of CG remains the same, only B will move. As a consequence, the hydrostatic thrusts at the ship's ends will change and so will its trim.

It is the effects of shallow water trim that will be the primary focus within this book.

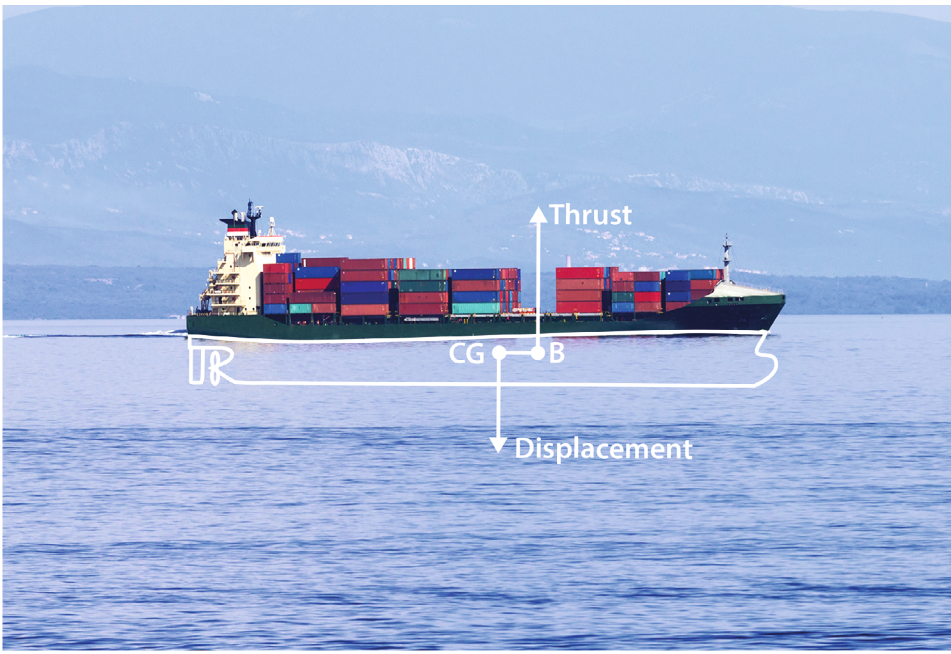

Figure 1.1 – C_b = <0.7

Figures 1.1 and 1.2 demonstrate how, as the profile of the wave changes, the underwater volume both fore and aft of the centreline will also change, creating a variation in B as the resultant hydrostatic thrust from the water is applied to the bottom. As the CG has not moved, there will be a change in the longitudinal stability, causing the trim to alter. This results in a change in directional stability.

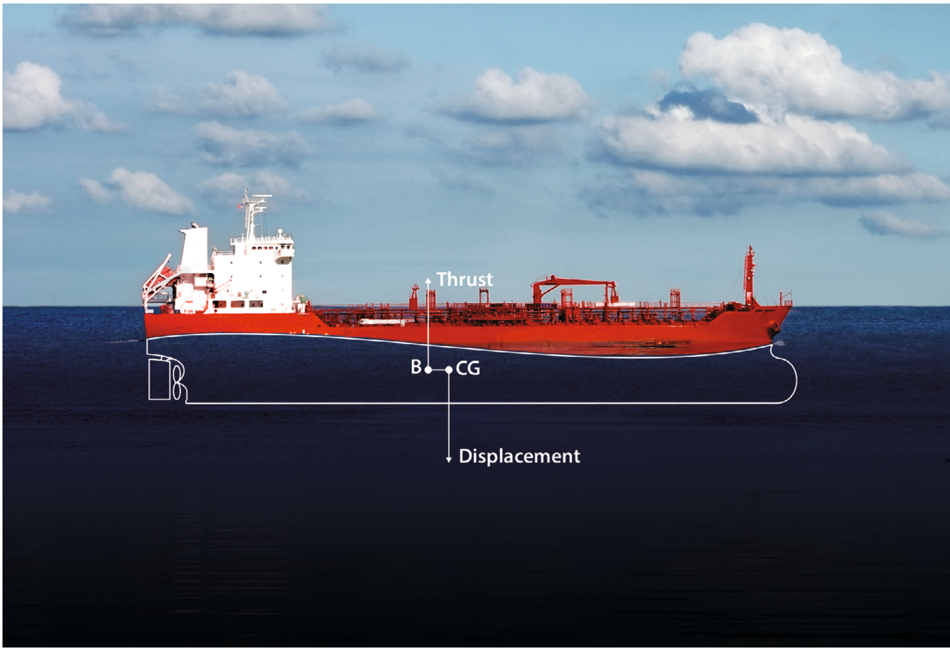

Figure 1.2 – C_b = >0.7

Chapter 2 – Directional Stability

Directional stability is the ship's ability to maintain her course while the rudder is amidships.

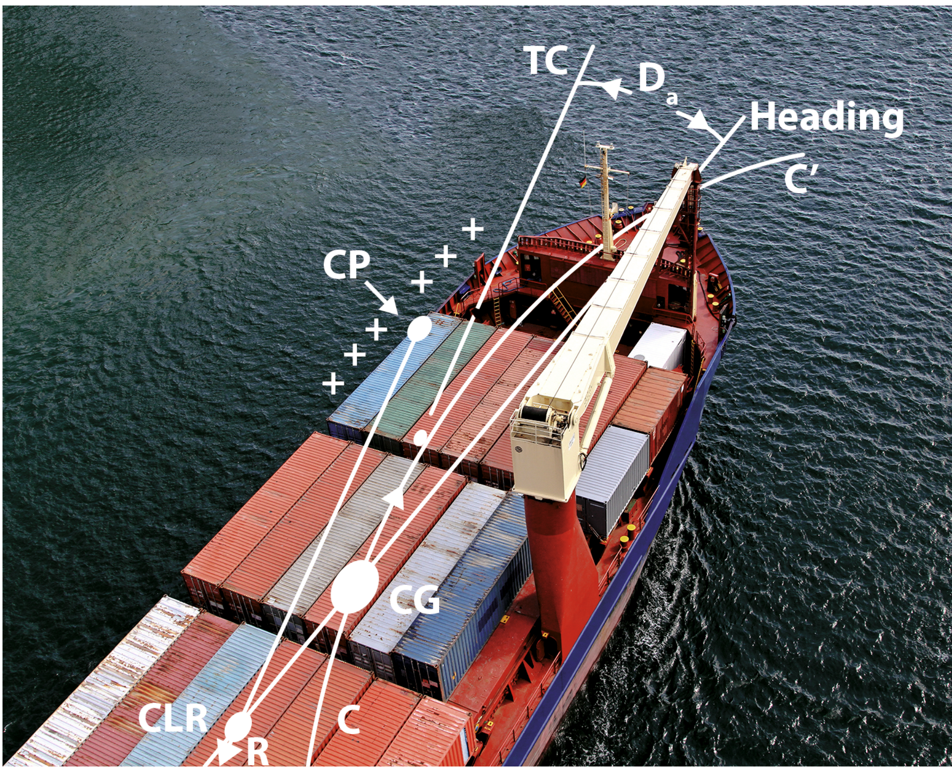

Figure 2.1 – Directional stability

How the ship responds to the rudder depends on the relative locations of the centre of lateral resistance (CLR) and the centre of gravity (CG).

Within this section, the labelling is defined as:

C-C':	**Curved path**	**Fn:**	**Rudder normal force**
CG:	**Centre of gravity**	**Fr:**	**Retardant force**
CLR:	**Centre of lateral resistance**	**Ft:**	**Transverse force**
CP:	**Centre of pressure**	**R:**	**Resistance**
Da:	**Drift angle**	**TC:**	**True course**

2.1 Centre of Lateral Resistance (CLR)

CLR is the geometric centre of the underwater profile of the hull. It can be described as the tangential projection of the CP over the hull centreline plane, where CP is the point where water resistance acts most strongly on the wet hull surface. While the total resultant forces of each water molecule across the hull act on the CLR, thrust from the propeller/s acts on the CG.

If the underwater volume changes, either forward or aft of the midship section, the wetted areas will also change. As a result, the CP and the CLR will move in front of, behind or to the same point as the CG.

Ships are divided into three categories according to the position of the CLR with regard to their CG.

Directionally stable ship

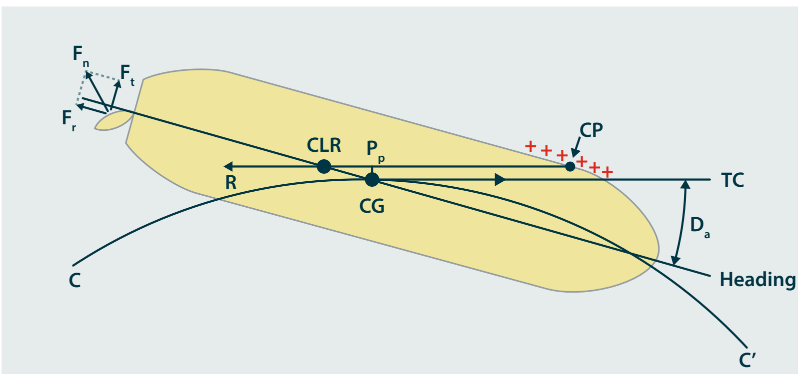

Figure 2.2 – Directionally stable ship

As the ship yaws, while on a set heading, if the projected CLR crosses the hull centreline plane aft of the CG, it causes a couple that usually keeps the ship on her course.

This means that, if there is a slight yaw while steering and the rudder is put amidships, the ship will reduce her ROT until the new course is met. If the rudder is kept amidships, any temporary yawing that is caused by either the wind or waves will be counteracted by the couple, stopping the ship from swinging.

While this type of stability is desirable, it should be recognised that the greater the directional stability, the greater the F_n required to maintain a curved path.

The most extreme case is where a directionally stable ship also has a large positive trim (ie a large trim by the stern). In such a combined condition, the turning curve will increase dramatically.

Directionally unstable ship

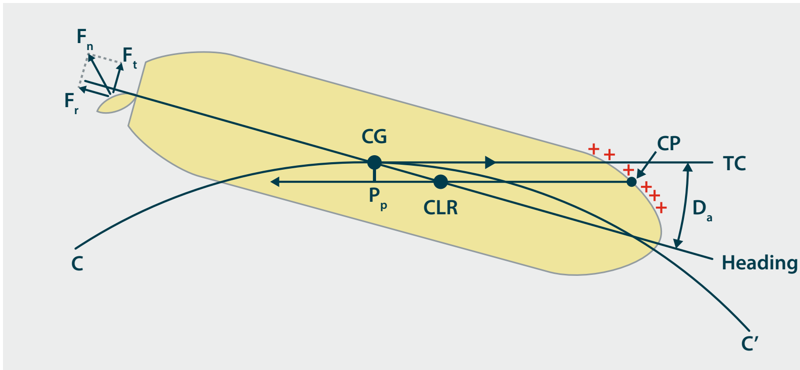

Figure 2.3 – Directionally unstable ship

A ship will be directionally unstable after yawing if the projection of the CLR moves forward of the CG.

If the ship with its rudder amidships experiences a loss of steering, she will not move in a straight-line path. She will tend to move on a zigzag course, deviating erratically from her set course. In this circumstance, the rudder must, therefore, continually be placed on either side of the ship to correct the deviations and prevent swinging.

The turning circle of a directionally unstable ship is proportionally smaller than a directionally stable ship of the same length.

A directionally unstable ship will typically have a full-form hull, particularly in the forward region, and so it is likely to be a tanker or bulk carrier with a high C_b (>0.9). These ships usually respond well to the rudder, but they require a good helmsman in order to remain on course as they will require continuous small rudder angle changes to avoid excessive zigzag movements. When using auto-pilot, the rudder will continually be observed to be adjusted.

A good example of a directionally unstable ship is a ship that has been trimmed by the head.

Directionally neutral ship

When swinging begins, if the CLR coincides with the CG, the ship will start to move on a curved path, even if the rudder is applied amidships, except when there is an external influence that alters the generated couple, such as waves, topography of the bottom or wind.

Such a ship is referred to as being directionally neutral.

A ship with a positive trim will increase her directional stability the more she trims by the stern. This will increase her turning circle. This is only important if the ship is excessively trimmed by the stern, particularly if the bow has a negative draught (ie the bow is clear of the water).

However, on an even keel ship, the trim will depend on the C_b. If the value of C_b is large, it is likely that she will have bad steering and a tendency to be directionally unstable. This may become worse if the ship is trimmed by the bow.

A fine-form hull with a low C_b will generally be directionally stable, even if there is zero trim.

The behaviour of a ship that has an intermediate C_b (~0.7) can only be determined by carrying out trials that have different types of loads and varied trim conditions.

It is generally assumed that a negative trim results in a directionally unstable ship. Ships that have negative dynamic trims will require larger rudder angles for longer periods of time to correct yawing. This makes them difficult to manoeuvre, particularly in restricted waters.

2.2 Influence of Drift Angle (D_a)

The CLR should not be thought of as a fixed point on the ship, even when the dynamic trim is stable, because it also depends on the D_a value.

So why does the directional stability of a ship affect its turning circle when D_a increases?

This is a factor of the distribution of the underwater body volumes forward or aft of the mid-point and the corresponding wetted waterplane surfaces.

The ship will turn due to the couple generated by the F_n that is applied in the geometric centre of the rudder blade, multiplied by the distance (d) from the perpendicular line crossing the CG.

This couple generates the ship's turning moment (T_m), ie the ability to swing.

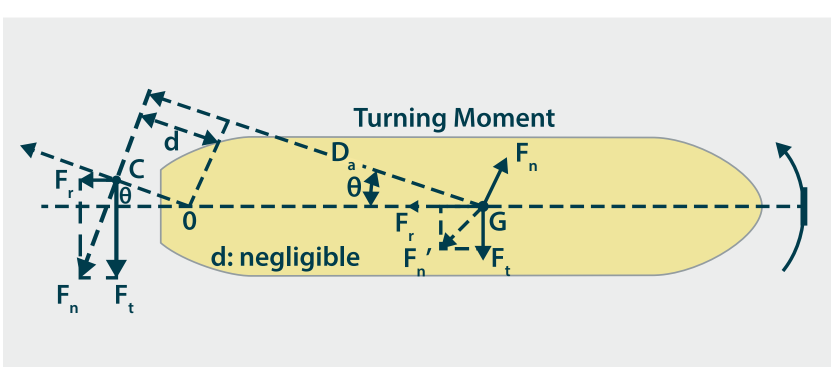

Figure 2.4 – Influence of D_a