Calculated EEOI improvements using ship energy efficiency methods

Santiago Suarez de la Fuente
John Calleya
Rachel Pawling
Tristan Smith

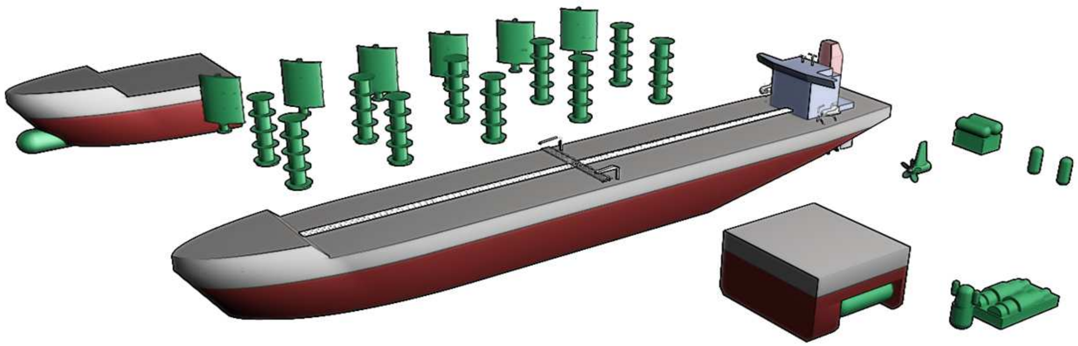


Image created by Rachel Pawling

Contents

- Objectives
- Efficiency Methods
- Calculation process
- Technology combinations
- Results
- Conclusions
- References

Objectives

- To provide state-of-the-art opportunities for reducing the CO_2 emissions for an MR Tanker
- To examine what technical and operational CO_2 emission reduction methods are technically feasible for today's MR Tanker
- To present:
  - a holistic ship design process, and
  - a range of efficiency gains, represented as changes in the EEOI

Efficiency Methods

- An efficiency method is any way of reducing energy consumption on board:
  - This could be by using any technology (or a combination of technologies) and/or by operation
  - Speed reduction is **not** taken as an efficiency method but used as a variable

Electric Turbocompound

[1]

Organic Rankine Cycle

[2]

Efficiency Methods

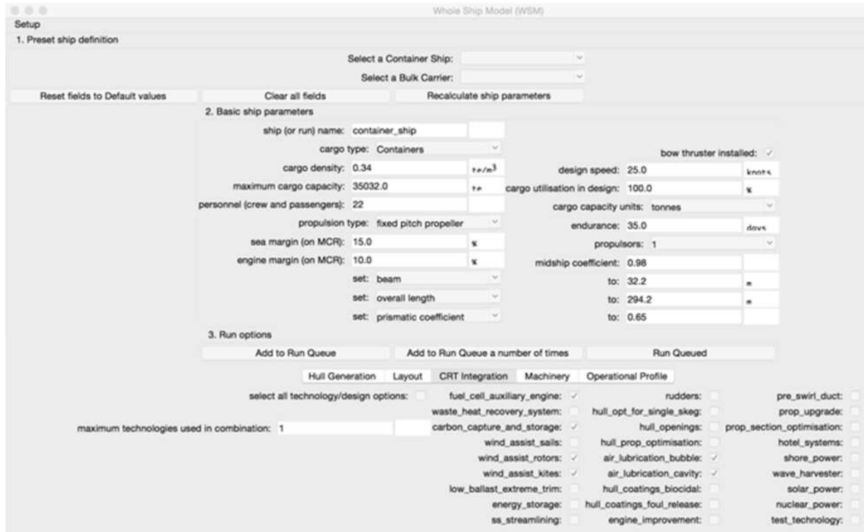
- An efficiency method is any way of reducing energy consumption on board:
  - This could be by using any technology (or a combination of technologies) and/or by operation
  - Speed reduction is **not** taken as an efficiency method but used as a variable
- Refined based on feedback:
  - From work carried out for the Danish Shipowners Association and Lloyd's Register
  - From equipment manufacturers to check the mechanism for the Energy Efficiency

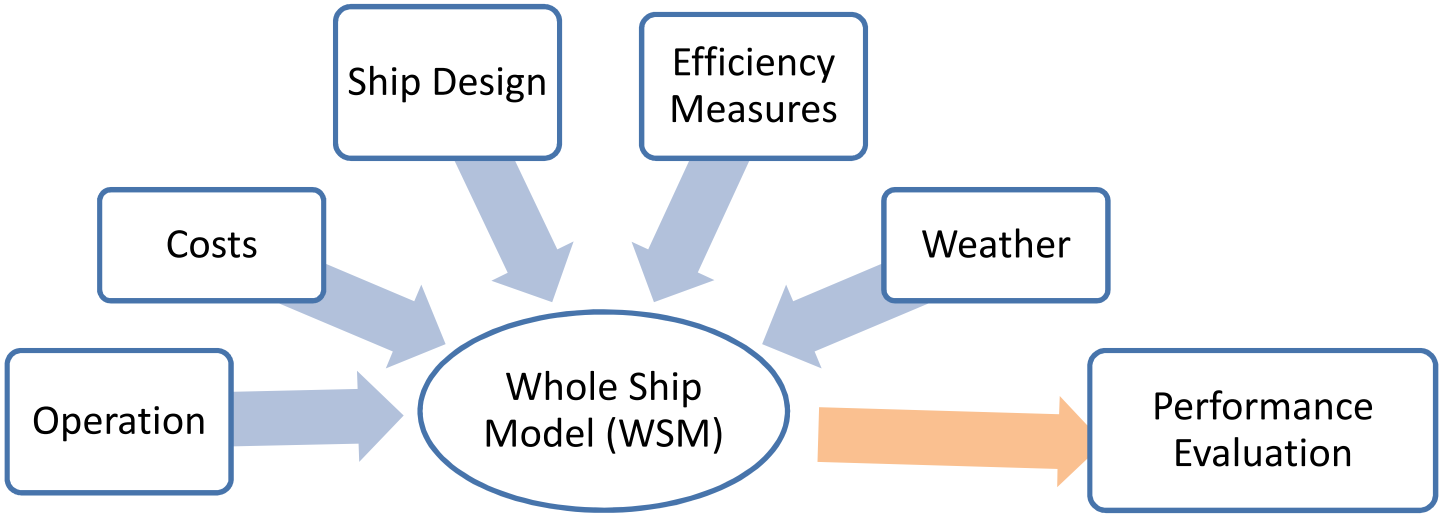
Calculation Process

- Based on physics:
  - Comparisons with sea trials
  - PhD Research
  - Operational Experience
  - Published data (Academic and Industry)
- Secondary effects on ship (engine, propeller, etc.) from efficiency methods are calculated
  - e.g. 2% + 2% ≠ 4%

Calculation process

- Whole Ship Model:
  - Complex sub-models.
  - Both a design process and an operational performance evaluation process.





Calculation process

EEOI and
design speed

From the Third GHG Study
(MEPC 67/Inf. 3, 2014)

Ship specification used (2010):

- **14.8 kn** MR Tanker
- EEOI speed of **11.7 kn**
- 46249 dwt
- Length = 174 m
- Beam = 32 m

[3]

Calculation process

- The baseline ship specifications (without efficiency methods) also include:
  - a 9% fouling and degradation factor
  - bulbous bows and a standard autopilot
  - exhaust gas boiler/economizer
- EEOI was used to measure transport efficiency because it measures actual emissions:

$$Average\ EEOI = \frac{\sum_i \sum_j \left(FC_{ij} \times CF_j\right)}{\sum_i \left(m_{cargo,i} \times D_i\right)}$$

Calculation process

EEOI and design speed

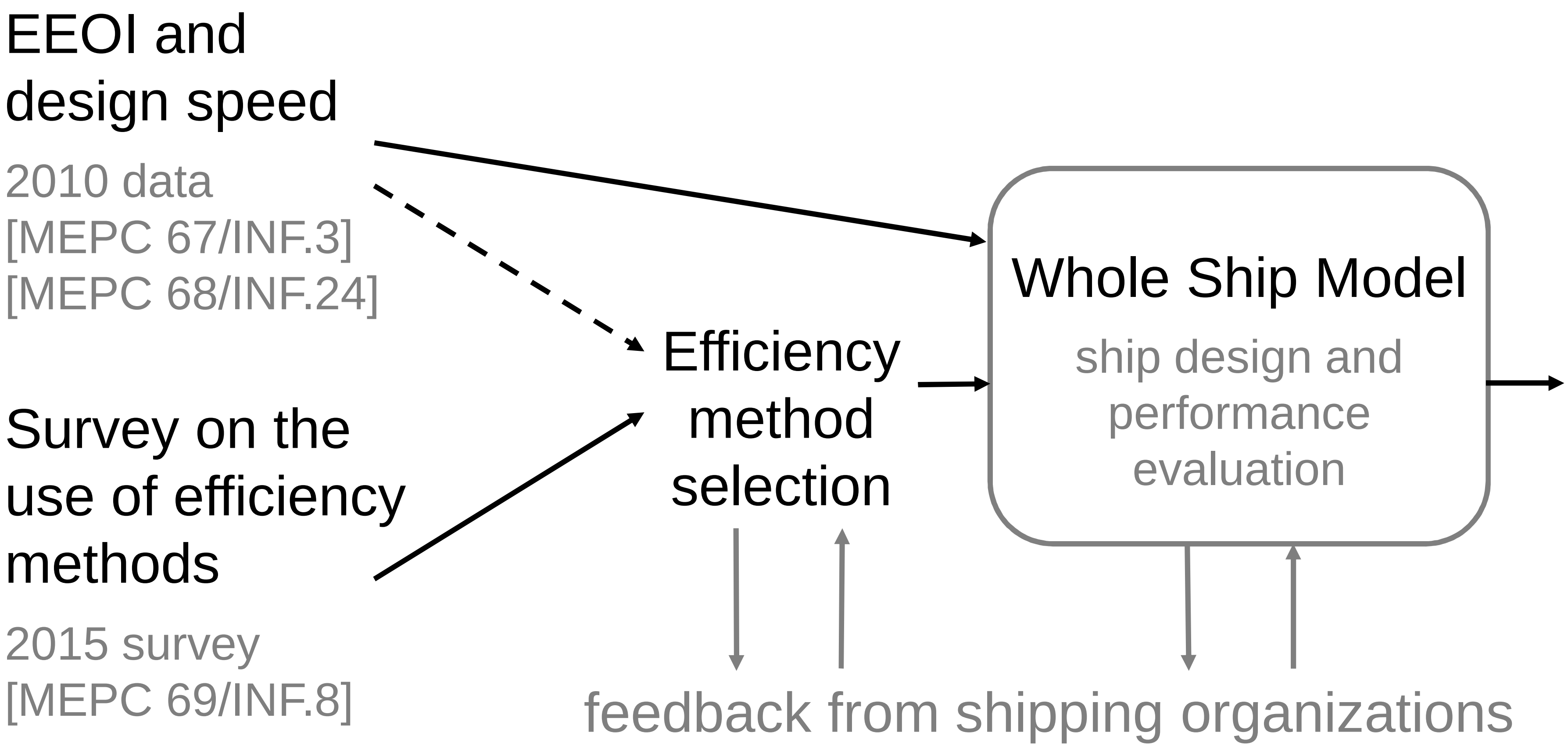
2010 data
[MEPC 67/INF.3]
[MEPC 68/INF.24]

Survey on the use of efficiency methods

2015 survey
[MEPC 69/INF.8]

- Survey of ship owners and operators on energy efficiency measures [4]:
  - Largest of its kind (covering around 5000 ships)
  - Carried out in 2015
- Survey confirmed some preconceptions:
  - Widespread use of bulbous bows, pre/post-swirl devices, engine modifications and waste heat recovery, and,
  - generally, adoption is small.

Calculation process



Technology Efficiency Method combinations

Current technologies combination	Future technologies combination
Rudder Bulb	Contra rotating propeller
End-plated Propeller	
Engine Derating	Engine Derating
Speed control of pumps and fans	Speed control of pumps and fans
Energy saving lighting	Energy saving lighting
WHR Steam	WHR Steam
	WHR Organic Rankine Cycle (ORC)
	WHR series turbocompounding
	High cost hull coating
	Air lubrication
	Block coefficient reduction
	Optimistic Flettner Rotors

Technologies that are not widely used

EEOI Reductions for a MR Tanker

EEOI change due to hydrodynamic and renewable methods (compared to 2010)

70% < $EEOI_{base}$ > 30%

$EEOI_{base}$ < 30%

EEOI Speed

MR Tanker – Hydrodynamic and renewable	Operating Speed (knots)	Baseline	Rudder bulb	Vane wheel	Contra rotating propeller (CRP)	End plated propeller	Air lubrication (AL)	Min. Flettner rotor	Max.Flettner rotor
	4.4	80.2%	80.0%	79.9%	80.9%	80.0%	86.2%	71.3%	73.0%
	5.9	72.0%	71.7%	71.4%	72.8%	71.7%	75.9%	55.5%	57.0%
	8.8	77.6%	77.1%	76.6%	77.6%	77.1%	78.6%	56.5%	49.1%
	9.6	82.6%	82.0%	81.4%	81.9%	82.0%	83.0%	60.5%	52.6%
	10.4	88.0%	87.3%	86.6%	86.5%	87.3%	87.8%	65.0%	56.7%
	11.1	94.2%	93.4%	92.6%	91.7%	93.4%	93.6%	70.4%	61.8%
	11.5	98.1%	97.2%	96.4%	95.0%	97.2%	97.3%	73.8%	65.1%
	11.7	**100.0%**	**99.1%**	**98.2%**	**96.6%**	**99.1%**	**99.1%**	**75.5%**	**66.7%**
	11.8	101.5%	100.6%	99.7%	97.9%	100.6%	100.5%	76.8%	68.0%
	12.6	110.2%	109.2%	108.2%	105.4%	109.2%	108.8%	84.4%	75.3%
	14.1	135.7%	134.3%	133.0%	129.0%	134.3%	133.5%	104.7%	94.7%
	14.8	157.0%	155.4%	153.8%	152.0%	155.4%	154.5%	119.0%	108.0%

EEOI Reductions for a MR Tanker

EEOI change using Waste Heat Recovery (WHR) and machinery modifications (compared to 2010)

MR Tanker – Waste heat recovery (WHR) and machinery modification methods	Operating Speed (knots)	Baseline	WHR steam (conventional)	WHR organic Rankine cycle (ORC)	WHR series turbocompounding	WHR parallel turbocompounding	Engine tuning	Engine derating	Speed controlled pumps and fans
	4.4	80.2%	80.4%	80.2%	76.9%	80.2%	79.6%	79.9%	79.6%
	5.9	72.0%	72.2%	72.0%	69.5%	72.0%	71.4%	71.5%	71.5%
	8.8	77.6%	78.1%	77.6%	76.0%	77.6%	77.0%	76.8%	77.3%
	9.6	82.6%	83.2%	82.6%	81.1%	82.6%	82.0%	81.6%	82.3%
	10.4	88.0%	88.6%	88.0%	86.6%	88.0%	87.3%	86.8%	87.7%
	11.1	94.2%	94.9%	94.2%	92.9%	94.2%	93.4%	92.8%	94.0%
	11.5	98.1%	98.9%	96.6%	96.8%	98.1%	97.3%	96.6%	97.8%
	11.7	**100.0%**	**100.8%**	**98.4%**	**98.7%**	**100.0%**	**99.2%**	**98.5%**	**99.8%**
	11.8	101.5%	102.3%	99.8%	100.2%	101.5%	100.7%	99.9%	101.2%
	12.6	110.2%	107.6%	108.0%	109.0%	107.8%	109.3%	108.5%	110.0%
	14.1	135.7%	132.3%	132.1%	134.6%	132.6%	134.6%	133.4%	135.5%
	14.8	157.0%	153.0%	152.3%	156.0%	153.8%	155.7%	154.3%	156.8%

70% < $EEOI_{base}$ > 30%

$EEOI_{base}$ < 30%

EEOI Speed

EEOI Reductions for a MR Tanker

EEOI change when using block coefficient reduction and combinations of methods (compared to 2010).

70% < $EEOI_{base}$ > 30%

$EEOI_{base}$ < 30%

EEOI Speed

MR Tanker – block coefficient reduction and combinations

Operating Speed (knots)	Baseline	Block coefficient reduction (BR)	Current combination (used in 2015)	Future combination (with CRP, AL, ORC, BR)	Future combination with wind (with CRP, AL, ORC, BC and FR)	Future combination with FR and 25% carbon factor	Future combination with FR and 50% carbon factor	Future combination with FR and 75% carbon factor
4.4	80.2%	79.7%	79.3%	85.7%	70.8%	53.1%	35.4%	17.7%
5.9	72.0%	71.3%	71.0%	74.8%	53.8%	40.4%	26.9%	13.5%
8.8	77.6%	76.1%	76.3%	74.8%	42.7%	32.0%	21.4%	10.7%
9.6	82.6%	80.8%	81.1%	77.7%	45.1%	33.8%	22.6%	11.3%
10.4	88.0%	85.8%	86.3%	81.1%	48.0%	36.0%	24.0%	12.0%
11.1	94.2%	91.5%	92.4%	83.5%	50.1%	37.6%	25.0%	12.5%
11.5	98.1%	95.1%	96.1%	83.7%	50.1%	37.6%	25.1%	12.5%
11.7	**100.0%**	**96.9%**	**97.8%**	**84.7%**	**51.0%**	**38.3%**	**25.5%**	**12.8%**
11.8	101.5%	98.2%	99.2%	85.5%	51.8%	38.8%	25.9%	12.9%
12.6	110.2%	106.2%	103.7%	90.3%	55.9%	42.0%	28.0%	14.0%
14.1	135.7%	129.3%	126.5%	109.3%	68.7%	51.5%	34.3%	17.2%
14.8	157.0%	148.3%	146.1%	131.4%	79.5%	59.7%	39.8%	19.9%

Efficiency methods for a MR Tanker

- For this particular ship at the EEOI speed:
  - A **2.2%** reduction in EEOI from combining 6 technologies that are currently in use.
  - A **15.3%** reduction in EEOI from combining 11 possible future technologies.
  - This is potentially **49%** if Flettner rotors are included.
  - An additional **3.1%** reduction in EEOI was found from operational methods (e.g. propeller polishing and hull cleaning).

Designing ships to particular speeds and conditions

- Ships in 2010 were designed for a higher design speed, but operated at lower speeds.
- As ships operate away from their design point the efficiency of the ship and efficiency methods change:
  - For example, a conventional WHR plant is only effective close to the its design point, and
  - Hydrodynamic efficiency methods may at low speeds increase the ship resistance.

Conclusions

- Assuming that the same operational EEOI speed is maintained:
  - **2.2%** reduction is achieved from technologies in use in 2015
  - **15.3%** reduction is possible from additional technologies available at the moment
  - Higher EEOI reductions require the use of wind energy and/or fuels with a lower carbon factor (electrification, bioenergy or synthetic fuels). The EEOI becomes **87.2%** (75% reduction in carbon factor) from the 2010 levels

Efficiency method decision tool
with IMO paper data is at:

www.efficientshipdesign.com

The Danish Shipowners study
was carried out by U-MAS

http://www.u-mas.co.uk

Image from Hans Otto Kristensen, CONTAZ units, Contra Rotating Propellers

Thank you

Questions?

Contact Details

Email: santiago.fuente.11@ucl.ac.uk

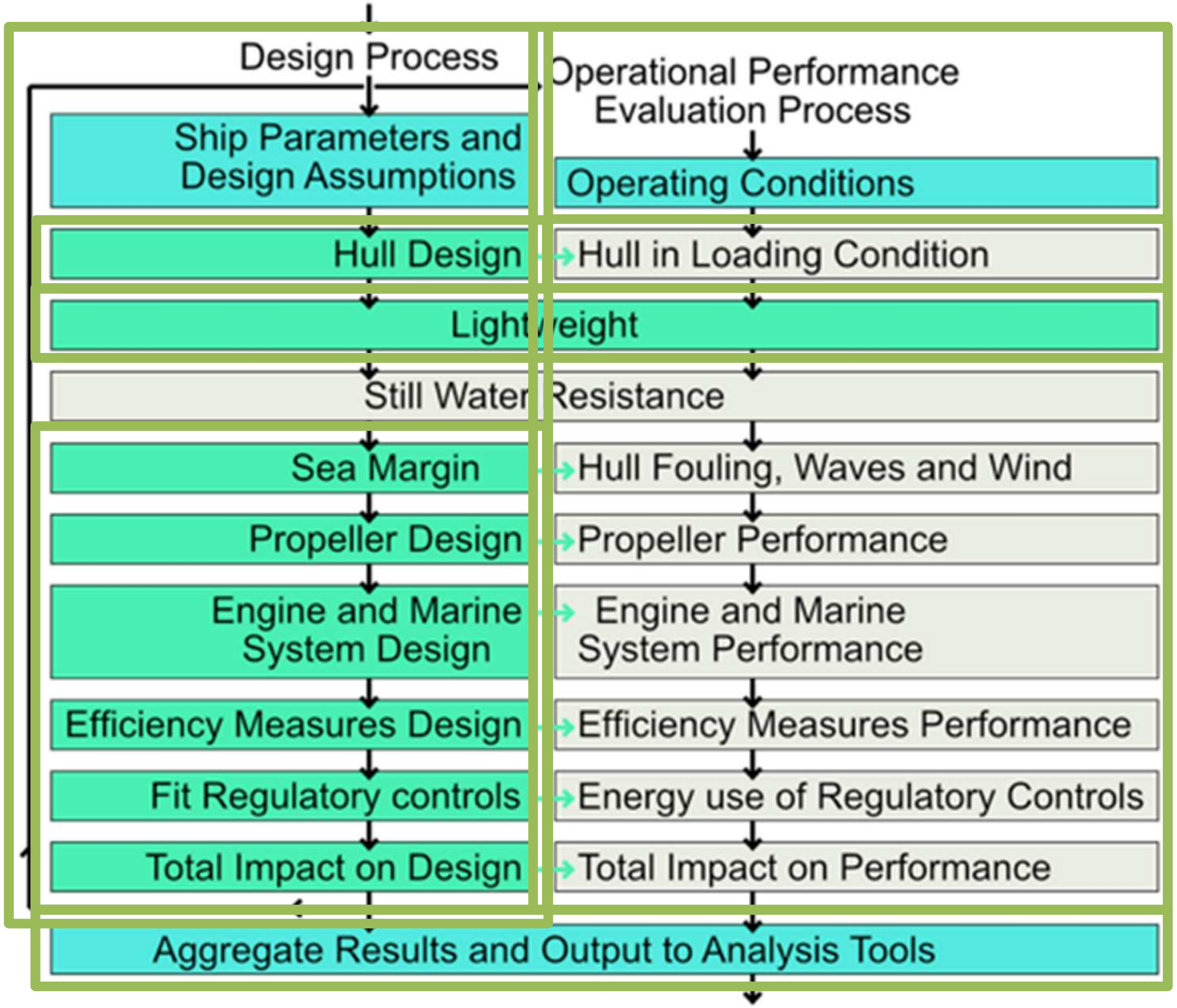
Linkedin:
Uk.linkedin.com/in/santiagosuarezdlf

Twitter: @wholeshipmodel

References

- [1]http://www.decentralized-energy.com/articles/print/volume-14/issue-6/features/making-gensets-greener-and-leaner.html
- [2]http://primeserv.man.eu/service-solutions/products-solutions/upgrades/primeserv-green/waste-heat-recovery-by-orc-(organic-rankine-cycle)
- [3]http://worldmaritimenews.com/archives/171731/ten-mr-tanker-newbuildings-for-oman-shipping-company/
- [4] Rehmatulla, N & Calleya, J 2016, 'The implementation of technical energy efficiency measures in shipping', MEPC 69 INF.8, Submitted by Institute of Marine Engineering, Science and Technology (IMarEST) and the Royal Institution of Naval Architects (RINA), London.

Modelling Process - Whole Ship Model

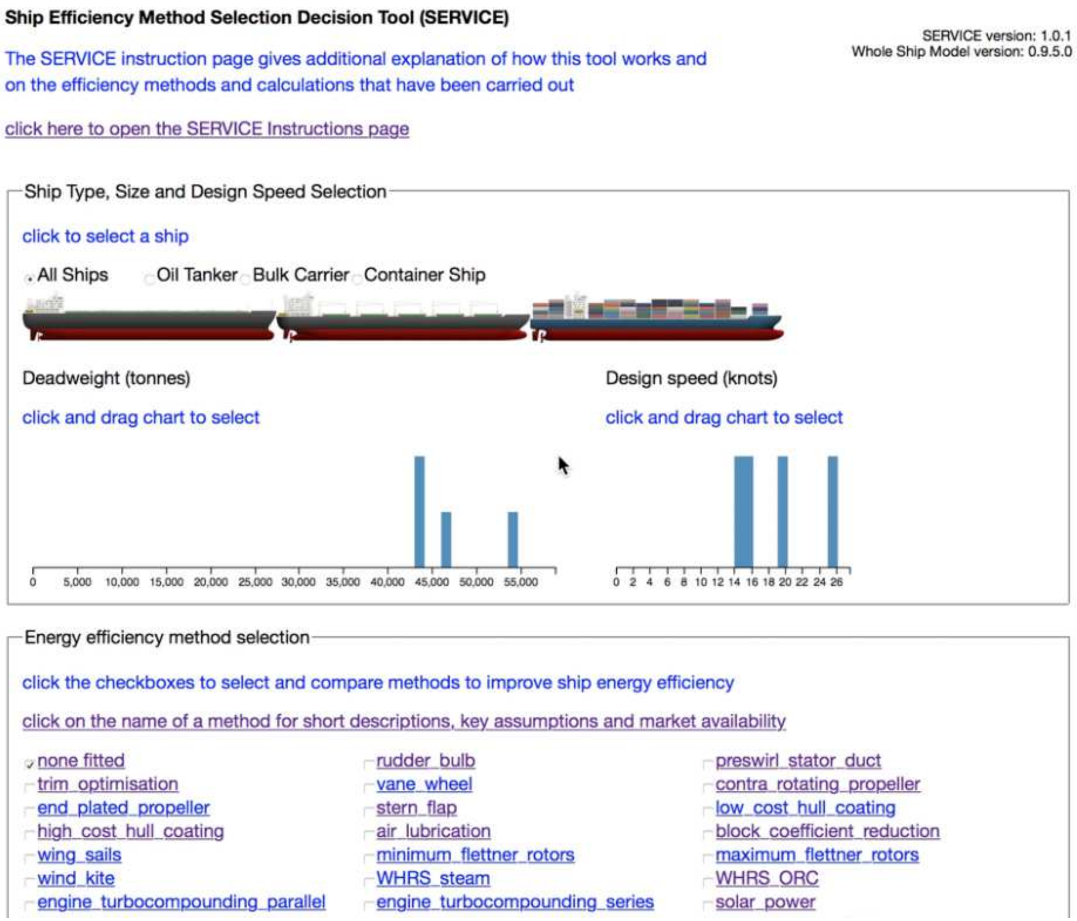


efficientshipdesign.com

Efficiency method decision tool with IMO paper data is at: www.efficientshipdesign.com

- This includes a cost and profit calculator for a range of efficiency methods and operating speeds
- click on each efficiency method for an explanation

Efficiency method decision tool was funded by a UCL Impact Acceleration Award and was developed with the Sustainable Shipping Initiative.



Modelling Process - Whole Ship Model