Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management
Dhaka, Bangladesh, January 9 – 10, 2010

Managing Material Flow at the US Shipbuilding Industry

MD B. Sarder
Industrial Engineering Technology
The University of Southern Mississippi (USM)
730 East Beach Blvd, Long Beach, MS 39560, USA

Ahad Ali
Department of Mechanical Engineering
Lawrence Tech University
Southfield, Michigan 48075, USA

Susan Ferreira
Systems Engineering Research Center
University of Texas at Arlington
Arlington, Texas 76019, USA

Mohammad A. Rahman
Industrial Engineering Technology
The University of Southern Mississippi (USM)
730 East Beach Blvd, Long Beach, MS 39560, USA

Abstract

The shipbuilding supply chain is a very complex process, especially due to the length of time it takes to complete one finished product. It can prove very difficult to successfully manage this type of supply chain without causing a negative impact on the rest of business functions and the overall profit of the company. This paper focuses on the shipbuilder's supply chain and in particular the management of the material and its impact on the company's bottom line. Improvements in material management will help position the shipbuilder to receive future contracts and ultimately provide the customers with quality of ships needed to carry out its purpose.

Keywords
Supply chain management, material flow management, shipbuilding

1. Introduction
Building a ship utilizes highly complex processes to design and construct built-to-order products that meet its customer requirements [1]. This process includes the cooperation of all parties, including the Customers, the shipbuilder and its suppliers. The process further necessitates a seamless interaction of the suppliers, material management, planning and scheduling, and production. It is this method of these interactions that can either cost the shipbuilder and customer due to rework and rescheduling or allow the shipbuilder to construct the ship at the cost and in the timeframe allotted by the contract and even more desirable, at a profit. Because of the high costs of constructing ships and current practices of shipbuilding, many times the shipbuilder does not make a large profit and sometimes not at all. In order to make a profit, the shipbuilder has to do two things: 1) Create processes and practices to reduce and eliminate rework, reschedule and low quality products, 2) Properly bid into the contract any normal production disruption caused in the schedule by Government dictated requirements, Government furnished information and equipment, and 3) Create processes to capture and charge for disruptions caused by change to requirements, schedules or low quality information or material provided by the Government or vendors. The shipbuilding industry is dependent heavily on the Government. The only domestic customers for ships have been either the U.S. Government or firms completely dependent on the government policy [2]. Therefore it is essential that shipbuilders take the necessary steps to make a profit within its limited market.

Shipbuilders do take advantage of multi-ship production contracts in order to reduce cost and ultimately increase profits. They take advantage of economic order quantity (EOQ) material purchases and lessons learned from previous ships [1]. But it takes anywhere from four to seven years to build a ship and therefore there are many changes to the original baseline, including design and material changes, specifically to keep up with technology changes. The ship design includes a large communications suite that must be technologically advanced, so what was up to date at the beginning of the contract, rapidly becomes out of date as the years progress. The Government must then issue contract changes that affect design and material. The same goes for vendors who can no longer provide the shipbuilder with certain materials. And of course without the material that is needed, production comes to a halt or a work around must be put in place. And this usually causes a schedule slip that translates into escalating costs and profits lost.

In recent years, shipbuilders have been plagued with out of control costs due to inefficient planning and scheduling and quality issues. Material issues have played a huge factor in this. In the marine industry, material and equipment make up over 50% of the cost of the delivered ship [3]. Material lead times, late identification of obsolete material, and low quality have wreaked havoc on the schedule and on costs. These inefficiencies of the shipyard have caused the government to investigate already delivered ships and ships that are currently in production. It has also caused Congress to question the amount of money that is being spent to produce the ships and the quality of ships that are being procured by the Government. The following challenges, along with Congress's scrutiny, present itself to the U.S. Customers as they predict their need for future shipbuilding [3]:

- keeping U.S. shipyards in business to maintain the industrial base,
- acquiring affordable ships,
- shortening the pre-contract, design and building cycle times, and
- maintaining ships.

2. SUPPLIER MANAGEMENT

At the beginning of a contract, the Government provides specifications and schedules that allow the contractor (shipyard) to determine what material and/or equipment will be needed and what will be government furnished or contractor furnished. Contractor furnished means that the shipyard has to go out and procure the material from commercial vendors. One such document that the Government supply is called Schedule A. Schedule A is a list of all Government Furnished Equipment (GFE) and the timeframe that it will be delivered to the shipyard. Schedule C is also supplied and it is a list of Government Furnished Information (GFI) and the delivery schedule for each GFI item. The GFI is the specification and installation directions for the items in Schedule A. The GFI helps the contractor determine if it has to purchase the support material for the equipment, such as the cables and the associated connectors. Inside of the GFI it will indicate whether the support material is supplied with equipment (SWE) or not supplied with equipment (NSWE).

It is from this information that planning and material begin to build a schedule of what material is to be purchased, who will it be purchased from, and when to purchase it to meet need dates. At contract baseline, the government and the shipbuilder determines what material and equipment is long lead time material (LLTM) and the government usually awards LLTM money before the contract is signed. That money is called bridge money. As discussed earlier on in the paper, shipbuilders usually receive multi-ship contracts and many times the ships are "rollover hulls". Rollover hulls mean the ship is a replica of previous constructed ships and design information can be rolled over. Shipbuilders will usually try to re-use vendors from previous hulls. Still a bidding process goes into effect with numerous vendors for the LLTM.

Vendors are provided with the requirements and specifications for the LLTM. The requirements are driven by the Government specifications. Some Government requirements are high level which allows the Contractor to determine lower level specifications, and others are completely driven by the Government down to the lowest level. Each vendor assesses its ability to meet the requirements and provides the shipbuilder with its cost bid and the timeframe the material can be delivered. The bid usually contains a breakdown of the vendor's services and the costs associated with it.

2.1 Supplier Issues

Shipbuilders run into numerous issues when working with their vendors. First, how does the shipbuilder get the lowest price possible for the material/equipment without sacrificing quality. This becomes increasingly difficult since there is a limited supply base for the shipbuilding market. Suppliers create a niche for certain materials and assembled sub-components to make themselves more valuable as a supplier to the industry and therefore they can take advantage price increases for their services. If there are no other vendors that supplies the material or equipment that is required by the Government, the shipbuilder can be cornered into buying at the price set forth by the supplier.

Once a vendor is accepted, the supplier is expected to deliver certain informational requirements set forth by the Government and the Contractor. This can include qualification reports, test reports, and installations drawings. The traditional method used from years back was to deliver these documents as hardcopies to the shipbuilder. Now most shipbuilders use software applications to electronically deliver these documents. One such application is Shipbuilding Partners and Suppliers (SPARS). SPARS provides a shipbuilding virtual enterprise using Web technology to re-engineer and replace manual, labor-intensive, paper-based, error-prone, and long-cycle interactions among yards, suppliers, and the Customers [4]. This is accomplished through electronic Internet-based shipyard-to-supplier business processes managed by an electronic workflow manager [4]. Figure 1 lays out the processes of the SPARS application.

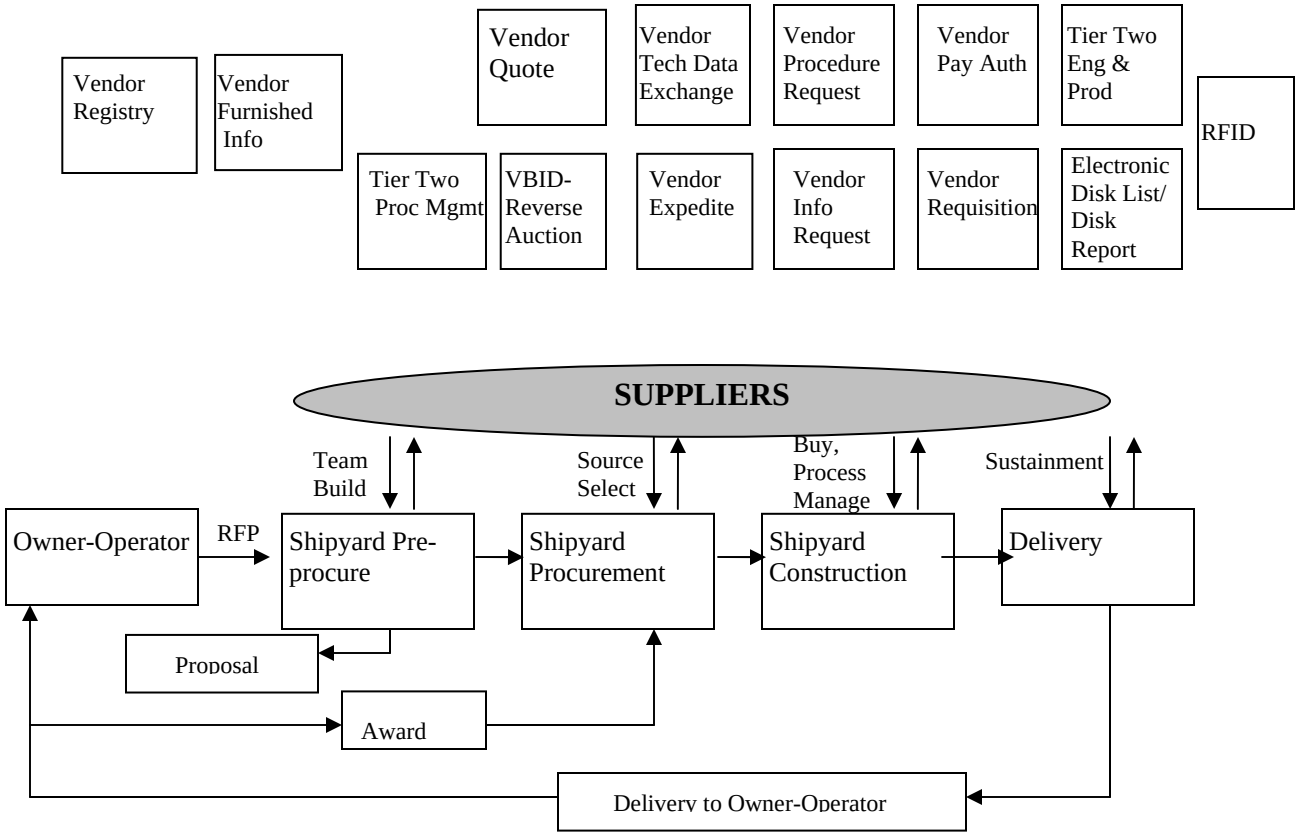

Figure 1. SPARS processes [4]

There are different, adaptable versions of the application. While this initiative was created to save money and make transactions quicker, shipbuilders have quickly found out that different versions of the applications are plagued by software issues that are contributing to the issues that it was meant to fix. Trying to meet the deadline submittal of their information, vendors try to upload the information into the application only to find it takes hours, and sometimes an entire day, for the information to upload. This also occurs on the shipbuilder's side. When a buyer or cognizant engineer needed to download the vendor's information, it would also hang up in the system, creating a delay in when the information was scheduled to be received and when it was actually received. As these occurrences pile up, a shift to the right in the schedule would occur to any associated activity and possibly others as a domino effect. The time it would take for buyers or engineers to realize the problem and relay these issues to the program office, the damage would already be done and a recovery schedule would have to be put in place.

Quality and correctness of the material and equipment received from the vendor also presents a problem to the shipbuilder. Quality issues have plagued the shipbuilding industry of late, and much of it has to do with the quality of the material delivered by the vendor and the ability of the shipbuilder to identify, assess, and control it in a timely manner. Quality issues require rework and extra work on the part of the shipbuilder to identify the issue and a fix for it. This adds time to the overall ship schedule and could possibly threaten the ship delivery date and the contract budget. Sometimes the material or equipment characteristics are just incorrect due to the vendor's misinterpretation of the requirements. As the specifications or the requirements are electronically passed to the vendor, the vendor

may read and interpret the requirements differently than the Government or Contractor intended. As a result the vendor will supply and/or build according to its own interpretation. Again, rework will be required to mitigate the issue.

2.2 Recommended Supplier Issue Solutions

To improve the current issues associated with its supplier base, the shipbuilder must assess its current state and create a strategic plan. This includes creating a strategic plan for supplier management. Many companies widely regarded for their excellence in supply chain management view the supplier management functions as central to their business performance and long term success [3]. Below are recommended solutions for each of the supplier issues presented above.

A. Limited Supplier Base and Material Cost:
   i. Change the relationships with the suppliers. Creating better relationships with the supplier can lead to long term relationships that can take different forms including strategic alliances, life of program agreements, and multi-year agreements. Shipbuilders can benefit from reduced supply chain management costs and much greater responsiveness from the vendor. The agreements often lead to continuous supplier improvement in price, delivery, quality, or technology because there is a stronger business and cultural case for supplier assistance and development by the customer firm, or for investment by the supplier [3].
   ii. If the supplier base is limited, if possible, help an existing company to develop a capability to act as a supplier to your company [3]. Japanese "transplant" automakers (Nissan, Toyota, and Honda) implemented this idea when they moved plants to the U.S. and did not have suitable suppliers to meet their requirements. They worked with potential suppliers to help bring their products and processes up to meet their requirements [3].
   iii. Where possible, consolidate multiple purchases that are different from one supplier into something like a master purchase agreement [3]. Integrated packages and greater volume both can result in fewer purchase orders, lower prices, better deliver performance and better supplier responsiveness to customer needs.

B. Vendor Quality and Requirement Compliance
   i. Build customer/supplier teams that can work together to solve problems, develop designs and eliminate waste. Working in teams can help eliminate wrong interpretations of requirements and eliminate rework due to the misinterpretations. Shipbuilders should consider allowing vendor representatives to participate in design reviews with the Government and themselves to work out any design issues with the vendor material right then. Sometimes shipbuilders or the government may not realize the limitations of the vendor's material and make design decisions that are not feasible.
   ii. Send quality representatives from the shipbuilder to the vendor's site before the material is shipped. If QA reps can catch the quality issues before the material leaves the factory, money, time and rework can be saved in the long run. Especially if the vendor is shipping large quantities of the same material.

3. RECEIVING AND WAREHOUSING

In shipbuilding, material and equipment is received by two sources: vendors (commercial) and the government. Figure 2 below shows the basic flow of the material and equipment at a shipyard. The supplier input shown is vendor furnished only. Government furnished equipment/material would also come in at the same receiving point.

The material and equipment comes into receiving where it is checked in and inspected. The determination is then made whether the material is stored or shipped to the shops or directly to the ship. Some material and equipment requires certain temperatures and are therefore stored in environmental warehouses.

When the material is received, the material is verified against the system using either the shipping list on the package or a bar code. Most shipbuilders still utilize the shipping list method. The material is then stored in a location in the warehouse depending on the availability and space within the warehouse. In many cases storage equipment has been modified to conform to the items being handled, however these modifications may not be the most efficient methods of storing current equipment [5]. Receivers who use the outdated method of logging in material and equipment using packing slips usually face extensive inaccuracies.

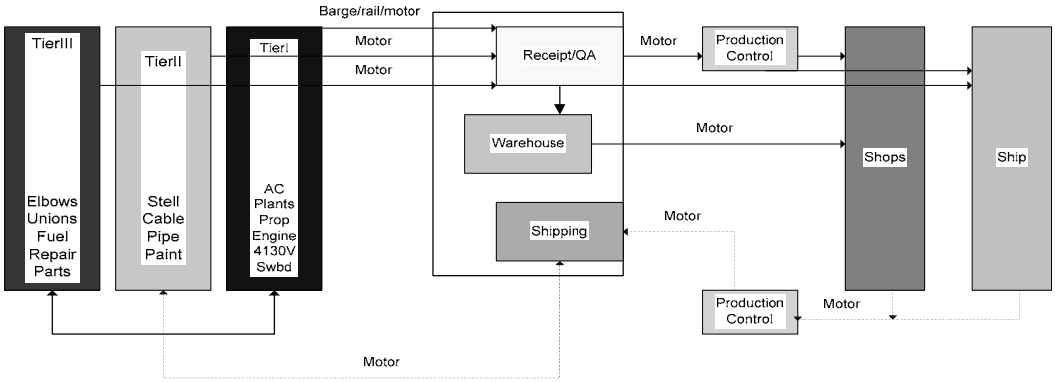

Figure 2. Basic Shipyard Material Flow Model

Manually doing this action can cause receivers to be overworked and have mistakes occurred because of it. The excessive work in doing this also adds unnecessary time to the schedule and costs the company additional money. Warehousing must properly store the material and equipment as it comes in. The goal of warehousing is to maintain an accurate count and physical control of material while minimizing handling and storage costs [6]. If not planned properly, the packages may be located incorrectly, and the warehouse may run out of room to house packages. Also if warehousing does not receive advance notice for need of the material by the shops or on the ship, it will not have time to palletize the material and meet the need schedule of the workstations and ship.

3.1 Receiving and Warehousing Issues Recommendations:

A. Packing List Method of Logging

a. Work with vendors (and Government) to begin implementing advanced tracking technology (ATT), by use of RFID, bar codes and mobile devices. This will create visibility of material throughout the supply chain, the ability to locate material quickly and verification of material through the use of hand held mobile devices [5]. This will also help to reduce paperwork. Less material will be lost with the capabilities of this technology.

b. Work with vendors (and Government) to make sure every piece of equipment is defined and scanned as part of the tracking system. Each piece, including material such as cables and connectors, should be trackable to reduce loss.

B. Warehouse Storage

a. Warehouse personnel should be proactive as opposed to being reactive. The tracking system mentioned above will help the warehouse plan the space for the needs of the contract. Advanced shipping notices will also allow personnel to have the correct people and equipment available to help store the equipment. Warehousing functions can take advantage of layout solutions that help optimize the space availability for the material that has to come in. There are also software solutions to help determine scenarios for flow of material from receiving to the warehouse to the shops/ship. Warehousing should adopt an application that allows orders with advance notice from the workstations to meet their schedule need.

4. MATERIAL FLOW TO SHOPS AND SHIP

Material flowing from the warehouse to the shops and ultimately the ship is shown in Figure 2. In shipyards, there are holding places (usually open spaces) for material to be used for work in progress (WIP). These places should be located to minimize travel distance and time for delivery flow by locating them closest to the point of use locations. But this is not always the case. Sometimes the holding places are located according the available space in the shipyard. Production Control (PC) (shown on Figure 2), prepares work packages and orders the appropriate material required to complete the job and maintain even workloads throughout the various workstations within the construction process [7]. They help to determine where the material will go, whether immediately to the work station, or to the holding places if craft is not ready to use it immediately. Many times the material may sit in the holding places for long extended periods because the material was not actually needed. And when it is needed, work must stop until that material is located, loaded up and then brought to the workstation. The time it takes to perform this task is dependent on the location of the holding place and its distance from the workstation or the ship. This of course causes a slip in the schedule for the work to be performed and time is money. Also if the material is not

taken straight to the workstations or ship, then the transportation (usually trucks, possibly cranes) will have to make multiple trips and cost the shipyard additional money.

4.1 Material Flow Issues Recommendations

A. Design Flow Issues

a. Perform a delivery flow analysis using simulations tools to determine the best locations for workstations and holding places. This will help to minimize distance traveled and the time it takes to reach the destination of the material. There is no 100% efficient flow pattern, however there can be a solution that, when considering all parameters and constraints, is the best [8].

B. WIP Material Holding Time

a. High WIP creates additional inventory handling/movement cost. Review WIP and determine if material is actually needed when requested. If WIP is high, manage it by reviewing the current schedule for need of material and make adjustments as necessary. WIP which exceeds allotted storage time can become damaged which requires movement of the material out of WIP to a repair locations. This goes for excessive handling also which increases the opportunity for material to be damaged.

5. CONCLUSION

There are many factors that play a part in creating a competitive and profitable company. Managing the supply chain is one of the biggest impacts a company can use to make the changes needed to improve its current state. With the market being limited and practically unprofitable at this point for shipbuilding, shipbuilders must take the necessary steps to transform their current practices. Current practices of shipbuilding is slowly driving the market down and putting the customers in a precarious predicament with Congress. But if the shipbuilder improves its processes which will in turn improve the quality and cost of producing ships, the market will be on the right path for competing with other industrial sectors. Material management is just a portion of the supply chain, but efficient management of material will prove to be very beneficial to the entire supply chain and ultimately the shipbuilder, supplier and the Customers.

REFERENCES

[1] Clark, Deborah L., Donna M. Howell and Charlie E. Wilson, Improving Shipbuilding Practices Project: Efficiency Through Rework Reduction, Naval Postgraduate School, September 2007, pg. 1-137

[2] Bunch, Howard M., Colin P. Hammon, Richard C. Moore and Richard Lee Storch, Ship Production 2nd Edition, Cornell Maritime Press Inc., 1995.

[3] Fleisher, Mitchell, Ronald Kohler, Thomas Lamb and Nathan Tupper, Shipbuilding Supply Chain Integration Project, Environmental Research Institute of Michigan, 1999, pg. 1-53

[4] Fowler, J, B. Gischner, L. Karns, and R. Wood, The National Shipbuilding Research Program Contribution in Advancing Information Technology in the Shipbuilding Enterprise, Journal of Ship Production, May 2008, pg. 57-64.

[5] Chakov, David, H. and Don Decedue, Re-engineer Internal Supply Chain /Material Delivery Process, Northrop Grumman Ship Systems, March 2006, pg. 1-47.

[6] Dwivedi, S.N. and Crisp, J. “Current trends in material management in the shipbuilding industry”, International Journal of Computer Application, Vol. 16 , Issue 1, 2003.

[7] Cakravastia, A. and Diawati, L. 1999. “Development of system dynamic model to diagnose the logistic chain performance of shipbuilding industry in Indonesia. Paper read at International System Dynamics Conference, Wellington, New Zealand.

[8] Koenig P.C.; Narita, H. and Baba, K; Lean Production in the Japanese Shipbuilding Industry? Journal of Ship Production, Vol. 18, Number 3, 1 August 2002 , pp. 167-174(8)