🚢 MARINE FUNDAMENTALS Developer Training Handout

A Professional Reference for Developers

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SHIP BASICS (FULL DETAILED EXPLANATION)

WHAT IS A SHIP?

A ship is a large engineered structure designed to float on water using the principle of buoyancy.

It is built to transport cargo, passengers, or perform special marine operations.

Ships must withstand waves, weather, currents, and long voyages across oceans.

PURPOSE OF SHIPS

• Transport goods globally (90% of world trade is via ships)

• Carry passengers (ferries, cruise ships)

• Support offshore operations (e.g., PSVs, AHTS)

Here's what those terms mean in the context of offshore vessels:

1. DP (Dynamic Positioning)

- A **computer-controlled system** that automatically maintains a vessel's position and heading using its own propellers and thrusters.
- Essential for offshore operations like drilling, subsea construction, and supply, where anchoring is impractical.

2. AHTS (Anchor Handling Tug Supply Vessel)

- A specialized vessel used to:
- Handle anchors for oil rigs and other offshore structures.
- Tow rigs to location.
- Supply equipment and materials to offshore platforms.

3. PSV (Platform Supply Vessel)

- Designed to transport supplies to and from offshore platforms.
- Carries:
- Drilling fluids, chemicals, fuel, water, and provisions.
- Perform dredging, research, defense, firefighting
- Enable marine construction and towing operations

TYPES OF SHIPS

Offshore vessels: Stay near oil rigs or platforms, not for cargo/passenger transport.

Onshore/coastal vessels: Operate near ports or short routes.

Ocean-going ships: Designed for global routes, high capacity, and compliance with international standards.

1. Bulk Carriers – Carry dry cargo like coal, ore; large box-shaped holds.

2. Tankers – Carry liquid cargo; require heating and inert gas systems.

3. Container Ships – Carry containers; high-speed vessels.

4. Ro-Ro Ships – Carry vehicles via ramps.

5. Offshore Vessels – DP2/DP3 capability, used for supply, anchor handling.

6. Special Purpose Ships – Dredgers, cable layers, research vessels.

GOVERNING BODIES

IMO

If we relate the governing bodies to a car,

Here's a clear comparison table between **MoRTH** and **IMO**:

Aspect	**MoRTH (India)**	**IMO (International)**
Full Name	Ministry of Road Transport and Highways	International Maritime Organization
Jurisdiction	National (India)	Global (UN specialized agency)
Domain	Road transport and motor vehicles	Shipping and maritime transport
Primary Role	Formulates policies, safety standards, and regulations for road vehicles	Sets international standards for maritime safety, security, and environmental protection
Key Regulations	Motor Vehicles Act, 1988; Central Motor Vehicle Rules (CMVR)	SOLAS, MARPOL, STCW conventions
Focus Areas	Vehicle safety, emissions, road infrastructure	Ship safety, pollution prevention, crew training

Aspect	MoRTH (India)	IMO (International)
Compliance	Mandatory for all vehicles in India	Mandatory for member states (implemented nationally)
Testing & Certification	ARAI, ICAT, VRDE under CMVR Rule 126	Flag states and classification societies

1.Classification Society (similar to ARAI, ICAT)

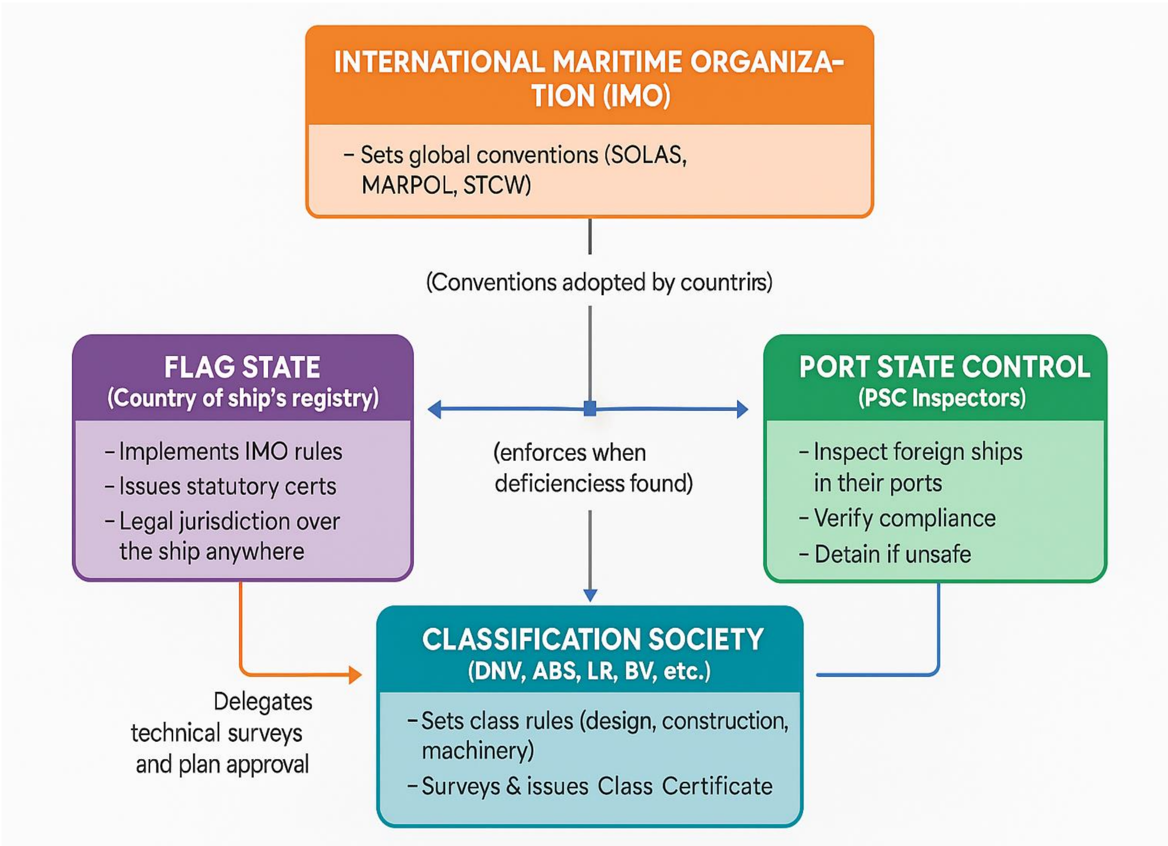
- Ensures the ship meets technical standards and remains "in class." – Technical Compliance (Similar to Automotive Research Association of India, International center for Automotive Technology)

2. Flag State

- Provides legal jurisdiction and statutory certificates. (Safety, Pollution and Registry) – Legal compliance (RTO)

3. Port State Control

- Inspects compliance when the ship enters foreign ports. (RTO other state)



KEY VESSEL PARTICULARS:

1. Deadweight (DWT)

- **Definition:** The total weight a ship can safely carry, including:
  - Cargo
  - Fuel
  - Fresh water
  - Ballast water
  - Crew and provisions
- **Unit:** Metric tons.
- **Purpose:** Indicates the ship's carrying capacity.

2. Gross Register Tonnage (GRT)

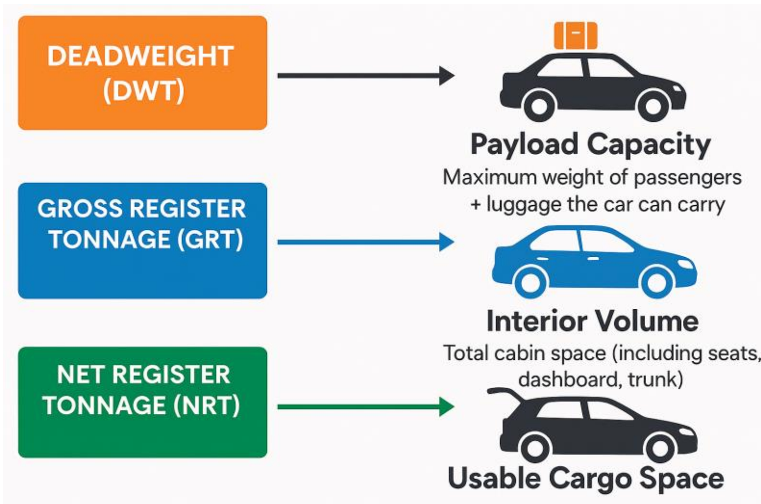
- **Definition:** A measure of the **total internal volume** of the ship's enclosed spaces.
- **Unit:** "Register tons" (1 register ton = 100 cubic feet).
- **Purpose:** Used for port dues, registration, and regulatory purposes.
- **Note:** It does **not** indicate weight, only volume.

3. Net Register Tonnage (NRT)

- **Definition:** The volume of cargo spaces available for revenue-earning cargo.
- **Unit:** Register tons.
- **Purpose:** Represents the earning capacity of the ship.

KEY DIFFERENCES

- **DWT** = Weight capacity (cargo + consumables).
- **GRT** = Total internal volume (all enclosed spaces).
- **NRT** = Volume available for cargo (after deducting engine rooms, crew spaces, etc.).



MAJOR DIMENSIONS

1. Length Overall (LOA)

- The maximum length of the ship from the foremost point to the aft-most point.
- Important for berth allocation and canal passage.

2. Length Between Perpendiculars (LBP)

- Distance between the forward and aft perpendiculars (usually at the waterline).
- Used in stability and hull design calculations.

3. Breadth (Beam)

- The widest point of the ship's hull.
- Affects stability and cargo capacity.

4. Depth

- Vertical distance from the keel to the main deck.

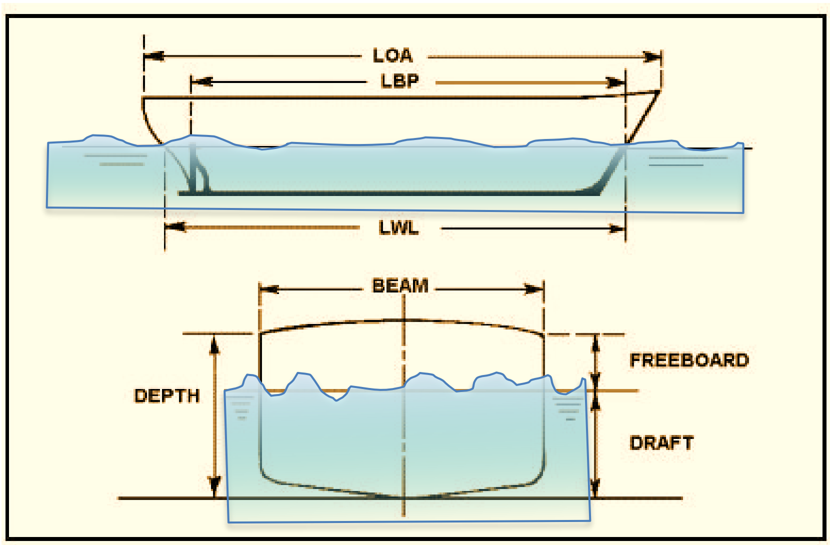
- Indicates hull strength and cargo space.

5. Draft

- Vertical distance from the waterline to the bottom of the keel.
- Determines how deep the ship sits in water (important for port entry).

6. Freeboard

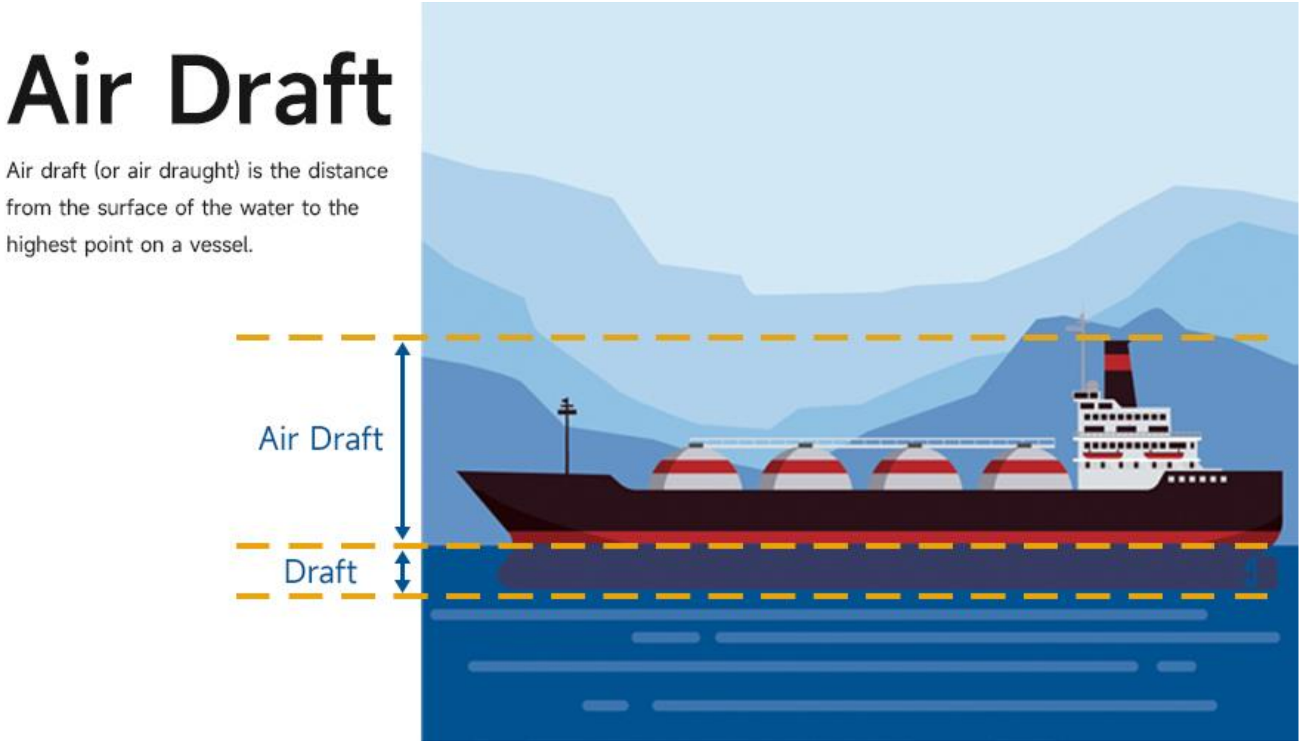
- Distance from the waterline to the main deck.
- Related to safety and load line regulations.



7. Air Draft

- Height from the waterline to the highest point of the ship.

- Important for passing under bridges.



PARTIES INVOLVED:

Here are the **main parties involved in operating a ship** and their roles:

1. Shipowner

- **Who they are:** The legal owner of the vessel.
- **Responsibilities:**
  - Provides the ship for trade.
  - Ensures compliance with flag state and IMO regulations.
  - Maintains insurance (Hull & Machinery, P\&I).

2. Ship manager

- **Who they are:** A company appointed by the owner to manage the ship.
- **Types of Management:**
  - **Technical Management:** Maintenance, repairs, crew management.
  - **Commercial Management:** Chartering, cargo bookings.
- **Role:** Acts as the operational arm of the owner.

3. Charterer

- **Who they are:** The party that hires the ship for cargo transport.
- **Types of Charter:**
    - **Voyage Charter:** Pays for a single voyage.
    - **Time Charter:** Hires the ship for a period.
    - **Bareboat Charter:** Takes full control (including crew) for a long term.
- **Role:** Decides cargo, ports, and voyage instructions.

4. Crew

- **Who they are:** Master and seafarers operating the ship.
- **Responsibilities:** Navigation, cargo handling, safety, compliance.

SCIENCE OF SHIP FLOATATION

How a ship Floats:

Ships float because of the principle of **buoyancy**, explained by **Archimedes' Principle**:

How It Works

1. **Archimedes' Principle**:
    - Any object submerged in a fluid experiences an **upward buoyant force** equal to the **weight of the fluid displaced** by the object.
2. **For a Ship**:
    - A ship is heavy, but it has a **hull designed to displace a large volume of water**.
    - The weight of the water displaced creates an upward force that balances the ship's weight.
    - As long as the **displaced water's weight ≥ ship's weight**, the ship floats.
3. **Why Shape Matters**:
    - Ships are hollow and wide, so they displace more water than a solid block of the same weight.
    - This increases buoyant force and keeps them afloat.

Key Forces

- **Weight (downward)**: Force due to gravity acting on the ship.
- **Buoyant Force (upward)**: Force from displaced water pushing up (Follows Newton's 3rd law, it's a reaction force against the weight (downward force) of the ship.

When these forces **balance**, the ship floats. If weight exceeds buoyant force, the ship sinks.

Imagine how oil floats in water due to density difference. Thus a steel hollow box structure with same weight as of a solid box has a density lesser than water.

- 90% volume = air
- 10% = steel

So the **average density** becomes **less than water** and thus it floats like oil.

BALLAST:

Why Ships Use Ballast

- **Ballast water** (or solid ballast) is added to:
  - **Maintain stability**: Prevent excessive rolling or capsizing.
  - **Control draft**: Ensure the propeller and rudder remain submerged.
  - **Trim adjustment**: Balance the ship fore and aft for safe navigation.

If No Ballast

- The ship will float because its hull provides buoyancy.
- But:
  - It will sit **very high in the water** (lightship condition).
  - **Propeller and rudder may be exposed**, making steering difficult.
  - **Stability is poor**, especially in rough seas.
  - **Structural stress** can increase due to uneven weight distribution.

WHAT IS DISPLACEMENT?

- **Definition**: The **weight of the volume of water displaced by the ship when afloat**.
- By Archimedes' principle, this equals the **actual weight of the ship** at that moment.
- Measured in **metric tonnes** (1 tonne = 1 cubic meter of seawater approximately).

Components

- **Lightship Weight**: Weight of the ship itself (structure, machinery, equipment).
- **Deadweight (DWT)**: Weight of everything the ship carries (cargo, fuel, water, stores, crew).
- **Displacement = Lightship + Deadweight**
  - When empty (ballast condition): Displacement ≈ Lightship + minimal consumables.
  - When fully loaded: Displacement = Lightship + full DWT.

Key Difference:

- **Deadweight** is the carrying capacity (cargo + consumables).
- **Displacement** is the total weight of the ship **as it floats**, including its own structure.

MOORING:

What is Mooring?

Mooring is the process of securing a ship to a fixed structure (jetty, berth, buoy) using ropes or wires so it stays safely in position.

- Prevents movement due to wind, waves, tides, and currents
- Ensures safe loading/unloading of cargo
- Performed during arrival, departure, and port stay

What Does Mooring Achieve?

Mooring keeps the ship:

- **Positioned** → aligned with the berth
- **Stable** → minimal movement
- **Safe** → prevents damage to ship & terminal
- **Accessible** → for crew, pilots, gangways, cargo hoses, cranes

COMMERCIAL ENGAGEMENT:

On-Hire

- This is the moment when the vessel is delivered to the charterer and becomes their responsibility.
- The charterer starts paying **hire** (daily rate) from this point.
- The vessel must be in the agreed condition and ready for service.
- On-hire surveys are conducted to record the ship's condition and fuel quantities at delivery.

Off-Hire

- This occurs when the vessel is temporarily unavailable for the charterer's use due to reasons like:
  - Mechanical breakdown
  - Dry-docking or repairs
  - Crew strikes or other operational issues
- During off-hire periods, the charterer **does not pay hire**.
- Off-hire clauses in the charter party define what situations qualify and how hire deductions are calculated.
- An off-hire survey is often done at redelivery to check condition and fuel.

Port Limits:

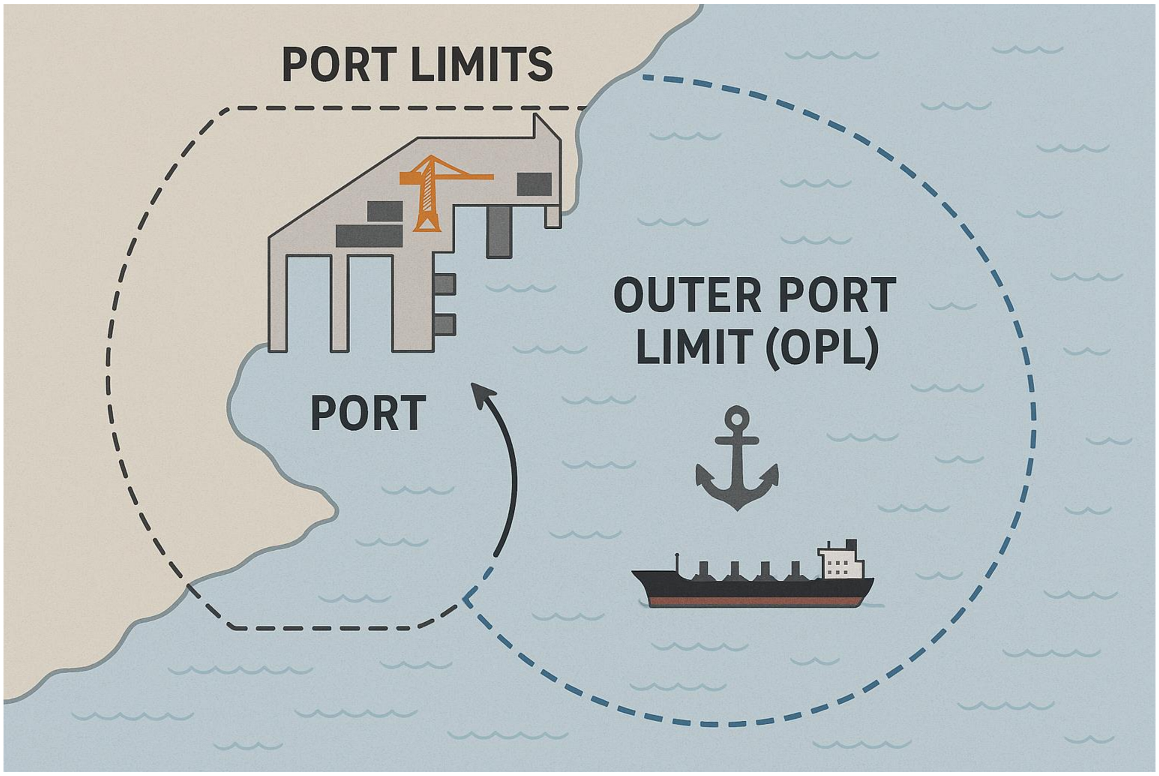
• Port **limits** define the **geographical boundaries of a port**, including piers, jetties, docks, and approaches.

• These limits are often shown on **Admiralty charts** and may include areas under port authority control.

• Outer **Port Limit (OPL)** refers to a designated boundary outside the port where vessels wait for clearance before entering.

• **Purpose:**

- Manage traffic and congestion.
- Ensure navigational safety.
- Comply with international regulations.
- OPL areas often include anchorage zones and safety buffers



Port Limits (left, dashed black line): the **geographical boundary of the port**—including quays, jetties, docks, and approaches under the port authority's jurisdiction.

OPL (Outer Port Limit) (right, dashed blue circle): a **designated waiting/anchorage area outside the port** where vessels may anchor to await clearance, berth availability, pilot boarding, or documentation before entering the port.

Vessels inside **Port Limits** can generally **tender NOR (Notice of Readiness)** if the charterparty requires "within port limits." If NOR must be "within port limits," anchoring **outside** these limits (even if directed by the port/VTS) may not be valid unless the contract provides otherwise.

PORT SERVICES FOR MOVING THE SHIP

1. Pilotage

- Service provided by a **marine pilot** who boards the vessel to guide it safely through port waters, channels, and berths.
- Mandatory in most ports for large vessels.

2. Towage (Tug Operations)

- Use of **tugboats** to assist vessels in maneuvering within port limits, especially during berthing, unberthing, or navigating narrow channels.

WHAT IS A TUG BOAT?

- A tug boat is a small but powerful vessel equipped with strong engines and towing gear.
- Its primary role is to **push or pull larger ships** that cannot easily maneuver on their own, especially when docking, undocking, or navigating narrow channels.

Key Functions

1. **Berthing and Unberthing Assistance**
    - Helps large ships move safely to and from berths.
    - Provides precise control in tight spaces where big ships cannot use their own propulsion effectively.
2. **Towing**
    - Can tow ships that are disabled or need to be moved without using their engines.
    - Used for moving barges or floating structures.
3. **Escort Services**
    - Assists tankers or LNG carriers in high-risk areas for safety.
    - Provides emergency support if a vessel loses steering or propulsion.
4. **Firefighting and Salvage**
    - Many tug boats are equipped with firefighting systems for emergencies.
    - Can assist in salvage operations during accidents.

Thrusters:

Bow Thrusters and **Stern Thrusters** are auxiliary propulsion devices installed on ships to improve maneuverability, especially in tight spaces like ports and harbors.

• Reduces reliance on tug boats.

• Saves time during docking.

• Improves safety in congested areas.

HOW A SHIP MOVES IN WATER

Ships move due to propeller thrust. The main engine rotates the propeller, pushing water backward.

Newton's Third Law → Forward thrust pushes ship ahead.

Hull form reduces resistance, rudder directs water flow for steering.

Voyages and Leg:

In maritime shipping, **Ballast Voyage** and **Laden Voyage** refer to two distinct phases of a vessel's operation:

1. Laden Voyage

- **Definition**: The voyage when the vessel is **carrying cargo**.
- **Characteristics**:
    - Heavier draft (ship sits lower in water).
    - Higher fuel consumption due to increased displacement.
    - Generates revenue for the shipowner (freight earnings).
- **Example**: A tanker sailing from the Middle East to India with crude oil.

2. Ballast Voyage

- **Definition**: The voyage when the vessel is **not carrying cargo** and is usually returning to load at the next port.
- **Characteristics**:
    - Lighter draft (ship sits higher in water).
    - Lower fuel consumption compared to laden voyage.
    - No freight revenue (cost-only leg).
- **Purpose**: To reposition the vessel for the next cargo loading.
- **Example**: The same tanker returning empty from India to the Middle East to load crude oil again.

Key Difference:

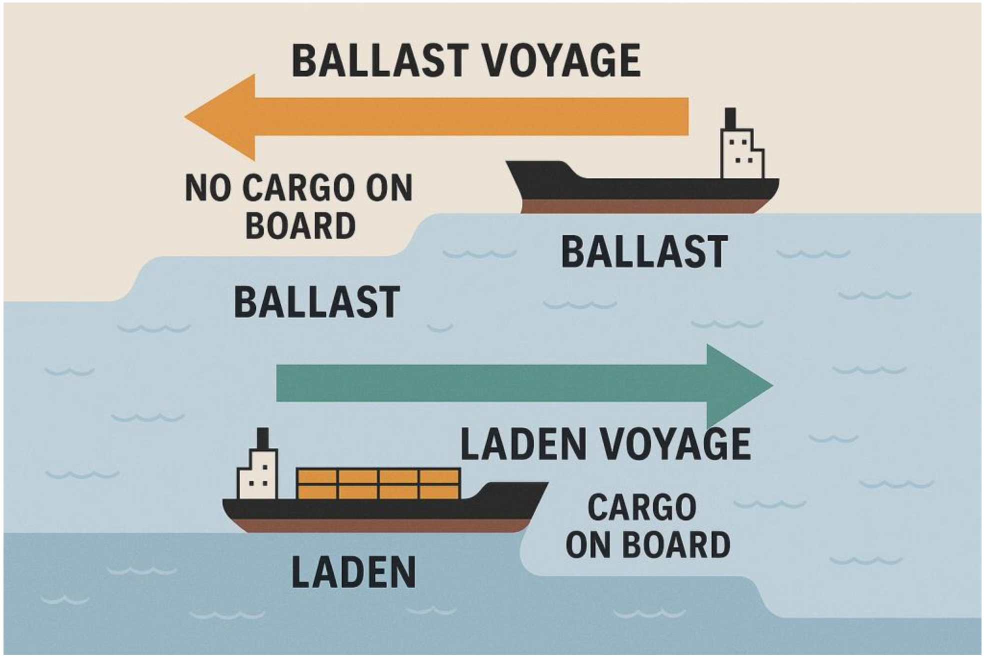
- **Laden = Cargo onboard (earning freight)**
- **Ballast = No cargo onboard (cost leg)**

Leg:

A leg refers to a segment of a voyage between two specific points.

Think of a voyage as a series of legs:

- **Example:**
    - Leg 1: Ballast voyage from Port A (discharge) → Port B (loading)
    - Leg 2: Laden voyage from Port B (loading) → Port C (discharge)


BALLAST VOYAGE
NO CARGO ON BOARD
BALLAST
BALLAST
LADEN VOYAGE
CARGO ON BOARD
LADEN

PERFORMANCE VERIFICATION TESTS

1. Sea Trial

- **Definition:** A sea trial is the **final performance test of a vessel in real operating conditions at sea** before delivery to the owner.
- **Purpose:**
    - Verify ship's speed, maneuverability, stability, and safety systems.
    - Test propulsion, steering, navigation, and communication equipment.
    - Ensure compliance with **classification society** and **regulatory standards**.
- **Conducted by:** Shipyard engineers, classification society surveyors, and sometimes the shipowner's representatives.
- **Environment: Actual sea conditions** (open water), simulating real voyage scenarios.

2. Shop Test

- **Definition:** A shop test is a **factory-level test of individual components or machinery before installation on the vessel**.
- **Purpose:**
    - Check mechanical and electrical integrity of equipment (e.g., engines, pumps, generators).
    - Verify performance against design specifications.
- **Conducted by:** Equipment manufacturer in a controlled environment (workshop or factory).
- **Environment: Static or controlled conditions**, not onboard the vessel.

- **Sea Trial**

1. Entire ship systems
2. Conducted at sea (open water)
3. Validates vessel performance
4. Done after ship construction

- **Shop Test**

1. Individual components
2. Conducted in manufacturer's workshop
3. Validates equipment functionality
4. Done before installation on ship

VARIOUS SPEED TERMINOLOGIES USED IN SHIPPING

1. Design Speed

- **Definition:** The speed the ship is intended to achieve during the design phase under ideal conditions.
- **Purpose:** Used for hull design, propulsion calculations, and fuel consumption estimates.
- **Example:** A container ship might have a design speed of 22 knots.

2. Contract Speed

- **Definition:** The speed guaranteed by the shipbuilder in the construction contract.
- **Verification:** Proven during **sea trials** under specified conditions (calm water, certain draft).
- **Example:** Contract speed could be 21 knots, slightly lower than design speed to allow tolerance.

3. MCR (Maximum Continuous Rating)

- **Definition:** The maximum power the main engine can deliver continuously without damage.
- **Usage:** Used during trials or emergencies, not for regular operation.
- **Relation:** Often required to achieve or exceed contract speed.

4. NCR (Normal Continuous Rating)

- **Definition:** Typically 85–90% of MCR, considered safe for continuous operation.
- **Usage:** Ships operate at NCR for **service speed** to balance fuel efficiency and engine life.

5. Economical Speed

- **Definition:** A reduced speed chosen to minimize fuel consumption and operating costs.
- **Usage:** Common during long voyages; usually 2–4 knots lower than service speed.

6. Slow Steaming

- **Definition:** Operating at significantly reduced speed (often 50–70% of full power).
- **Purpose:** Reduce fuel costs and emissions.
- **Typical Speed:** 12–16 knots for large container ships.

SUMMARY TABLE:

Term	Meaning	Typical Use Case
Design Speed	Target speed during design phase	Basis for calculations
Contract Speed	Guaranteed speed during trials	Builder's obligation
MCR	Max engine power for continuous use	Trials/Emergency
NCR	85–90% of MCR, safe continuous power	Service speed
Economical Speed	Lower speed for fuel efficiency	Long voyages
Slow Steaming	Very low speed for cost/emission savings	Container trade

EXPLANATION OF ACTIVITIES AND EVENTS IN A SHIP'S OPERATION

1. Port Call (When the Ship Is Inside a Port)

A **port call** is simply the period when the ship is at a port doing activities such as loading/unloading cargo, taking bunkers (fuel), taking fresh water, or any other operation.

- A port call starts from the **departure timestamp of the previous port** (when the last line is cast off).
- And it ends at the **departure timestamp of the next port**.
- This full stretch between two ports is considered **one leg** of the voyage.

2. Sea Passage (When the Ship Is Sailing at Sea)

A **sea passage** is the time when the ship is actually moving at sea from one port towards another.

- It starts when the ship **leaves the port and crosses the point BOSP** (Beginning Of Sea Passage).
  This is when the ship is fully clear of port limits and starts open-sea navigation.
- It ends when the ship reaches **EOSP** (End Of Sea Passage) near the next port.
- This is also called **"Underway"**, meaning the ship is continuously moving.
  If the vessel temporarily stops due to weather or instructions, those stoppages are excluded.

3. Port Stay (The Time Spent Inside a Port Before Leaving Again)

A port stay is **everything the ship does inside the port** before finally departing.
It can be broken into **three stages**:

a) Inbound Port Stay

- Starts when the ship reaches **EOSP** outside the port.
- Ends when the **first line is ashore** (ship officially arrives and ties to the berth).

b) Berth Time

- Starts from **first line ashore (arrival)**.
- Ends at **last line onboard (departure)**.
- This is when cargo operations, bunkering, fresh water loading, or any maintenance work happen.

c) Outbound Port Stay

- Starts from **last line onboard** (when the ship leaves the berth).
- Ends at **BOSP** (when the ship exits port limits and enters open sea).

Note

A port stay may include:

- **Anchorage** (waiting area before getting a berth)
- **Drifting** (ship moves slowly without anchoring)
- Or a mix of both, depending on port congestion or charterer instructions.

Other Activities

4. Anchoring and Drifting

Sometimes the ship cannot immediately proceed, so:

- **Anchoring** = ship drops anchor and stays at a fixed area.
- **Drifting** = ship moves slowly without anchoring.

These can happen:

- During any type of **port stay** (common while waiting for berth).
- Even during a **sea passage**, if there is a major engine breakdown or if the charterer instructs the ship to wait.

5. Bunkering (Taking Fuel or Ship Supplies)

Bunkering simply means **loading fuel** for the main engine, generators, or boilers.
It may also include loading:

- Fresh water
- Lubricating oil

Key points:

- Can happen during **any port stay** stage.
- In rare emergencies, bunkering can happen during sea passage (though uncommon).

6. Technical Breakdown

- A breakdown can occur **any time**, whether in port or at sea.
- Depending on the severity, the ship may drift, anchor, or even need tug assistance.

7. Cut and Run (Operational and Berth Scenario)

Cut and Run refers to a situation where a ship **arrives at the berth**, completes all formalities, **but leaves the port WITHOUT STARTING the planned cargo operation**.

Why does this happen?

A vessel may "cut and run" from the berth when circumstances make it impossible or uneconomical to start the operation. Typical reasons include:

- **Severe port congestion**
- **Cargo not ready**
  (e.g., cargo owner delays, shore pipelines not ready, loading arm issues)
- **Charterer's instruction to cancel the operation**
- **Weather restrictions** (high swell, wind limits for cranes, etc.)
- **Terminal equipment failure**
- **Port authority denying/withdrawing permission**
- **Tide window closing**, needing to vacate berth

Since the ship has already berthing formalities completed but **has not handled any cargo**, the vessel must **vacate the berth immediately** to free it for other ships.

What the phrase actually means

In this commercial context:
Cut = Stop the planned operation before it even begins

Run = Leave the berth/port immediately
The vessel may still have spent time at berth, consumed fuel for maneuvering, used tugs, or paid port dues — **but no cargo loading/unloading occurs.**

Think of a ship's journey like a person travelling in a car:

Ship Scenario	Simple Analogy
Sea Passage	You're driving on the highway.
Inbound Port Stay	You're entering a parking area.
Berth Time	Your car is parked and you're loading/unloading things.
Outbound Port Stay	You're leaving the parking area and heading back to the main road.
Anchoring	You're waiting in a safe spot with brakes on.
Drifting	You're waiting but slowly rolling forward.
Bunkering	Refueling the car.
Cut and Run	Parking your car at the mall but driving away immediately because the work you came for cannot start.
Technical Breakdown	Car stops unexpectedly anytime.

OCEAN DYNAMICS:

Waves (Wind Sea)

- **Origin:** Created by local winds blowing over the water surface.
- **Appearance:** Irregular, choppy, with varied heights, periods, and directions.
- **Energy:** Directly influenced by local wind strength, duration, and distance (fetch).
- **Travel:** Move with the local wind; change direction as the wind changes.

Swell

- **Origin:** Generated by powerful, distant storms (e.g., hurricanes) far out at sea.
- **Appearance:** Smooth, organized, long-wavelength, with uniform crests.
- **Energy:** Retains energy from the distant storm, traveling vast distances.
- **Travel:** Can travel thousands of miles, often arriving with no local wind, and can be directional.

Ocean Currents

Ocean currents are continuous, directed flows of seawater, like rivers within the ocean, driven by wind, Earth's rotation (Coriolis effect), temperature/salinity differences (thermohaline circulation), tides, and gravity, moving heat and nutrients globally, influencing climate and marine life through surface gyres and deep-sea currents. They range from powerful, wide streams like the Gulf Stream to deep, slow flows, impacting weather and ecosystems worldwide.

Causes of Ocean Currents

Wind: Drives surface currents, creating large rotating patterns called gyres (clockwise in Northern Hemisphere, counter-clockwise in Southern).

Coriolis Effect: Earth's rotation deflects moving water, influencing the direction of wind-driven currents.

Density (Thermohaline Circulation): Differences in temperature (thermo) and salinity (haline) create density variations, causing deep currents (the "Global Conveyor Belt").

Tides: Lunar and solar gravity create regular tidal currents, especially strong near coasts.

Gravity & Topography: Influences density-driven flows and current paths near ocean floor features.

VESSEL PERFORMANCE PARAMETERS:

1. SPEED THROUGH WATER (STW)

Definition:

The speed of the ship relative to the water directly around it.

How to explain it simply:

The ship is moving THROUGH a moving fluid (water).
If the water itself is moving (current), your speed relative to water is **not** the same as your speed relative to land.

Analogy: Car on a treadmill

Imagine a car moving at **20 km/h** on a treadmill that moves backwards at **10 km/h**.

- The car's WHEEL SPEED = 20 km/h → **this is STW**
- But the car's NET MOVEMENT RELATIVE TO GROUND = 10 km/h → this is SOG

Same for a ship:

- Propeller pushes ship through water → STW
- Water may be moving → current affects actual progress over ground

2. SPEED OVER GROUND (SOG)

Definition:

The actual speed of the ship relative to the seabed (Earth).
Measured by **GPS**.

Developer analogy:

SOG is like the **net result** after adding external forces in a physics simulation:

```
SOG = STW + Current Effect
```

Analogy: Car in wind

If your car moves at **60 km/h** but a strong tailwind pushes you forward on a loose surface, your "ground speed" changes.

On a ship:

- If current pushes ship forward → SOG > STW
- If current opposes ship → SOG < STW

3. RELATIVE WIND

Definition:

The wind felt on the ship, combining natural wind + ship's own motion.
This is the wind measured on the ship's anemometer.

How to explain simply:

Relative wind = True wind – Ship's motion

```
Relative Wind = True Wind - Ship Speed
```

Analogy:

When a car drives at 60 km/h:

- Even on a calm day, you feel wind hitting your face at **60 km/h**
- If natural wind blows against the car at 20 km/h → you feel **80 km/h** wind
- If natural wind blows from behind at 20 km/h → you feel only **40 km/h** wind

Same for a ship:
The faster the ship moves, the stronger the headwind it creates.

4. Propeller Slip

Slip = The difference between the theoretical distance a propeller SHOULD move the ship and the actual distance it moves.

A propeller is like a screw in water — but water is not solid, so some rotation is "lost."

Technical Definition

When a propeller rotates, it “screws” itself forward.
If water were a solid, every revolution would move the ship forward by the **pitch** of the propeller.

But in real water, the ship moves **less** than the theoretical distance because of:

- Water resistance
- Hull drag
- Wake flow
- Propeller inefficiencies

So slip is:
`Slip (%)` = (Theoretical Speed – Actual Speed) / Theoretical Speed × 100
Where:
 * **Theoretical Speed** → Pitch × RPM
 * **Actual Speed** → STW (speed through water)

Car Analogy (Very Easy to Understand)

Imagine a car on a muddy road:

- You press the accelerator
- Wheels rotate
- But the car does **not** move forward as much as it should
- Because wheels "slip" on mud

This is exactly what happens with a propeller in water.

Differences:

- Car → tires grip the road
- Ship → propeller pushes water (water “gives way”), so some energy is lost

More slip → ship moves less for the same RPM.

MAJOR MACHINERY OR EQUIPMENT ONBOARD:

FPP (Fixed Pitch Propeller)

- Blades fixed at one angle
- Speed control only via RPM
- Simple and rugged
- Suitable for deep-sea ships with predictable load

CPP (Controllable Pitch Propeller)

- Blades change angle using hydraulic mechanism
- Allows thrust control at constant RPM
- Important for DP vessels and ferries
- Enables quick maneuvering and fine thrust adjustments

Main Engine

- Provides propulsion power
- Connected to propeller via shaft line
- Responsible for vessel speed and voyage fuel efficiency

2-Stroke Engines (Main Engine)

- Slow-speed engines (60–120 RPM)
- Very high torque, ideal for direct propeller drive

• Use heavy fuel (HSFO/VLSFO)

• Efficiency ~50%

• Most common propulsion engines for tankers, bulkers, container ships

4-Stroke Engines (Diesel Generators)

• 400–900 RPM

• Used for electrical power production

• More compact than 2-stroke

• Easy start/stop, high responsiveness

• Found in all vessels for auxiliary power

Diesel Generator

• Supplies electric power to entire ship

• Runs navigation equipment, pumps, compressors, HVAC

• Driven by Engine – Auxiliary Engines (AE)

• Driven by Steam Turbine – Turbo generators (TG)

• Coupled to Propeller shaft – Shaft Generator

• Minimum 2 Nos. All combinations possible.

• Emergency Generator – Power outage (Blackout)

Supplies power to Essential consumers.

Boiler

• Produces steam for heating fuel oil (to reduce viscosity)

• Provides accommodation heating

• Used for cargo tank heating in tankers

• Standalone unit – Auxiliary Boilers (consumes fuel)

Used for port stays and back up during sailing in cold weather or during slow steaming.

• Exhaust gas Boiler (Economizer) – Uses Main Engine

Exhaust heat – Functions only during sailing.

• Composite Boiler – combination of above two types - Single unit.

Compressor

• Produces compressed air

• Used for starting main engine

• Also used for control systems and pneumatic tools

Steering Gear Purpose

• Moves rudder using hydraulic rams

• Essential for ship maneuvering

• Usually duplicated (redundant) for safety

MARINE FUEL OIL (ISO 8217:2017

Marine Residual Fuels (HFO / LFO)

Distillate Marine Fuels (HFO / LFO)

Grade	Viscosity @ 50 °C (cSt)	Typical Use
RMA 10	10	Light residual (LFO)
RMB 30	30	Light residual (LFO)
RMD 80	80	Light residual (LFO)
RME 180	180	Heavy Fuel Oil (HFO)
RMF 180	180	Heavy Fuel Oil (HFO)
RMG 380	380	Heavy Fuel Oil (HFO)

RMK 700	**700**	**Heavy Fuel Oil (HFO)**

Distillate Marine Fuels (MGO / MDO / Bio Fuel Blends)

Grade	Viscosity @ 40 °C (cSt)	Typical Use
DMX	1.4 – 5.5	Emergency use
DMA (MGO)	2.0 – 6.0	Marine Gas Oil
DMZ (MGO)	3.0 – 6.0	Marine Gas Oil (cold climates)
DMB (MDO)	2.0 – 11.0	Marine Diesel Oil
DFA / DFZ / DFB	Similar to DMA/DMZ/DMB	Biofuel blends

• **HFO =** High-viscosity residual grades (RMG 380, RMK 700).

• **LFO** = Lower-viscosity residual grades (RMA 10, RMB 30).

• **MGO** = DMA / DMZ (pure distillate).

• **MDO** = DMB (distillate + residual blend).

Alternate Marine Fuels

Why Alternate Fuel?

- **Environmental Regulations**
  - IMO 2020 sulfur cap (≤0.50%) and ECA limits (≤0.10%)
  - IMO GHG reduction targets for 2030 and 2050
- **Emission Reduction**
  - Lower SOx, NOx, and particulate matter
  - Reduce CO_2 footprint to combat climate change
- **Compliance & Future-Proofing**
  - Meet MARPOL Annex VI and regional green shipping rules
  - Avoid penalties and port restrictions

- **Energy Transition**
    - Shift from fossil fuels to renewable and sustainable sources
    - Support decarbonization goals in shipping industry
- **Operational & Market Benefits**
    - Access to green corridors and eco-friendly ports
    - Enhance corporate sustainability image

Types of Alternate Fuel?

- **LNG (Liquefied Natural Gas)**
    - Lower CO_2 emissions (~20–30%)
    - Cuts SOx, NOx, PM
    - Needs cryogenic storage and bunkering infrastructure
- **LPG (Liquefied Petroleum Gas)**
    - Low SOx and NOx emissions
    - Easier storage than LNG
    - Still emits CO_2
- **Methanol**
    - Liquid at ambient temperature (easy bunkering)
    - Reduces SOx, NOx, PM
    - Toxic and low flash point (safety concerns)
- **Biofuels (HVO, FAME, etc.)**
    - Drop-in compatible with existing engines
    - Up to 80–90% lifecycle CO_2 reduction
    - Feedstock sustainability challenges
- **Ammonia**
    - Zero carbon emissions at combustion
    - Toxic and corrosive; needs special handling
    - Lower energy density
- **Hydrogen**
    - Zero CO_2 when used in fuel cells
    - Requires cryogenic or high-pressure storage
    - Limited infrastructure
- **Synthetic e-Fuels (e-Methanol, e-Ammonia, e-Diesel)**
    - Carbon-neutral potential
    - High production cost and limited availability

- **Wind-Assisted Propulsion**
  - Rotor sails, kites, rigid wings
  - 5–20% fuel savings (retrofit), up to 50% (new builds)
- **Battery-Electric & Hybrid Systems**
  - Ideal for short voyages and port operations
  - Zero emissions during operation
  - Limited range and heavy batteries

Biofuel Examples

- **FAME (Fatty Acid Methyl Esters)**
  - Produced from vegetable oils or animal fats
  - Common in biodiesel blends
- **HVO (Hydrotreated Vegetable Oil)**
  - Renewable diesel from hydrogen-treated oils
  - Drop-in replacement for conventional diesel
- **BTL (Biomass-to-Liquid)**
  - Synthetic fuel from biomass via Fischer-Tropsch process
- **Bio-Methanol**
  - Methanol produced from renewable biomass sources
- **Bio-LNG**
  - Liquefied biogas from organic waste
- **UCOME (Used Cooking Oil Methyl Ester)**
  - Biodiesel from recycled cooking oils
- **Algae-based Biofuels**
  - Derived from microalgae; high potential for scalability

MAJOR FUEL PROPERTIES IN BUNKER REPORT OR LOGS

1. Sulfur Content

- **Why it matters:**
  - Impacts compliance with **MARPOL Annex VI** emission regulations.
  - High sulfur → more SOx emissions → acid rain and corrosion.
- **Operational impact:**
  - Requires scrubbers or low-sulfur fuel in ECAs (≤0.10% sulfur).

2. Density

- **Why it matters:**
  - Affects **mass-to-volume ratio** for energy calculation.
  - Higher density → more energy per liter but harder to pump.
- **Operational impact:**
  - Influences fuel handling and purifier settings.

3. Viscosity

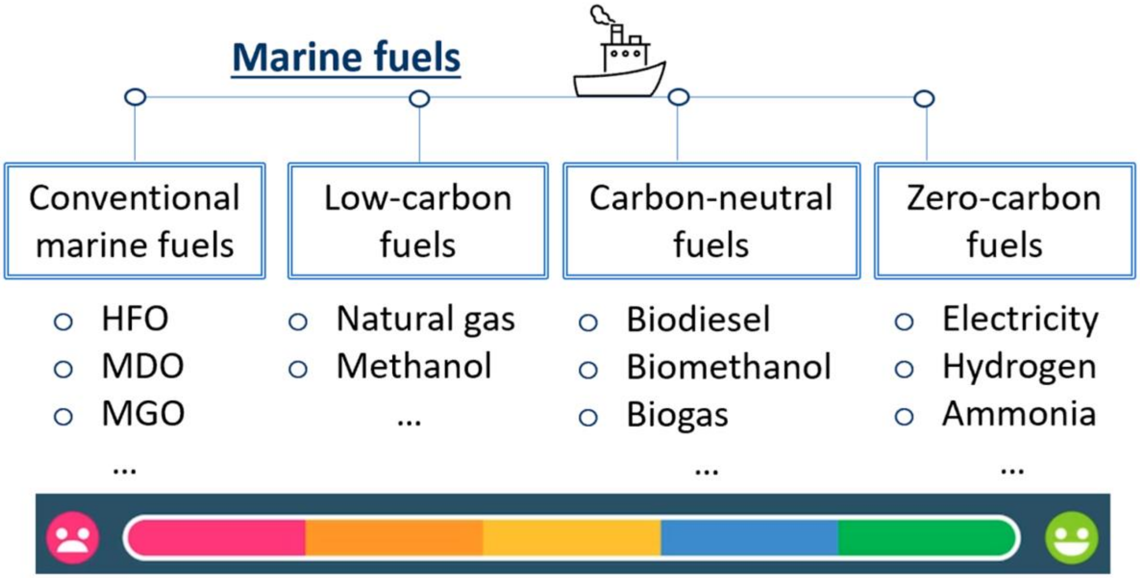
- **Why it matters:**
  - Determines **flow and atomization** in injectors.
  - Too high → poor atomization, incomplete combustion.
  - Too low → leakage in pumps and injectors.
- **Operational impact:**
  - Residual fuels need heating to reach correct viscosity before injection.

4. Flash Point

- **Why it matters:**
  - **Safety parameter**: minimum temperature at which fuel vapors ignite.
  - Marine fuels must have **≥60 °C** (except DMX emergency fuel ≥43 °C).
- **Operational impact:**
  - Ensures safe storage and handling onboard.

5. Lower Calorific Value (LCV)

- **Why it matters:**
  - Indicates **energy content per kg** of fuel.
  - Higher LCV → more energy output → better efficiency.
- **Operational impact:**
  - Used for voyage planning and fuel consumption calculations.



DUAL-FUEL ENGINE

Definition:

- Engines designed to run on **two types of fuel**: a primary gas fuel and a secondary liquid fuel (usually marine diesel oil).

Operation:

- Normally operates on gas (LNG, LPG, Methanol, etc.)
- Uses liquid fuel for ignition or backup mode.

Fuels Commonly Used in Dual-Fuel Engines

- **LNG (Liquefied Natural Gas)** – Most common for dual-fuel engines.
- **LPG (Liquefied Petroleum Gas)** – Alternative for gas-powered engines.
- **Methanol** – Increasingly used in new dual-fuel designs.
- **Bio-LNG / Bio-Methanol** – Renewable options for lower carbon footprint.

VESSEL PERFORMANCE EVALUATION – CYCLE ANALOGY (WITH TRANSMISSION LOSS)

1. Bicycle Analogy for Ship Hull Fouling & Engine Degradation

- **Base Scenario (Smooth Road, Normal Load)**
  Imagine a bicycle runs on a flat smooth surface with a fixed load (50 kg). This represents a **clean hull and healthy engine** in a ship. The power required is minimal and efficiency is high.
- **Hull Fouling Analogy**
  Over time, marine growth on the hull increases resistance, similar to **tyre wear adding extra power demand** in your data. Just as the cyclist needs more energy to maintain speed when tyres wear out, a ship needs more fuel to maintain speed when hull fouling occurs.
- **Engine Degradation Analogy**
  The cyclist's performance deteriorates with added injury (extra drink consumption per Whr). Similarly, an engine loses efficiency over time, requiring more fuel for the same output.

2. Shop Test Data vs Sea Trial Data

- **Shop Test Data**
  This is like testing the bicycle in a controlled environment (monocycle with no transmission loss, smooth road, fixed load, no wind). It gives a baseline performance—similar to the reference power and drink consumption values.
- **Sea Trial Data**
  This is like riding the bicycle outdoors where conditions vary (Bi cycle with transmission loss). It reflects real-world performance, which often deviates from shop test values due to various factors.

3. Damaged Road Analogy for Rough Weather

- A **damaged or uneven road** increases rolling resistance, just like **rough seas increase hull resistance**.
- When analyzing performance, these external factors are **negated or normalized** to isolate the true condition of the hull and engine—similar to ignoring potholes when comparing bicycle efficiency.

4. Load Variation Analogy (Draft Change)

- Adding **20 kg extra load on the bicycle** is like increasing ship draft due to cargo variation.
- More load means more power and energy consumption. In ships, this is normalized by applying correction factors so performance comparisons remain fair—just as you would adjust calculations to compare bicycle performance under different loads.

5. Normalization Concept

- For ships, normalization removes the effect of:
  - **Weather (road condition analogy)**
  - **Draft/load changes (extra weight analogy)**
- This ensures performance trends reflect **true hull and engine condition**, not external influences.

Now, after months of operation:
- The ship's hull and propeller have fouling (marine growth), which increases water resistance.
- The cycle's tires have worn out or are underinflated, increasing rolling resistance.

In both cases, the engine/ cyclist must work harder to maintain the same speed. This means more fuel/energy drink is burned for the same performance.

Power Delivered vs Effective Power
- **Power Delivered**: The power produced by the engine at the crankshaft (Power delivered to the pedals)
- **Effective Power**: The power actually available to overcome resistance after transmission losses (gearbox, shaft, bearings). For ships, this is power at the propeller; for cycle, power at the wheels after transmission losses (sprocket chain assembly).

Why Added Resistance Increases Fuel Consumption
When resistance increases, extra power is needed. This extra power translates into extra energy over time, which means extra fuel consumption. To isolate engine health, we must remove this extra fuel and power from calculations.

Let's take the above analogy as an example and assume a cyclist with a known performance gets engaged in a contract to deliver some goods to a destination at a specified speed,

Cyclist's Performance data: (Equivalent to shop test data)

Test vehicle used	Mono cycle	
Age, Years	20	
Max power Produced, watts	100	
Effective Power developed to carry 50 kgs load on a flat smooth surface, watts	70	
Speed achieved, Kms/hour	10	
Distance travelled, Kms	50	
Travel Time, Hrs	5	Dist / speed
Total Energy consumed, Whr	350	Power x Travel time
Energy Drink type **(Fuel Type)**	A	
Energy Drink calorific value, Whr/ml **(LCV)**	0.2	
Drink consumed vol, ltrs **(FOC)**	1.75	
Energy Drink Specific consumption, ml/Whr **(SFOC)**	5	drink consumed/Energy consumed

Commercial Engagement terms:
(Equivalent to Charter Agreement)

Vehicle Features	
Vehicle Type	Bicycle
Cycle Transmission Loss, watts	5
Tyre wear added power rate, watt/Month (on a flat smooth surface)	1
Trip Details	

Trial Performance data after contract:
(Equivalent to Sea Trial data)

Load carried per trip, kgs	50
Required Speed, Kms/hr	10
Trip Distance, Kms	50
Trip time, hrs	5
Road Condition	Flat smooth
Energy Drink Type supplied	A

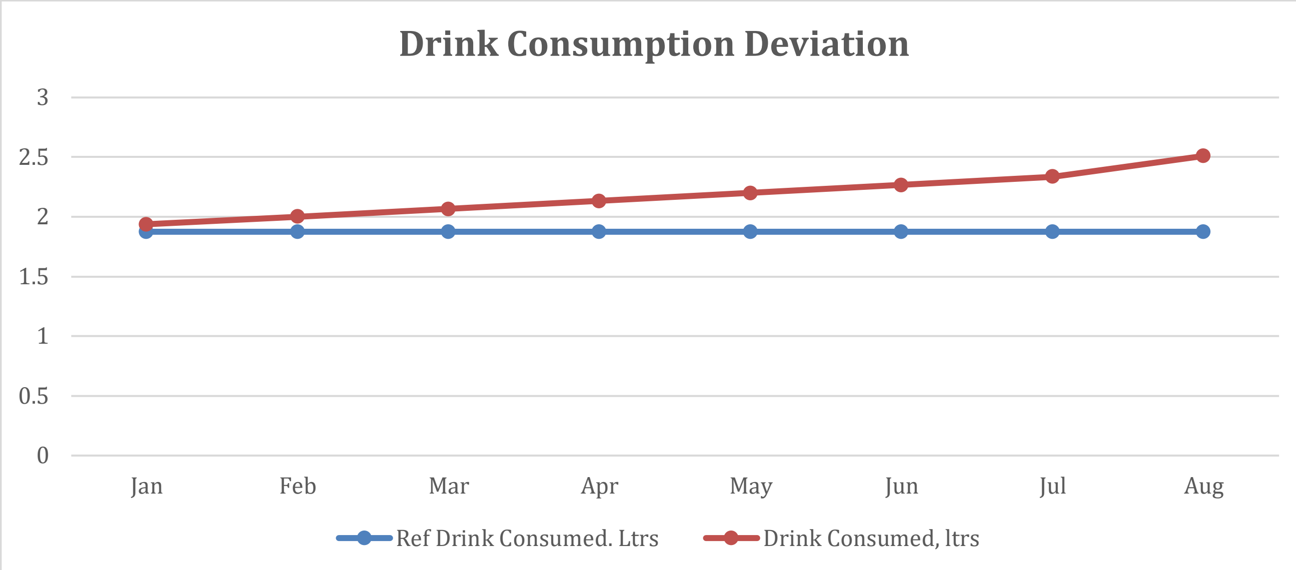
Power Delivered, watt	75	Power added 5 watts
Total Energy consumed, Whr	375	75 x 5
Drink consumed vol, ltrs	1.875	Energy Consumed/Drink calorific value
Energy Drink Specific consumption, ml/Whr	5	

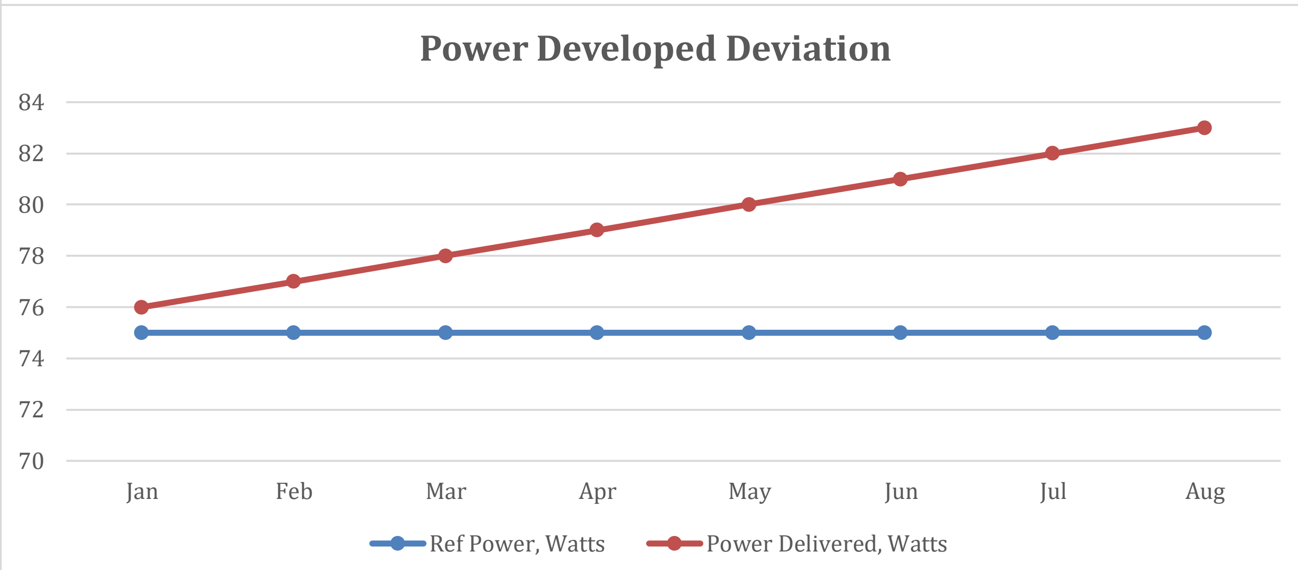
Say, Cyclist agreed for a contract of 8 months and the cycle tyre wears at a rate of 1 watt/month, either the energy drink consumption will increase for compensating the added tyre wear power or the speed is going to decrease. However, the cyclist has to follow the contract speed to maintain the ETA.

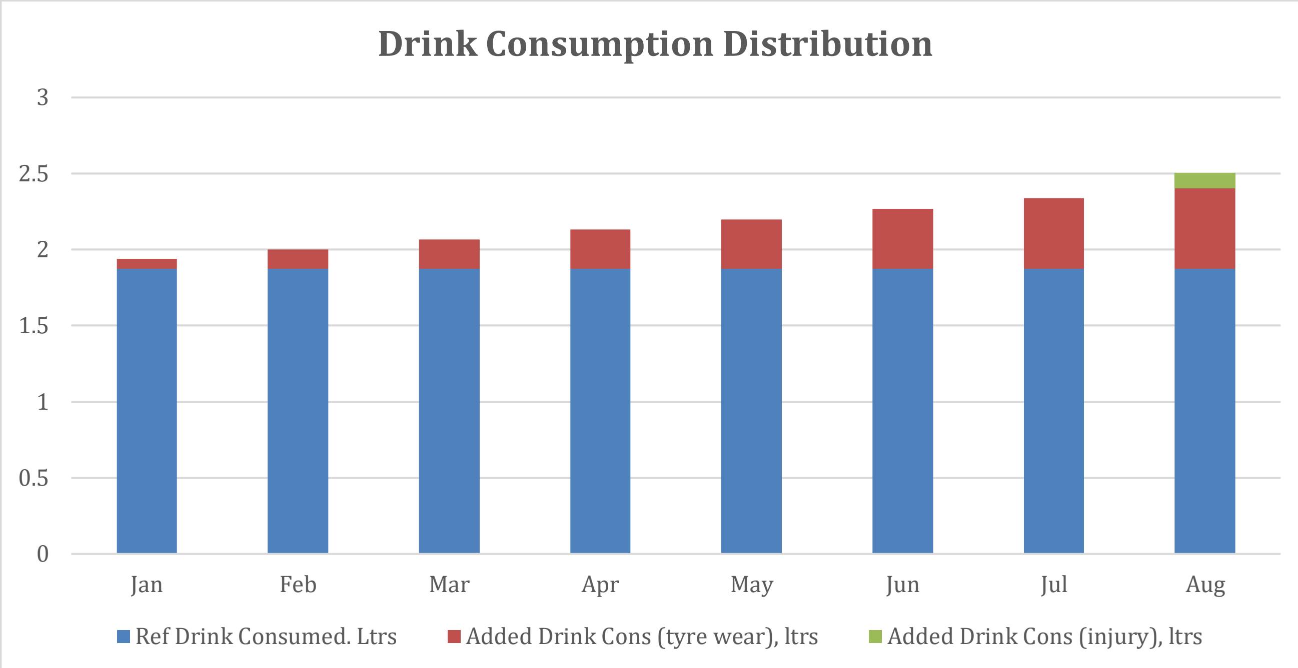
In the following table, it can be seen that the cyclist got injured in the month of August which is going to decrease his efficiency and in turn increases the energy drink consumption to maintain the same power/speed.

Cyclist Performance over a period: (Equivalent to HP performance monitoring)

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Ref Power, Watts	75	75	75	75	75	75	75	75
Power Delivered, Watts	76	77	78	79	80	81	82	83
Added Power (Tyre wear), watts	1	2	3	4	5	6	7	8
Total Energy delivered, Whr	380	385	390	395	400	405	410	415
Ref Drink Consumed. Ltrs	1.875	1.875	1.875	1.875	1.875	1.875	1.875	1.875
Drink Consumed, ltrs	1.94	2.00	2.07	2.13	2.20	2.27	2.34	2.51
Added Drink Cons (tyre wear), ltrs	0.06	0.13	0.19	0.26	0.33	0.39	0.46	0.53
Added Drink Cons (injury), ltrs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Energy Drink Specific consumption, ml/Whr	5.1	5.2	5.3	5.4	5.5	5.6	5.7	6.05


Drink Consumption Deviation
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Ref Drink Consumed. Ltrs
Drink Consumed, ltrs


Power Developed Deviation
84
82
80
78
76
74
72
70
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Ref Power, Watts
Power Delivered, Watts



From the above graph, a steady increase in drink consumption can be seen as the tyre wear progresses. Also in the month of August, consumption has increased slightly more than the usual trend due to an injury of the cyclist.

The above scenario is applicable when the contract conditions and the trial conditions are same.

Lets assume 2 scenarios now.

Scenario No.1: If the cyclist has to travel across rough roads (equivalent to bad weather for a ship), additional drink is consumed to achieve the contract speed.

Scenario No.2: If the load carried per trip is increased, again and additional drink is consumed.

Combination of above 2 scenarios is possible and can happen many times during any point of the contract period. Including this added power or fuel consumption will mislead the cyclist's performance evaluation.

In such cases, the additional power required to overcome riding on damaged roads is negated from the total power delivered and the additional power required to overcome the extra load is Normalized to the reference condition. This makes our performance evaluation easy and accurate to compare with the reference conditions.

Vessel performance evaluation is performed following a similar approach. However, it's complex as it depends purely on the quality of data reported by the vessel crew and the sensors installed onboard ships. Human error and sensors malfunction are a major challenge in understanding and handling the data. One data point mismatch, if not handled properly at the data processing level, could lead to a completely wrong evaluation. Hence, it's important and critical to understand the outliers and process them, before generating the output.

Below is the Example calculation pertaining to a ship, assuming the sailing conditions are same as the sea trial conditions (calm sea and no wind conditions)

Step-by-Step Example Calculation for a ship

Given:
-

Parameters	Actual Data	Sea Trial Data
Speed, kNOTS	14	14
Total Delivered Power, kW	10,000	9,500
Run Time (Hours)	10	
LCV Fuel, kJ/kg	42,700	42,700
Tot Fuel Consumed, kg	25,000	

Transmission loss = 2% of delivered power
- Weather and external influencing factors are assumed to have no effect

Step 1: Calculate Added Power due to Hull and Propeller fouling
Added Power (ΔP)= Total actual delivered power – Total delivered power during sea trial = 10,000 × 9,500 = 500 kW

Step 2: Calculate Added Energy
Added Energy (ΔE) = Added Power × Time = 500 × 10 = 5,000 kWh
Convert to kJ: 5,000 × 3600 = 18,000,000 kJ

Step 3: Calculate Added Fuel
Added Fuel (ΔF) = ΔE / LCV = 18,000,000 / 42,700 ≈ 421.31 kg

Step 4: Calculate Effective Power with Transmission Loss
Effective Power (P_eff) = (P_delivered – ΔP) × (1 - 0.02)
= (10,000 – 500) × 0.98 = 9,310 kW

Step 5: Effective Fuel Consumption
Effective Fuel (F_eff) = (Total Fuel – Added Fuel Hull Fouling) × Transmission Loss = (25,000 – 421.31) × (1 – 0.02) = 24,087.116 kg

Step 6: Calculate Effective SFOC
Convert fuel to grams: 24,087.116 × 1000 = 24,087,116 g
SFOC = (Fuel per hour) / Power
Fuel per hour = 24,087,116 / 10 = 2,408,712 g/hr
SFOC = 2,408,712 / 9,310 ≈ 258.72 g/kWh

This corrected SFOC can now be compared to the shop test SFOC at the same effective power to understand engine degradation.

Assume Shop test SFOC @ 9310 Kw is 257.69 g/kWh, SFOC has increased by 1.03 g/kWh (258.72 – 257.69)

- Added Fuel due to Engine Degradation = (Effective SFOC – Shop Test SFOC) × Effective Energy
- Effective Energy = Effective Power × Time = 9,310 × 10 = 93,100 kWh
- Added Fuel due to Engine Degradation = (258.72 – 257.69)× 93,100 = 95,893 g = 95.89 kg
- Total Fuel Consumed = 25, 000 kg
- Fuel added due to Hull & Propeller Fouling = 421.31 kg

- Fuel added due to Engine Degradation = 95.89 kg

COMMERCIAL & REGULATORY FUNDAMENTALS

1. Carbon Intensity Indicator (CII)

CII is a **rating system** (A to E) that measures **how efficiently a ship transports cargo** in terms of carbon emissions.

What it means:

CII = CO_2 emitted per tonne-mile of cargo moved.

Car Analogy:

Think of CII as a car's **fuel efficiency rating (km/l)**.
A car that consumes more fuel for the same distance gets a **bad rating**, just like a ship.

Why developers should care:

- NAVIK and similar systems calculate efficiency.
- Poor-quality data = wrong CII grade = fines/financial impact.
- Correct voyage, cargo, fuel data is essential.

2. EU ETS (European Union Emission Trading System)

EU ETS charges a ship **money** for the CO_2 it emits.
More fuel burned → More CO_2 → More cost.

Car Analogy:

Imagine paying a **penalty for every liter of petrol** based on how much pollution your car emits.

How it affects shipping companies:

- 40–70% of EU voyages fall under ETS rules.
- Fuel inefficiency = higher carbon cost.
- Accurate data reporting becomes financially critical.

Developer Impact:

Systems must calculate:

- Fuel consumption
- CO_2 emissions
- ETS cost impact per voyage

Incorrect values → direct financial loss for client.

3. FuelEU Maritime

FuelEU Maritime is an upcoming rule that checks **how clean the fuel is** and **how efficient the ship operates**.

Car Analogy:

It's like a rule forcing cars to use:

- Cleaner fuel blends (ethanol, biodiesel)
- Less polluting engines

FuelEU penalizes ships that:

- Use high-carbon fuels
- Operate inefficiently
- Fail to meet GHG intensity limits

Developer Impact:

Your systems must compute:

- Carbon intensity (gCO_2/MJ)
- Fuel blends (biofuel %, fossil %)
- Compliance score
- Penalties or credits

4. EEOI (Energy Efficiency Operational Indicator)

EEOI measures **fuel consumed per tonne of cargo per nautical mile**.

Why it matters:

EEOI shows the **real operating efficiency**, not theoretical.

Car Analogy:

It's like calculating **km per liter** when your car is fully loaded vs empty.
More load = different mileage.

Developer Impact:

Requires quality data on:

- Fuel consumption
- Cargo mass
- Distance traveled

EEOI is often used to detect:

- Hull fouling
- Engine degradation
- Inefficient operation
- Poor weather routing

5. Why Accurate Data Matters in Regulations

Commercial and regulatory systems depend entirely on **data quality**.

If data is wrong:

- CO_2 values wrong → ETS fines
- CII grade wrong → operational restrictions
- EEOI incorrect → clients blame software
- FuelEU intensity wrong → penalties

Car Analogy:

Imagine calculating your car's mileage using:

- Wrong odometer reading
- Wrong fuel amount
- Wrong tank size

You get a completely incorrect fuel efficiency value.

Ships face the same problem — but penalties involve **millions of dollars**.

6. Why Developers Must Understand These Regulations

You are building tools that must correctly compute:

- Fuel → CO_2
- Efficiency → Ratings
- Distance → Emissions
- Biofuel blend → GHG intensity
- Voyage segments → ETS applicability
- Cargo → EEOI & CII

Even a **small error** in:

- Fuel logs
- Distance
- Correction factors
- Sensor mismatch
  …can lead to **large financial inaccuracies.**

Understanding commercial rules ensures:

- Correct algorithms
- Correct validations
- Correct client reporting
- Higher confidence in your product