Aalto University
School of Engineering

MEC-E1004 Principles of Naval Architecture

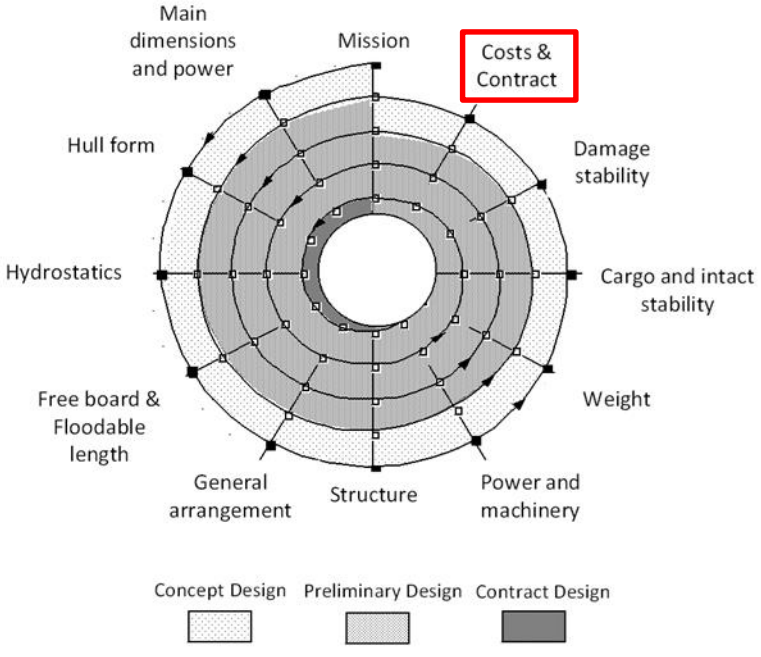
Lecture 10 – Economic assessment

Learning points !

After this lecture, you will be able to :

- List and explain
  - *Different cost categories*
  - *Different types of economic KPIs for ships*
  - *Measures that can be taken to reduce shipbuilding costs*

- Carry out an economic assessment of your ship project



Assignment 10 – Economic assessment

- Roughly estimate the total building costs of your ship.
  - *Calculate the cost of different ship systems and spaces based on estimated cost coefficients (costs per weight, capacity, performance, or volume unit).*
    - Use the SFI system (1st – 2nd level) as "check list" to make sure that you have considered all relevant components
  - *Compare with publically available cost information on similar/reference ships (if available)*
- Define and assess at least one economic KPI for your ship (e.g. the payback period, IRR etc.).
- Describe by what means the values of the KPI(s) could be improved.
- Considering the defined mission, objectives, and KPIs, perform a SWOT analysis of your ship project.

Running costs categories

Operating costs
- Expenses involved in the day-to-day running of the ship—essentially those costs such as crew, stores and maintenance that will be incurred whatever trade the ship is engaged in

Periodic maintenance costs
- Costs incurred when the ship is dry-docked for major repairs, usually at the time of its special survey

Voyage costs
- Variable costs associated with a specific voyage and include such items as fuel, port charges and canal dues

Capital costs
- Depend on the way the ship has been financed (e.g. dividends to equity, or interest and capital payments on debt finance)

Cargo handling cost
- Expense of loading, stowing and discharging cargo

Analysis of the major costs of running a bulk carrier

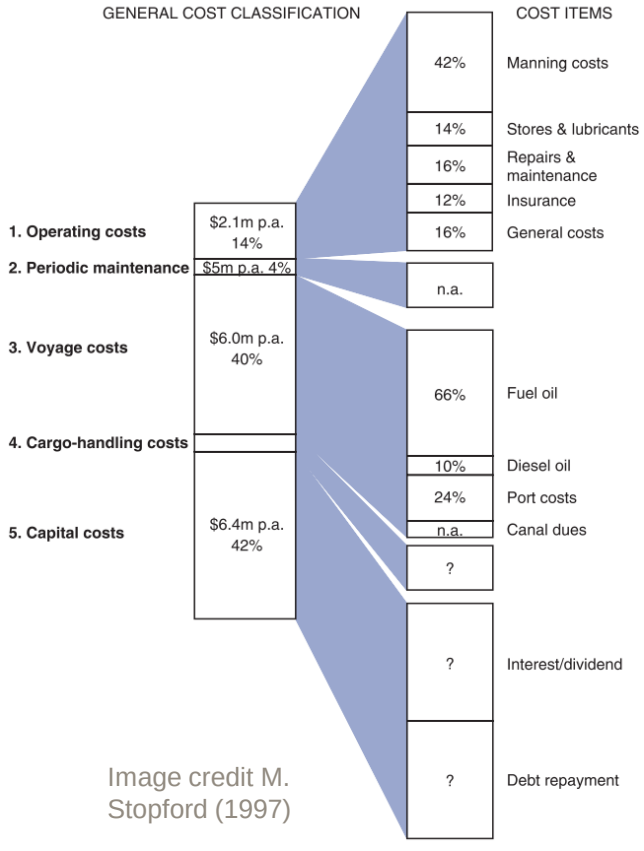


Image credit M. Stopford (1997)

Stopford M, 1997. Marine Economics, 2nd ed., Routledge, London. ISBN 0-203-75090-X.

Cost categories

Example: development of a ship's cost structure over time

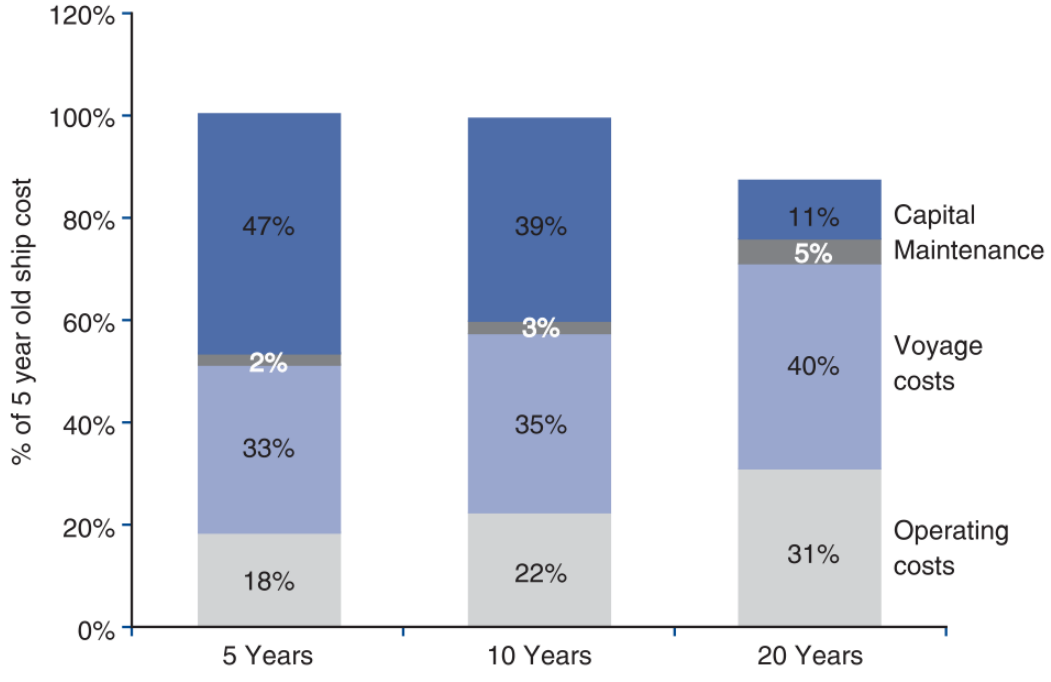


Image credit M. Stopford (1997)

Economic KPIs

Example of economic KPIs of a ship

- Net present Value (NPV)
- Net Present Costs (NPC)
- Internal Rate of Return (IRR)
- Required Freight Rate (RFR)
- Payback period
- Average Annual Costs (AAC)
- Life Cycle Costs (LCC)

Economic KPIs - Net Present Value (NPV)

- The economic performance of a ship is assessed based on
  - *Price at purchase (initial investment)*
  - *Expected interest rate*
  - *Expected life-cycle costs and revenues*
  - *Currency fluctuations*

- Revenues are difficult to predict
- Costs are somewhat more predicable

$$NPV = -C_0 + \sum_{i=1}^{n} \frac{C_1}{1+r}$$

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_n}{(1+r)^n}$$

$-C_0$	= Initial investment (ship price)
C_n	= Cash flow (= revenues–cost) during year n
r	= Interest rate
n	= Year

Example - NPV

- A ship owner is considering to invest in a system that recovers energy from his ship's exhaust gases. The system costs 2M€ and is expected to reduce the ship's daily fuel consumption by 2 tons (fuel price = 700 €/ton). The maintenance costs for the system are 20.000 € / year. The ship operates 230 days / year. The interest is 12 % and the equipment is expected to have a life time of 10 years. Do you recommend him to invest in the system?

Initial investment	2 000 000	EUR
Saving in daily fuel consumption	2	ton/day
Fuel price	700	EUR/ton
Annual operating days	230	
Annual saving in fuel costs	322 000	EUR
Annul maintenance costs	20 000	EUR
Annual savings	302 000	EUR
Interest rate	12.0 %	

Year	NPV, annual cash flow	NPV
0	-2 000 000 €	-2 000 000 €
1	269 643 €	-1 730 357 €
2	240 753 €	-1 489 605 €
3	214 958 €	-1 274 647 €
4	191 926 €	-1 082 720 €
5	171 363 €	-911 358 €
6	153 003 €	-758 355 €
7	136 609 €	-621 746 €
8	121 973 €	-499 773 €
9	108 904 €	-390 869 €
10	97 236 €	-293 633 €

Negative NPV → Investment not recommended!

Economic KPIs – Required Freight Rates (RFR)

- The RFR is that which will produce a zero NPV, i.e., the break even
- Is calculated as the sum of the present value (PV) of a ship's operating costs and acquisition costs, divided by its cargo capacity

$$RFR = \sum_{i=1}^{n} \left[\frac{Present\ value\ of\ operating\ costs + Present\ value\ of\ acquisition\ costs}{cargo\ tonnage} \right]$$

Example RFR

- A ship-owner expects to transport 450.000 tons of cargo annually with ship that costs 200 M€ to buy and is expected to have an life time of 20 years. The ship's total annual costs are 10M€ and the interest is 12 %. What is the required freight rate?

Initial investment	200 000 000	EUR
Transport capacity	450 000	ton/year
Freight rate	102.30	EUR/ton
Annual revenues	46 035 000	EUR
Annual costs	10 000 000	EUR
Annual cash flow	36 035 000	
Interest rate	12.0 %	

Year	NPV, annual cash flow	NPV
0	-200 000 000 €	-200 000 000 €
1	32 174 107 €	-167 825 893 €
2	28 726 881 €	-139 099 011 €
6	18 256 452 €	-120 842 559 €
7	16 300 404 €	-104 542 155 €
8	14 553 932 €	-89 988 223 €
9	12 994 582 €	-76 993 641 €
10	11 602 306 €	-65 391 335 €
11	10 359 201 €	-55 032 134 €
12	9 249 287 €	-45 782 847 €
13	8 258 292 €	-37 524 555 €
14	7 373 475 €	-30 151 080 €
15	6 583 460 €	-23 567 620 €
16	5 878 089 €	-17 689 531 €
17	5 248 294 €	-12 441 237 €
18	4 685 977 €	-7 755 261 €
19	4 183 908 €	-3 571 353 €
20	3 735 632 €	164 279 €

Shipbuilding costs

Question: What is the difference between shipbuilding costs and ship price?

Shipbuilding costs

Labor and overhead
- Overheads (Indirect costs)
- Direct labor

Materials
- Other
- Major purchases
- Main engine
- Steel

Related costs
- Interest on capital

Shipbuilding costs
- A shipyard's expenses for building a ship

Ship price
- The amount charged for a ship
  - *Profit = Price - Costs*

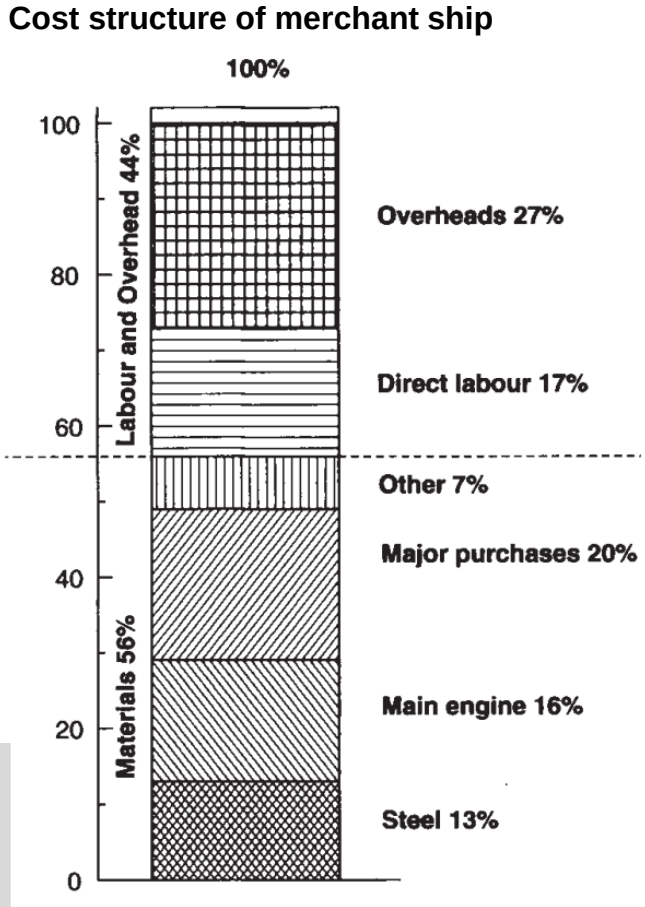


Image credit M. Stopford (1997)

Shipbuilding costs

Question: What measures can a shipyard take to reduce costs?

Shipbuilding costs

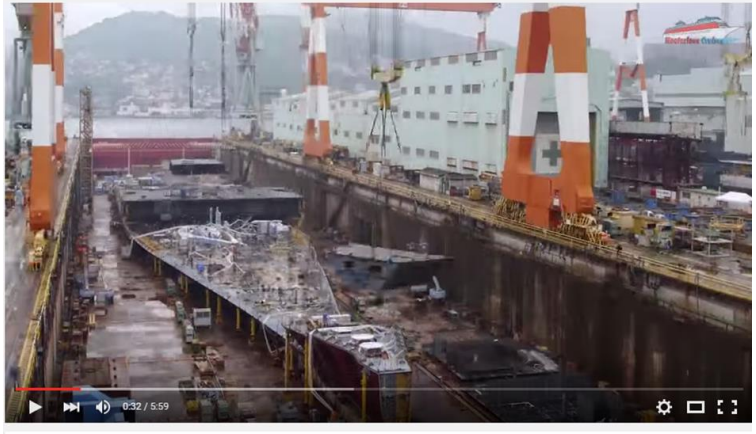
Shipyards' ability to influence costs

- A shipyard can lower its costs mainly by increasing the efficiency of its operations
  - *Decrease in man-hours → lower labor costs*
  - *Lower lead time → lower capital (interest) costs*
- Efficiency gains can be achieved for instance by applying new/updated building methods, and by organizational measures

Measures of shipyard efficiency

- Amount of production (e.g. tonnage) / number of employees
  - *To compare shipyards building different types of ships, so-called "compensated gross- tonnage" (CGT) can be used*

Example of modern ship assembly



AIDAprima Cruise Ship : Full Construction Time-lapse by MKtimelapse

New Technologies can reduce shipbuilding costs Examples

- Laser scanning
  - *Enables reverse engineering and quality control*
  - *Meyer Wert Gmbh, Signal International, Babcock International*

- CAD models for refit projects
  - *Digital prototyping*
  - *Finite Element Analysis (FEA)*
  - *Virtual reality*

These measures focus on design, but design cost is only a small part of the total cost of building a ship

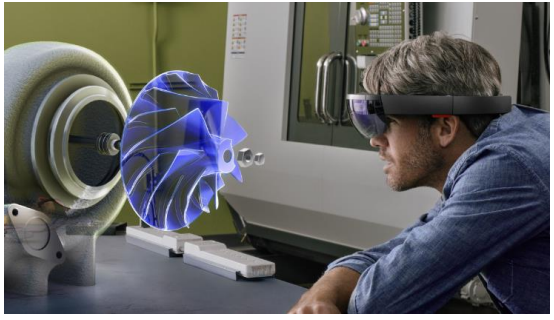
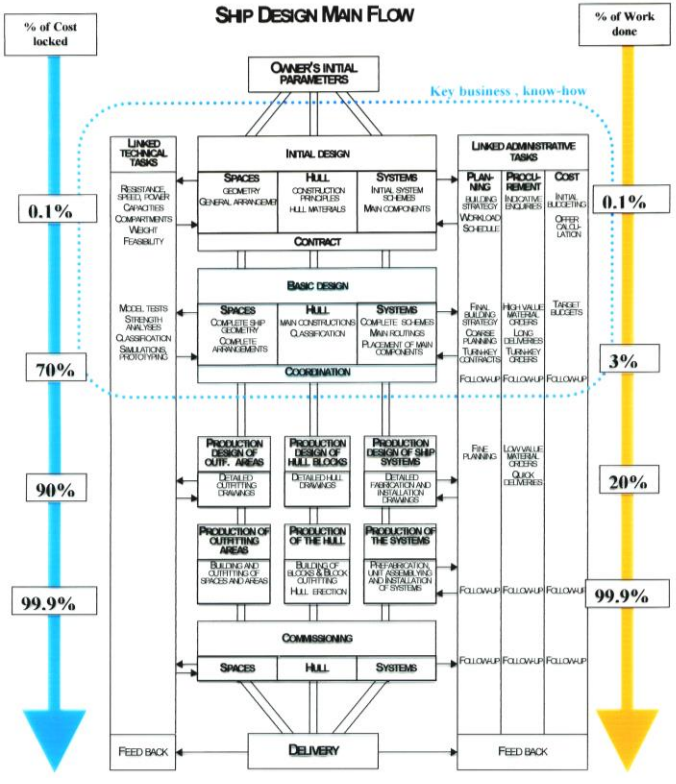


Image credit https://thenextweb.com/

Shipbuilding costs – Quality Matters

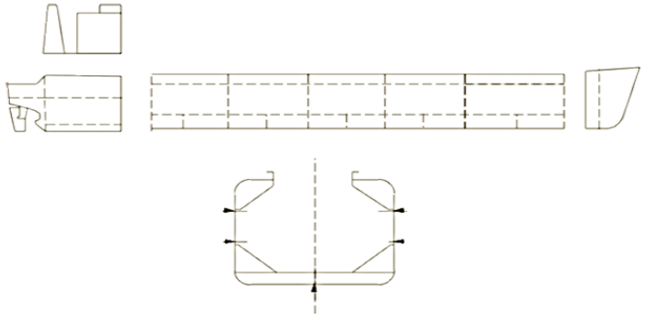
- The quality of the preliminary and basic design stages largely determine the success of a ship project
  - *About 5% of work done*
  - *About 70% of total costs locked*



Shipbuilding costs – Block Construction (1)

- Module-based assembly
  - *The method was developed in the U.S. during World War II*

- Main steps
  1. *Blocks are prefabricated in a block-factory (might include the installation of various systems)'*
  2. *Blocks are moved/lifted to the building dock*
  3. *Block are assembled in the building dock*



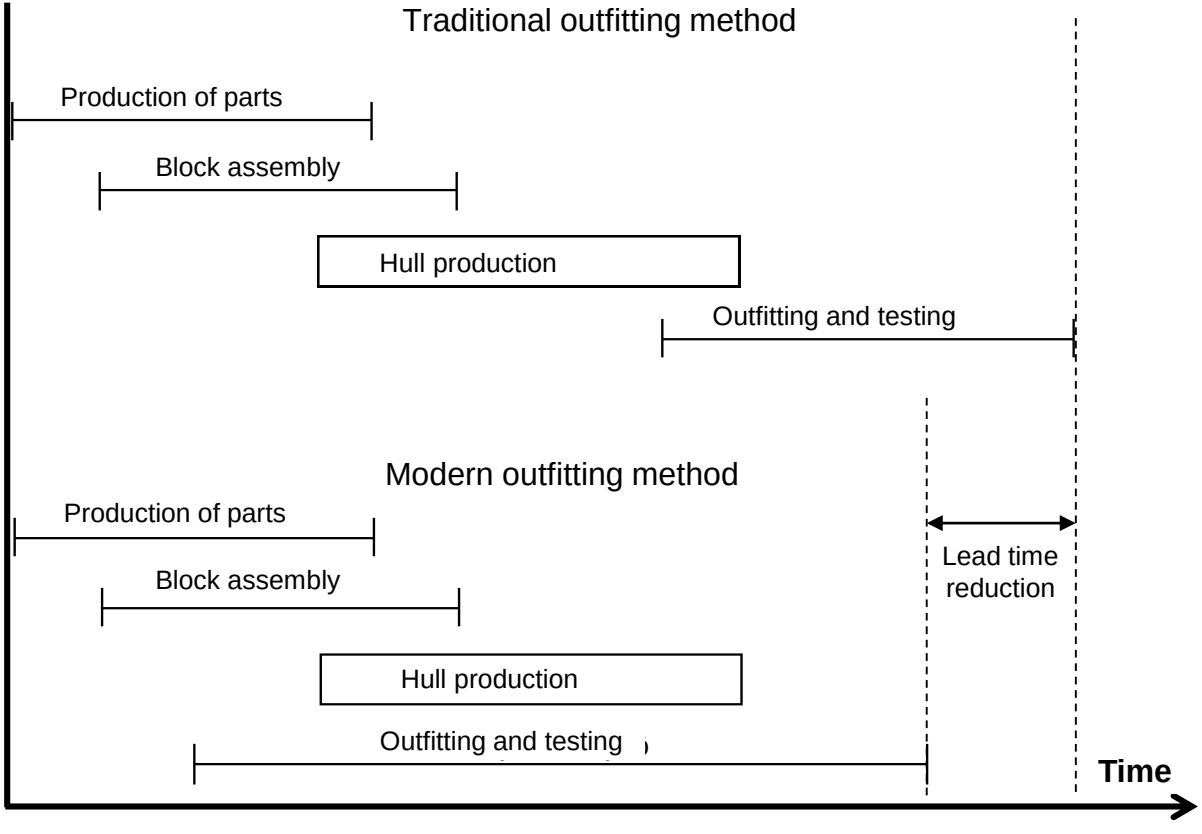
- In comparison with the earlier practice, where the steel parts were transferred to the building dock one by one, block construction provides very significant efficiency gains

- Grand blocks should be "as large as possible"
  - *The size of individual blocks is largely limited by weight / shipyard facilities*

Image credit Meyer Turku

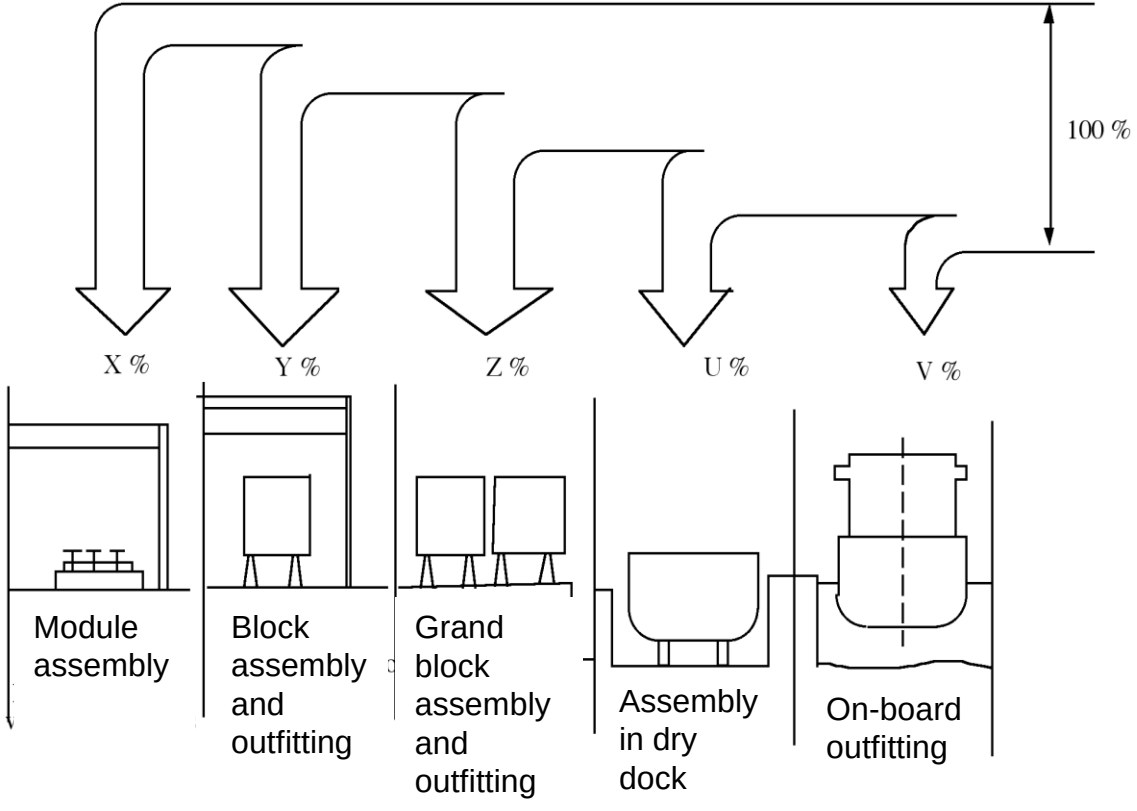
Shipbuilding costs – Block Construction (2)

- Shipyards have been able to reduce their lead times by performing outfitting and testing already in the block assembly phase



Shipbuilding costs – Assembly methods

- Block-based construction limiting the amount of work carried out onboard the ship



Shipbuilding costs - Modularisation

- Prefabrication → Minimization of on-board work → More efficient working environment → Efficiency and quality gains

- Facilitate standardized solutions
  - *Better knowledge on weight and performance of ship systems*
  - *Standards for commercial products with respect to price , quality, and performance*
  - *Supports the use of Computer Aided Manufacture (CAM)*

- Facilitate subcontracting

- Facilitates maintenance/refurbishment (if replaceable units)

- Advance commissioning (inspection, testing) of subsystems/modules possible

Examples of modules

- Machine modules, piping modules, cabin modules,..

Ready made cabin-module. Image credit Piikkio Works

Shipbuilding costs - Materials

- The quality of materials is often fixed by the ship specification (contract) → Difficult to change

  - *In turnkey delivery (total subcontracting), both the material and work is purchased*

  - *In the contract, it is essential that material prices/costs are related to international price levels (indexes) and as such defined in the shipbuilding contract*

    → For instance, if the price of steel increases, the selling price of the ship will also increase

Image WRS Tech

Shipyard organization

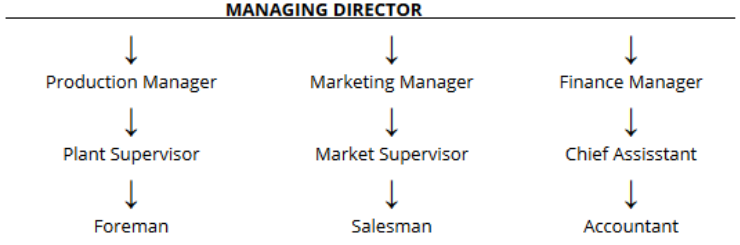
A shipyard is an assembly place and a client for many suppliers

- Propulsion machinery and machine systems
- Steel fabrication and welding equipment
- Outfitting including interior and cargo handling
- Management systems

Shipyard organization

- Line organization
- Matrix management
- Shipbuilding project organization
  - *Often reflecting the prevailing trend; today's rend is non-hierarchical (light) and flexible organization*
  - *Responsibility and flexibility of individual workers tend to increase*

Example: Line organization



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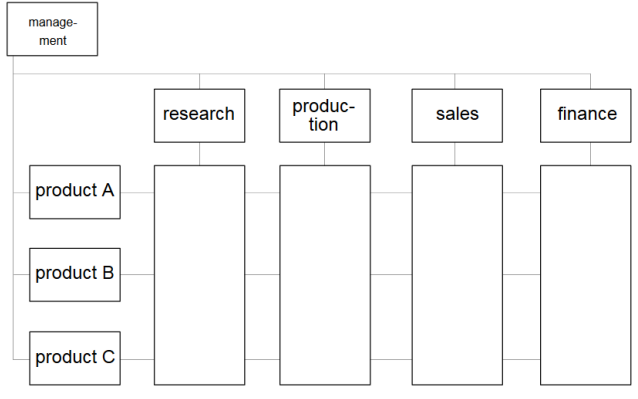
Example: Matrix organization



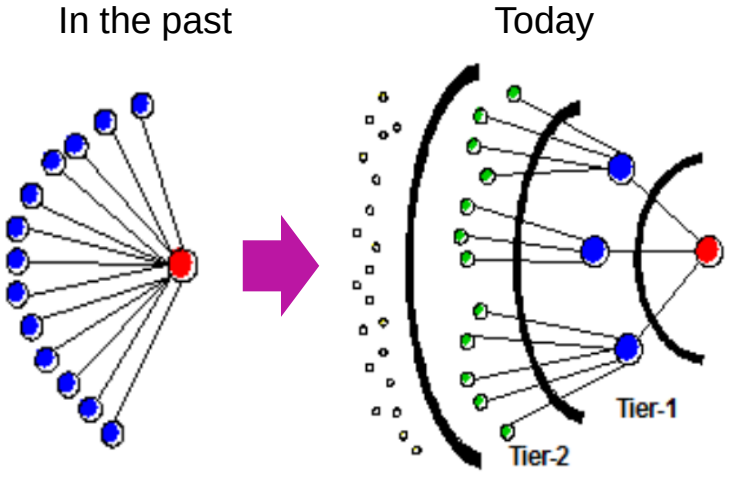
Shipyard organization

Network

- Shipyards' network of subcontractors/ partners/ suppliers very important
  - *The amount of subcontracting has increased in resent years due to*
    - Specialization, expensive production technology
    - Varying demand
    - Internationalization
    - Certification requirements
    - Etc.

Different types of subcontracting

- Special subcontracting, because
  - *The shipyard does not have the necessary know-how for own manufacturing*
  - *Specific product or service (e.g. main engine)*
- Standard subcontracting, because
  - *Cheaper than the own manufacturing, e.g. due to efficiency of scale*
- Capacity sub-contracting, because
  - *The shipyard does not have sufficient capacity*
  - *To achieve flexibility in production capacity and low fixed costs*



Subcontracting challenges

- Delivery problems, delays
  - *Force majeure reasons*
- Transportation challenges
- Quality / performance issues
- Communications, information flow
  - *E.g. no information about delays*
  - *Cultural/language issues*
- Intellectual property rights (IPR) issues

Image credit E-ISG Asset Intelligence

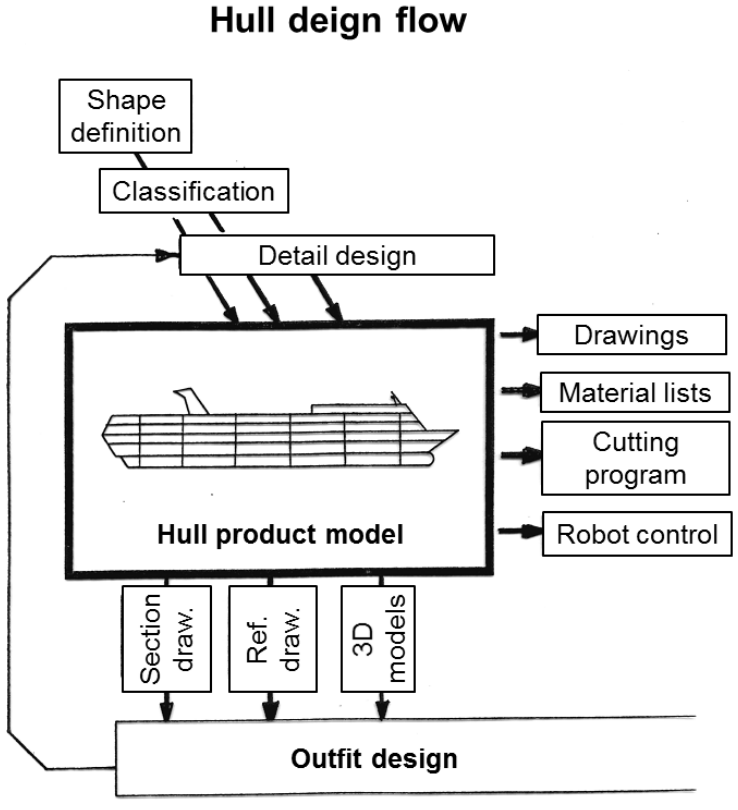
Design Tools

- Different tools for different purposes
- The ability to transfer data between different systems (system integration) is increasingly important

Objective	System
Preliminary design	NAPA, etc.
FEM (strength analysis)	FEMAP, FinnSap, etc.
3D visualiton	DeskArtes, etc.
Hull detail design	Tribon, etc.
Hull production design	TAE, etc.
Design for outfitting	Medusa, etc.
2D and 3D design	MedusaShipBuider, etc.
Design for piping schema	MedusaShipBuider, etc.
3D model design	MPDS, etc.
3D HVAC design	HVAC, etc.
Pipe system design	Comiso, etc.
Routing design	MASA, etc.
Caple routing design	Eldok, etc.
Work scheduling/ planning	Excel, MS Project,etc.
Data management	Kronodoc, etc.

Ship production models

- Hierarchical
- Becomes more detailed throughout as the design process progresses
- All including (comprehensive) ship models are still rare
  - *Use of sub-models*
    - Steel model of hull
    - Engine room model
    - Etc.



The Shipbuilding Contract

A shipbuilding contract is a contract for the complete construction of a ship

- Specifies the obligations and rights of the shipyard undertaking to build a ship and the buyer (ship owner, guarantor)

Contract preparations

- Preliminary design
  - *The aim of the preliminary design is to secure a shipbuilding contract*
    - Includes the definition of ships technical characteristics and performance
    - Estimation of building cost
    - Quantitative calculations to support production planning

- Sales support in technical issues

1. **Concept design**
2. **Preliminary design**
3. **Basic design**
4. **Detail design**
5. **Commissioning and warranty**

Shipbuilding contract performance criteria

- Weight, stability, trim
  - *Lightship weight, deadweight*
- Capacity
  - *Cargo volume, number of containers / car spaces/container, …*
- Sea trial speed, resistance
- Noise, vibrations
- Requirements given in the ship specification

Image credit Gard

- Fulfilling international and national safety and environmental regulations
- General requirements for good shipbuilding practice
  - *Overall performance and functionality, maintenance, corrosion protection, ergonomic,…*

Failing to meet contract criteria typically result in significant penalties or cancellation of contract

Summary

- Ship building and running costs can be divided into various categories such as labour costs, material costs, voyage costs, operating costs,...
- The economic performance of a ship concept can be assessed by various economic KPIs; e.g. Net present Value (NPV), Required Freight Rate (RFR), ...etc.
- A shipyard's costs for building a ship can be reduced by various means such as the use of advanced production tools, block production, modularization, ...
- Shipyards typically have a large network of partners/subcontractors
- A shipbuilding contract specifies detailed performance criteria of a ship. A failure to meet criteria might result in significant penalties or cancellation of contract