Aalto University
School of Engineering

MEC-E1004 Principles of Naval Architecture

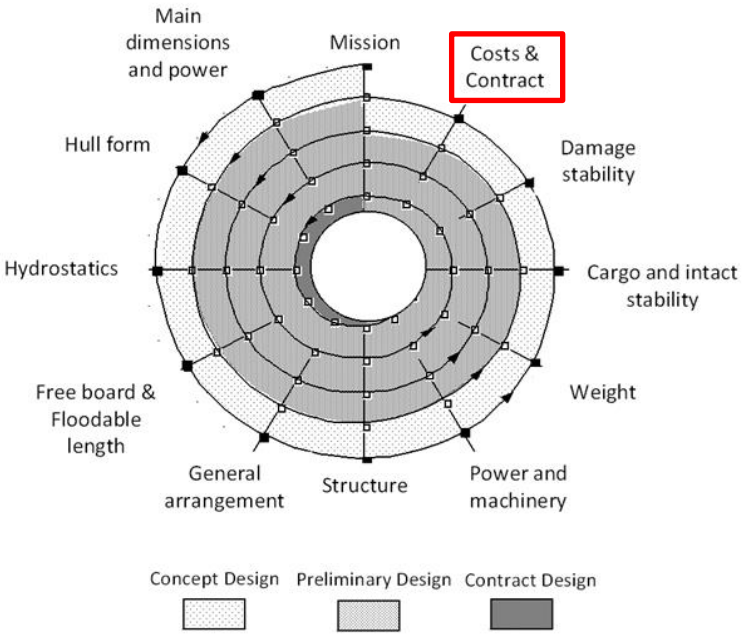
Lecture 10 – Design economic assessment and ship building

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 openly available cost information on similar/reference ships (if posssible)*
- 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

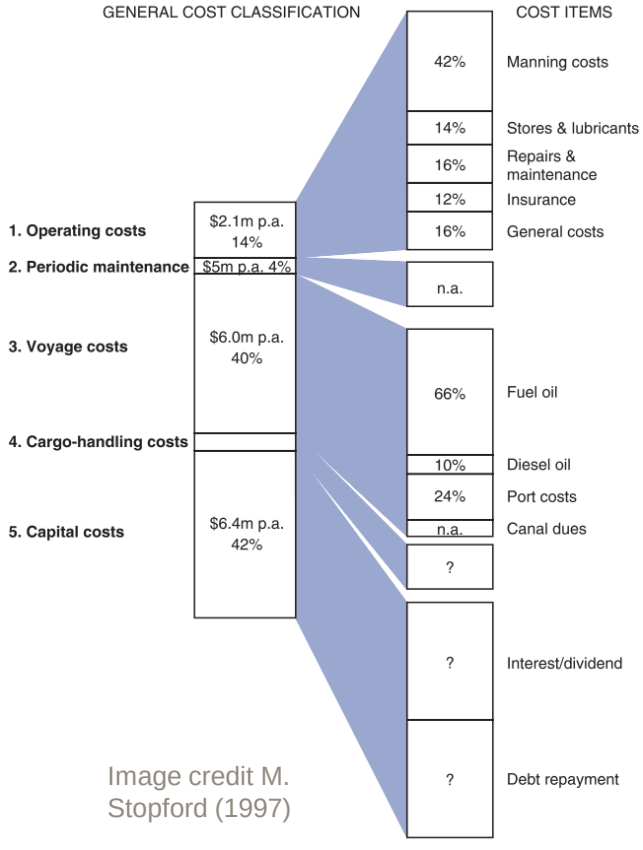
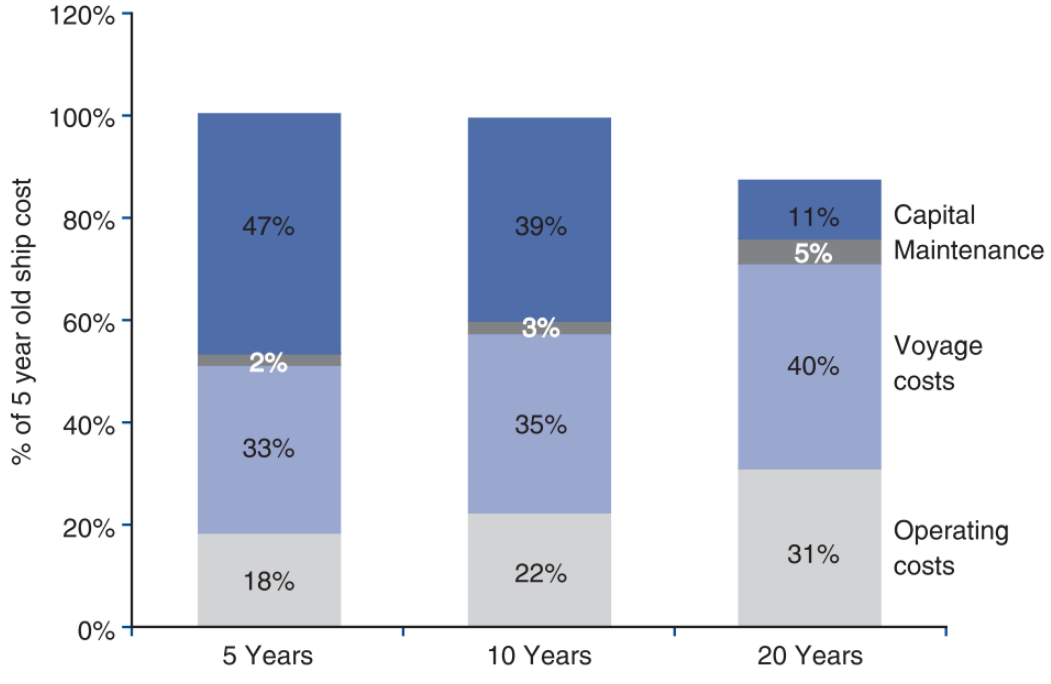


Image credit M. Stopford (1997)

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



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Economic KPIs of ships

- 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)

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

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?

Number of years $n = 10$ years ; $i = 12\%$

Initial investment $P_I = 2000000$ €

Saving in daily fuel consumption $S_d = 2$ ton/day

Fuel price $F_C = 700 \cdot$ €/ton

Annual operating days $D_O = 230$ day

Annul maintenance costs $M_A = 20000$ €/year

Answer

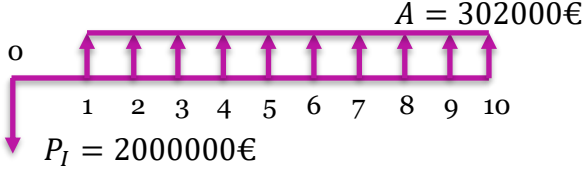
Annual saving in fuel costs

$$S_A = S_d \cdot F_C \cdot D_O = 322000 \text{ €/year}$$

Annual savings

$$A = S_A - M_A = 302000 \frac{€}{year}$$

$$NPV = A \cdot \left(\frac{(1+i)^n - 1}{i \cdot (1+i)^n} \right) - P_I = -293632.645 \text{ €}$$



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

$$RFR = \left[P \left(\frac{i(1+i)^n}{(1+i)^n - 1} \right) + A \right] / C$$

- Where P is the capital costs, A uniform annual operating costs, C annual tons of cargo, i interest rate and n the ship's lifetime

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?

$i = 12\%$ $n = 20\ years$

Acquisition costs $P_I = 200{,}000{,}000$ €

Total annual costs $A_C = 10{,}000{,}000$ €/year

Cargo to export annually

C= 450,000 ton

Answer

$$RFR = \frac{P_I\left(\frac{i(1+i)^n}{(1+i)^n-1}\right) + A_C}{C}$$

$$RFR = \mathbf{81.724\ €/ton}$$

Break even analysis

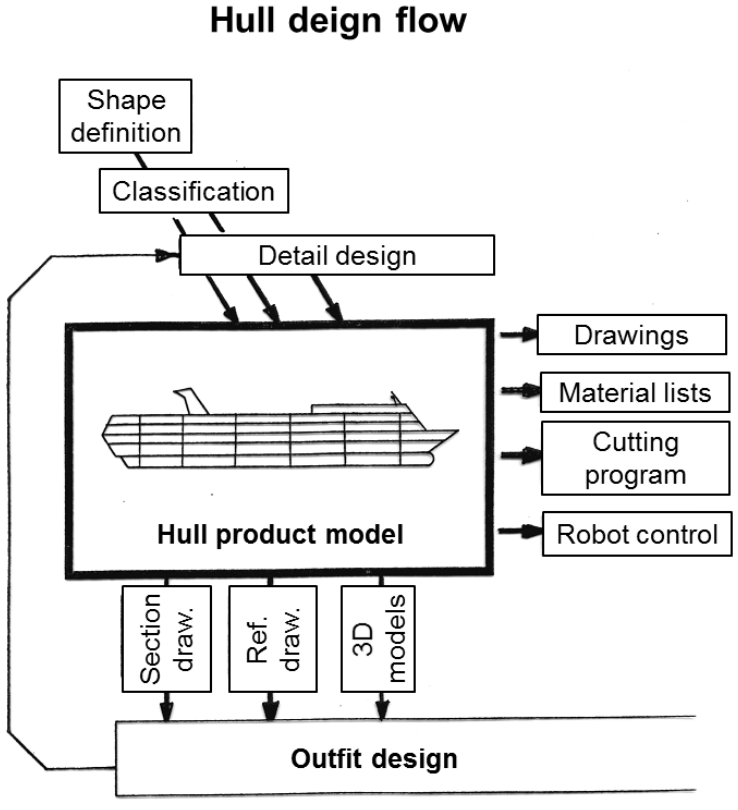
$$C \cdot C_Q \cdot \left(\frac{(1+i)^n-1}{i(1+i)^n}\right) - P_I - A_C\left(\frac{(1+i)^n-1}{i(1+i)^n}\right) = 0$$

$$C_Q = \mathbf{81.724\ €/ton}$$

Shipbuilding models

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

Shipbuilding costs

What is the difference between shipbuilding costs and ship price?

What measures can a shipyard take to reduce costs?

Shipbuilding costs

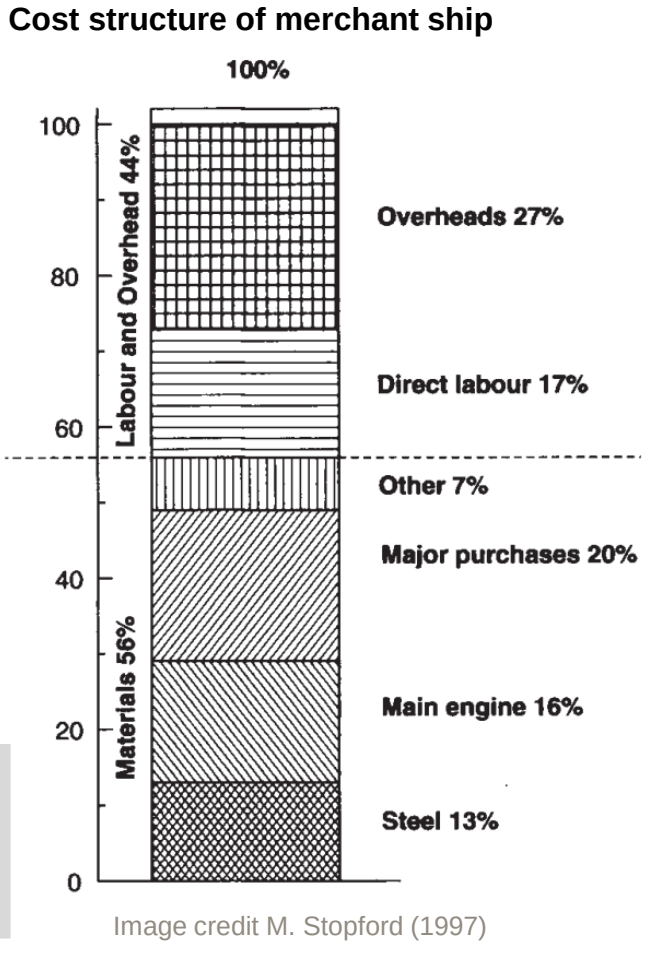
Labor and overhead
- Overheads (Indirect costs)
- Direct labor

Materials
- Major purchases
- Main engine
- Steel
- Other

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*



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Shipbuilding costs

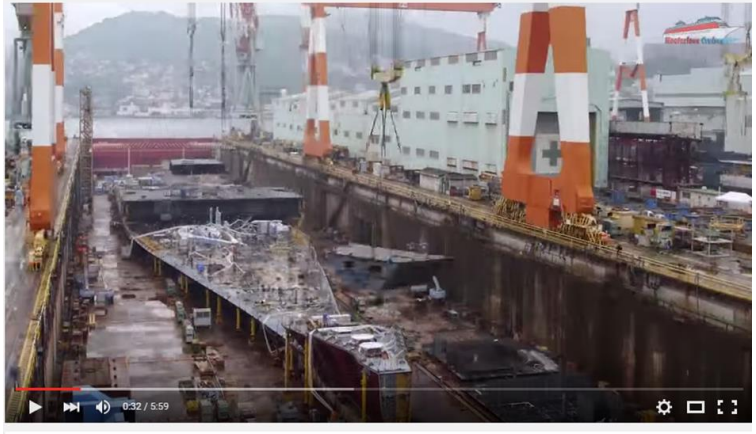
Shipyards' ability to influence costs

- 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



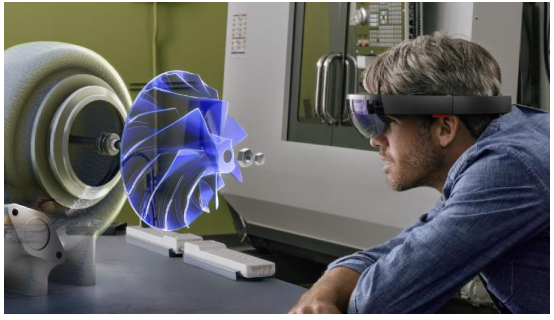
AIDAprima Cruise Ship : Full Construction Time-lapse by MKtimelapse

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



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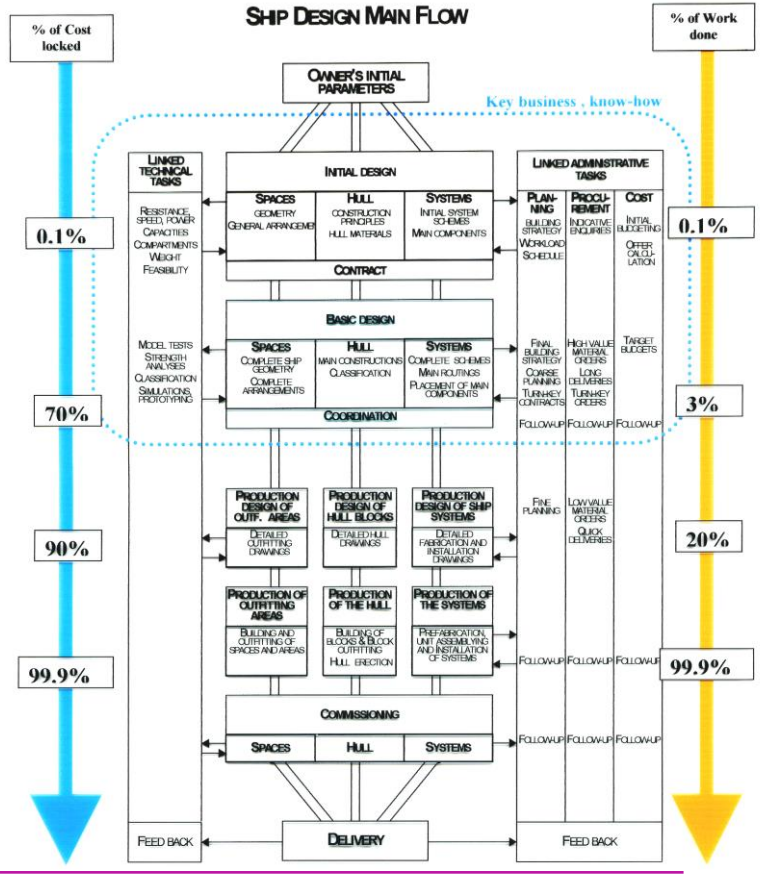
Shipbuilding costs – Quality Matters

- 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*



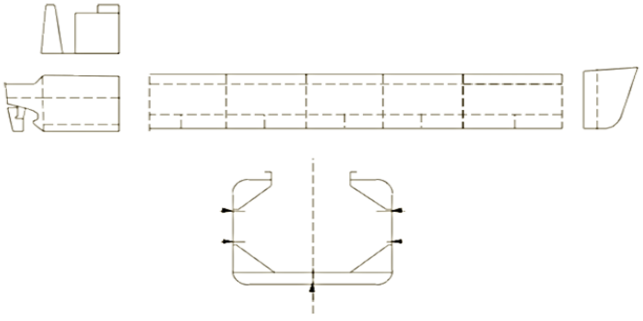
Shipbuilding costs – Block Construction (1)

- 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*



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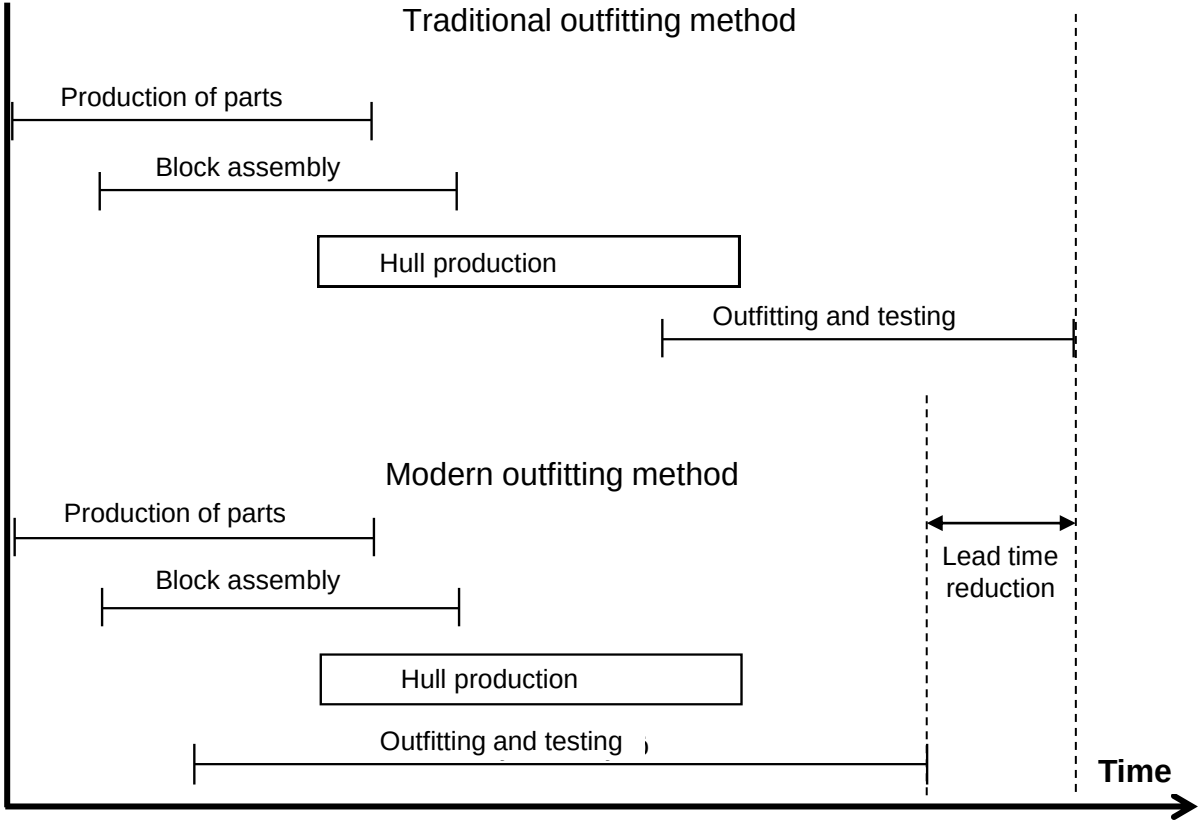
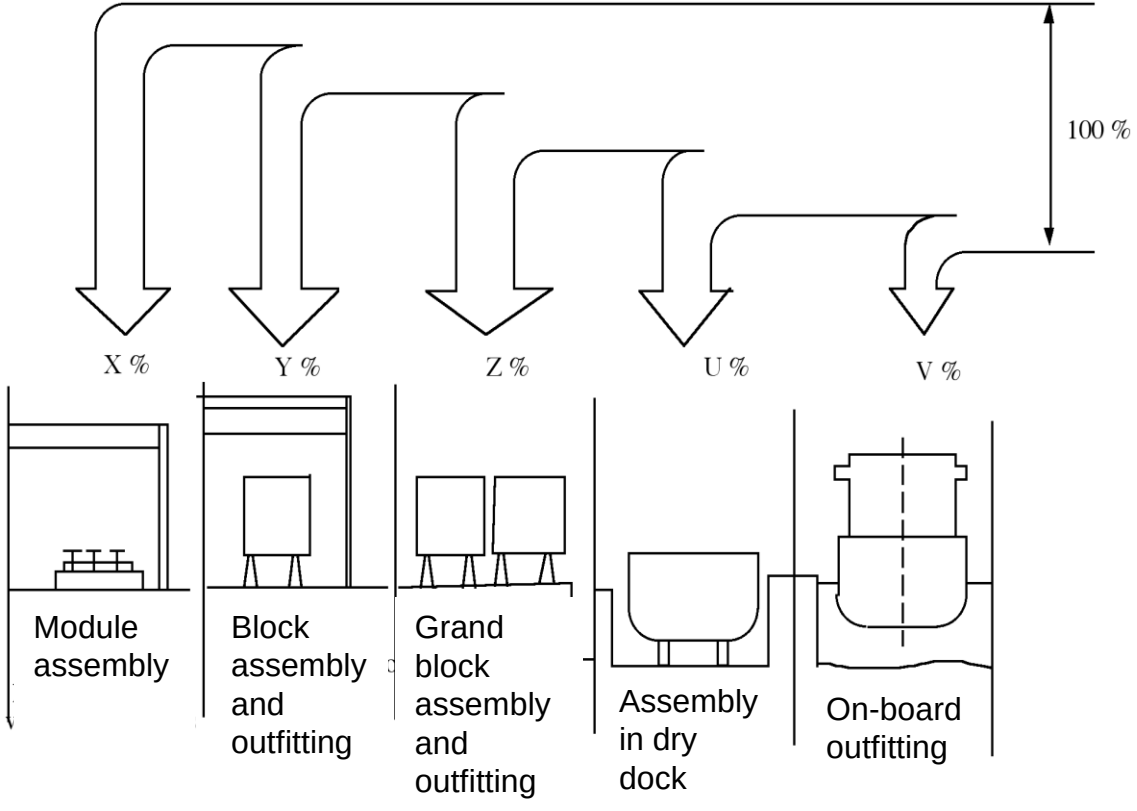
Shipbuilding costs – Block Construction (2)

- 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

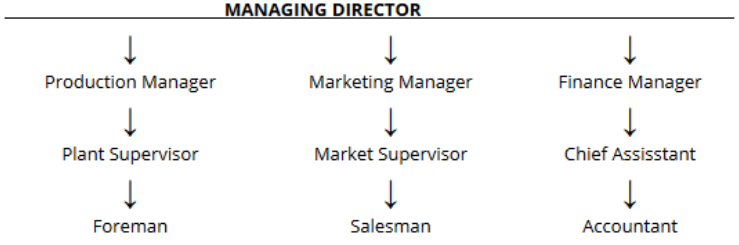
A shipyard is an assembly place and a client for many suppliers

- 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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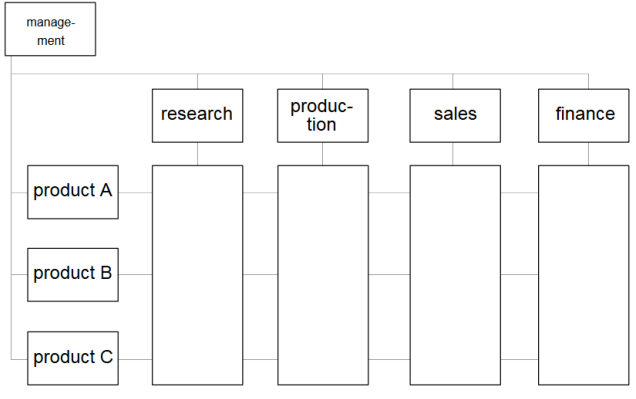
Example: Matrix organization



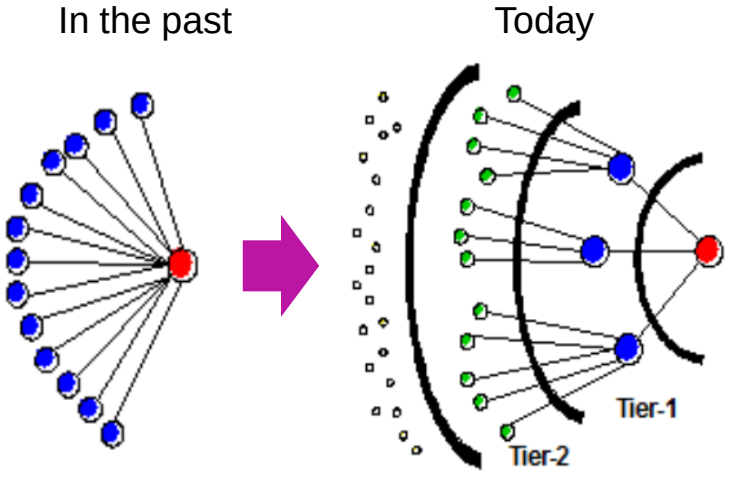
Shipyard organization

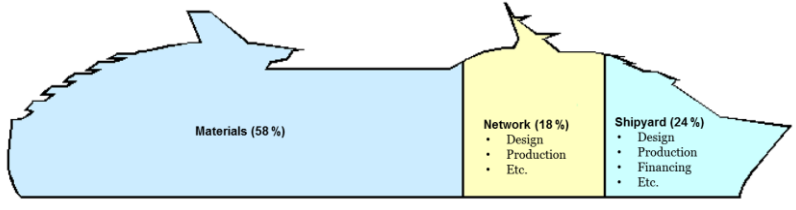
Network

- 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

Summary

- Ship building and ship 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

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Thank you !!