“A Paradigm Shift in Shiphandling”
(The Pivot Point)

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Ship-handling vs. Car-driving

The Art of Shiphandling involves the effective use of forces under control to overcome the effect of forces not under control.

(Charles H. Cotter, 1963)
Timsbury Shiphandling Centre
Research Topics in Ship Manoeuvring

- Ship to Ship/Pier Interaction
- Effects of Shallow and Restricted Water
- Bank Effect
- Squat
- Scale Effect
- Hull/Propeller/Rudder Interaction
  - Pivot Point
What does a Shiphandling Training Centre say about the Pivot Point?

“In the one-week basic curriculum, over half the time is spent demonstrating and proving the validity and importance of the concept [of the PP]………”
The Pivot Point: Why needed?

• Knowledge about the **position of the pivot point** in a manoeuvring situation has been a basic requirement for the shiphandler to understand how and why the ship behaves in a certain way.
1. The Pivot Point of a Ship

So what is it?
Surge
(eg. making sternway to a point)
Yaw (accompanied by Sway)
The Pivot Point: Definition

\[ v + (GP \times r) = 0 \]

where, \( v(\text{m/s}) = \) sway speed of \( G \);
\( G = \) Centre of Gravity;
\( P = \) Pivot Point;
\( GP(\text{m}) = \) distance to \( P \) from \( G \);
\( r(\text{rad/s}) = \) yaw Speed.
Turn and Drift

The pivot point moves from P1 to P2.
Where does the PP come from?
(Turn and Drift)
Drift and Turn

The pivot point moves from P1 to P2.
Where does the PP come from? (Drift and Turn)
In Zig-Zag run, the PP disappears into the forward infinity, reappears from the aft infinity, each time the rudder turns.
Why is the PP Concept useful?

Drift + Turn = An Imaginary Turn
(Two Motions $\rightarrow$ One Motion)
2. In the Literature

- Textbooks
- Training Manuals
- Lecture Notes
- Journals
- Conference Proceedings
- Theses
- Magazines
- Web Sites
Nearly Two Centuries ago

“The power of the rudder in steering a ship is augmented in proportion to its greater distance from the centre of rotation (the pivot point).”

The Theory and Science of Naval Architecture

1836
These are still mentioned:

- A point on the centerline about which the ship turns.
- Located at 0.25-0.33L from the bow when moving ahead, and from the stern when moving astern.
These are still mentioned:

- The rudder at the stern is thus more efficient as it is farther away from the pivot point.

- Moves instantly to a third of ship length from the bow.
Commonly seen drawing: Where is it?

**Fig. 1 The Pivot Point**

- a) ship stopped
- b) making headway
- c) making sternway

On Even Keel

| 1/4 L |
Commonly seen drawing: Peripatetic

Fig. 2  Turning Levers and Moments

a) ship stopped

On Even Keel

15 tonne

b) making headway

15 tonne

15 tonne

c) making sternway

Proof of Pivot Point Movement

15 tonne

15 tonne
Yet another: Effect of its Position

Fig. 16 Effect of Wind — with Headway

Fig. 17 Effect of Wind — with Sternaway
The Real Reason is:
Yet another: How is it used?

Fig. 49 Working Astern to a Berth

1

2

3

Peripatetic Pivot Point
What really is a Pivot Point?

The pivot point is a point on a ship’s centreline which appears to be the centre of rotation. (It is the centre of imaginary yaw motion.)
What really is a Pivot Point?

The position of the Pivot Point is irrelevant to the sense of Surge motion.
What really is a Pivot Point?

The Pivot Point can **not** be used as the fulcrum to calculate the turning moment.

It is **not** a fixed point.

It is an **imaginary, geometrical and peripatetic** point.
What really is a Pivot Point?

The Pivot Point comes into existence as a **result** of a ship’s motion. It is **not** the **cause** of motion.
Very commonly seen drawing
What really is a Pivot Point?

It moves **gradually** according to the **gradually** changing aero- and hydro- dynamic environment.

A ship with its huge momentum cannot change the motion in jerky manner unless in contact with a solid or tethered.
The **Real-Life** PP Movement (Marina Class Ship)
What really is a Pivot Point?

- The pivot point is a point on a ship’s centreline which gives the shortest turning circle radius.

- The pivot point is a point on a ship’s centreline at which the drift angle is zero.

- The pivot point is a point on a ship’s centreline whose motion vector is always in the direction of ship’s heading.
Geometrical Consideration
“A Paradigm Shift in Shiphandling” (The Pivot Point)
The Paradigm Shift:

Where is the pivot point?

How do I move it to where I want it to be?
3. Obtaining the Position of PP

The changing positions can be calculated in real time using the transverse displacement of two body points.

This is possible because the PP is a result of the ship’s motion geometry.
Obtaining the Position of PP
How to present the information?

The Pivot Point moves gradually. This means extrapolation into the immediate future is justified. Now the future locations can be shown together with the past and current locations.
- Each length of bar represent one time unit apart.
- Red bars are for the future. These could be animated to flash.
4. How do we control the PP?

Equations for GP:

\[
\left( \frac{F_c}{2\Delta} \right) t^2 = GP \times \left( \frac{F_c \times GF_c}{2I} \right) t^2
\]

where, \( F_c \) = transverse component of the resultant of all applied force, \( GF_c \) = longitudinal displacement of \( F_c \) from \( G \), \( \Delta \) = ship’s mass, \( I \) = second moment of ship’s mass about the vertical axis through \( G \), \( t \) = time taken for the motion.
4. How do we control the PP?

\[ GP = \frac{-1}{V \times GF_{c}} \int r^{2} dV \]

for a solid ship with uniform density.
4. How do we control the PP?

• Negative sign (-) indicates the pivot point appears on the other side of the centre of gravity from the applied force.

• The farther the applied force is, the closer the pivot point will be to the centre of gravity.
The Coordinate System
Some Calculated Results

- Box Barge

\[ y = \frac{B}{2} \left\{ 1 - \left( \frac{2x}{L} \right)^2 \right\} \]

- Wall-Sided Vessel

\[ y = \frac{B}{2} \left\{ 1 - \left( \frac{2x}{L} \right)^2 \right\} \left\{ 1 - \left( \frac{z}{T} \right)^2 \right\} \]

- Wigley Hull.
Some Calculated Results

Assuming Fc at rudder stock, $B = L/7$, $D = L/7$, the results below are obtained.

<table>
<thead>
<tr>
<th></th>
<th>Box Barge</th>
<th>Wall-Sided</th>
<th>Wigley Hull</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_b$</td>
<td>1.0</td>
<td>2/3</td>
<td>4/9</td>
</tr>
<tr>
<td>$I$</td>
<td>0.0017 $L^5$</td>
<td>0.0007 $L^5$</td>
<td>0.0005 $L^5$</td>
</tr>
<tr>
<td>GP</td>
<td>0.1701 L</td>
<td>0.1023 L</td>
<td>0.1016 L</td>
</tr>
<tr>
<td>From Bow</td>
<td>0.3299 L</td>
<td>0.3977 L</td>
<td>0.3984 L</td>
</tr>
</tbody>
</table>
Some Calculated Results

The results show that the bigger the block coefficient \((C_b)\) is, the closer the pivot point will be to the bow.
5. Suggested Training Exercises

Some basic manoeuvres could be included in the training program.
Ship Turning, No Surge, No Sway (ESP)

Point Colors
Black E: Centre of Planar Rotation
Green S: Centre of Bodily Rotation
Red P: Pivot Point
Gap between Hull and Jetty is set to \((B/4)\)m.

Clockwise Time (s) : 1.46
Run Time (s) : 0.46

Graph showing the relationship between different variables.
Ship Turning and Drifting, No Surge, PP between Midship and Bow (ESeP)

Black E: Centre of Planar Rotation
Green S: Centre of Bodily Rotation
Red P: Pivot Point
Yaw and Sway
Ship Turning and Drifting, No Surge, PP ahed of Bow (ESeP)

- Black E: Centre of Planar Rotation
- Green S: Centre of Bodily Rotation
- Red P: Pivot Point
No Surge
Ship Turning and Moving Forward, No Drifting, S and P Coincide (EeSP)

- Black E: Centre of Planar Rotation
- Green S: Centre of Bodily Rotation
- Red P: Pivot Point
Surge, Turn, No Drift

Gap between Hull and Jetty is set to \( \frac{B}{4} \) m.

Run Time (s) : Clockwise Time (s) :
General Planar Motion

Ship Moving Forward and Turning and Drifting, (ESePe)

Black E: Centre of Planar Rotation
Green S: Centre of Bodily Rotation
Red P: Pivot Point
Head, Drift, Turn
Short Round

Pivot Point Posn 1 at G

Pivot Point Posn 2

Pivot Point Posn 3

Pivot Point Posn 4

Pivot Point Posn 5

Pivot Point Posn 6

Pivot Point Posn 8 at G
Entering a Cut
An Example of Actual Manoeuvre

CMA CGM Marco Polo
(L = 396 m, 16020 TEU)
At Southampton Container Terminal

CMA CGM Marco Polo.jpg
The following sequence of screen shots have been taken from the PPU on the departure of the “CMA CGM Marco Polo” from Southampton. The pilots portable unit is an AD Navigation ADX-XR which includes RTK, giving a very precise position. The performance criteria are:

- **Position Accuracy:**
  - 1-2 cm (RTK mode)
  - 0.8 m with EGNOS/WAAS
  - 2 m uncorrected GPS/GLONASS

- **Bow and Stern Speed:** 1 cm/sec (0.02 knots)

- **Vertical/Squat:** 2-3 cm (RTK mode)

- **Heading:** 0.01 deg (20m POD separation)

- **Rate of Turn:** 0.1 deg/min
Minding the PP
Minding the PP
Just Drifting
Just Turning (Smallest Swift Area)
Still conscious of the PP
Future Works

• Safer and More Efficient
  Ship Handling Modules for:
  - the Bridge
  - Remote Control Systems
  - Auto-Pilot Systems
  - Simulation Packages
    (commercial & educational)
If you are interested in further development of this topic, please, contact the author direct.

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