especially true if they offer standardized and modularized product. This would easily lead to an expansion of the service and maintenance business, which in some other industrial areas has become a bigger business than the original product. It will, therefore, likely be the suppliers who will play a major role in introducing Product Lifecycle Management systems for shipbuilding and shipping.