DEDS Winter School Presentation

ESR#2.4 Analytic Operators for Trajectories

8 March 2023

Song WU

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Agenda

Current Status

Research Progress: Comparison of Vessel CO_2 Emission Models
- Motivation
- Framework Design
- Model Analysis
- Experiments

Next Steps

Current Status: where & progress

Relocation

- 1st year: ULB, 1 Sep 2021 - 31 Aug 2022
- 2nd year: AAU, 1 Sep 2022 - present

Research Output

- one 6-page workshop paper at the MDM'2022 conference
- one 10-page research paper submitted to MDM'2023 conference

Current Status: courses

Activity	At	ECTS	Type	Status
Introduction to the PhD Study	AAU	0.5	General	completed
Applying the Danish Code of Conduct for Research Integrity to your Research	AAU	1	General	completed
Academic Writing in English	AAU	2.5	General	on-going
Writing and Reviewing Scientific Papers	AAU	3.75	General	on-going
Data quality management	AAU	2	Project	planned
Understanding theory of science	AAU	2	General	planned
Professional Communication	AAU	2.5	General	planned
Winter School (ARC)	ARC	3	General	completed
Summer School (ULB)	ULB	3	Project	completed
Winter School (AAU)	AAU	3	General	on-going
Summer School (UPC)	UPC	3	Project	planned
Conference attendance	T.B.D.	6	Project	planned

Total: 32.25; Project: 14; General: 18.25.

Comparison of Vessel CO_2 Emission Models

Motivation

some facts:

- About **90%** of global trade is fulfilled by shipping.
- In 2018, shipping CO_2 emissions were estimated to be **1,056 million tons** by IMO [8].

motivation:

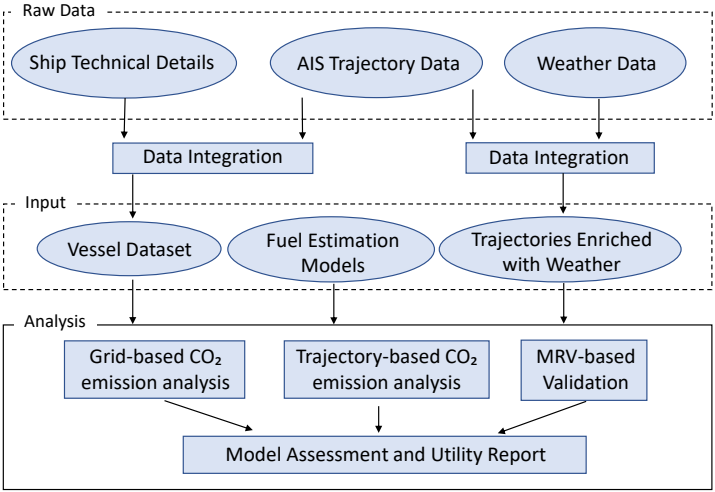
accurate estimation of shipping CO_2 emissions is important for developing regulations to combat greenhouse effect.

research gap:

- None of the review studies [1, 10, 9] conducts a quantitative comparison of different models.
- The comparative studies [6, 7] are restricted to a small area near the Strait of Gibraltar.

Comparison of Vessel CO_2 Emission Models

Framework Design



Comparison of Vessel CO_2 Emission Models

Model Analysis

Currently, five models are considered in our framework.

- **Baseline**: assumes a certain amount of CO_2 are emitted per metric ton of cargo per kilometer of transport, 3 grams CO_2 / (ton · km) [2].
- **GrossTonnage [5]**: The daily fuel consumption C is linearly related to the gross tonnage of a ship, and the CO_2 emissions per ton of fuel depends on operation mode.
- **SpeedCubic [3]**: speed is considered, and the emission factor (gCO_2/kWh) depends on engine type and fuel type.
- **IMO [8]**: speed and draught are considered. The emission factor (gCO_2/kWh) depends on engine type/load/generation and fuel type.
- **STEAM [4]**: speed is considered. A speed penalty is added based on wave conditions.

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Comparison of Vessel CO_2 Emission Models

Model Analysis

summary of required input by the five models

Models	TPC	DWT	D	P	S	GT	RPM	Year	Length	Beam	Wave
Baseline	✓	✓	✓								
GrossTonnage					✓	✓					
SpeedCubic				✓	✓		✓				
IMO			✓	✓	✓		✓	✓			
STEAM				✓	✓				✓	✓	✓

TPC: tons per centimeter
D: maximum draught
S: maximum speed
RPM: revolutions per minute

DWT: deadweight
P: maximum power
GT: gross tonnage

Comparison of Vessel CO_2 Emission Models

Experiments: datasets

AIS data

One-month data from May 2022 was downloaded from the Danish Maritime Authority[1].
41,024,724 records from 1,571 cargo ships were used.

Ship Technical Details

Public information in six websites were collected.
① BalticShipping ② Bureau Veritas ③ FleetMon
④ MarineTraffic ⑤ ShipAtlas ⑥ VesselTracker

Wave Data (wave height and direction)

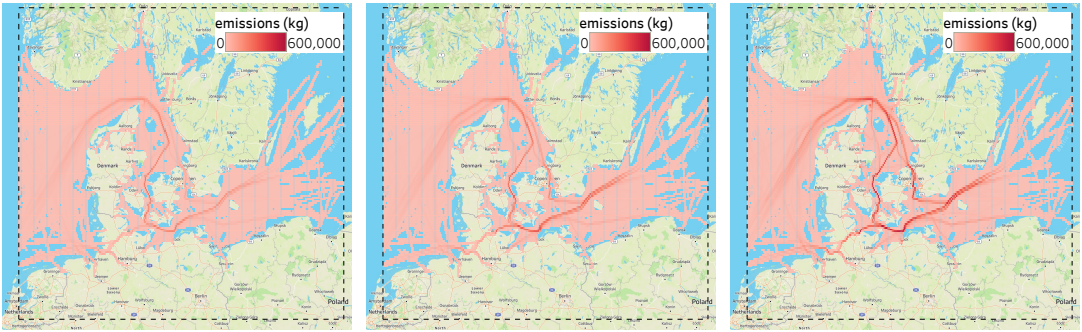
Two products were used from the Copernicus Marine Service.
- Baltic Sea[2]: spatial res. 1nm $\times$ 1nm ; temporal res. 1 hour
- North Sea[3]: spatial res. 3km $\times$ 1.5km ; temporal res. 1 hour

[1] https://web.ais.dk/aisdata/
[2] https://goo.by/FKzLj
[3] https://goo.by/vPwnP

Comparison of Vessel CO_2 Emission Models

Experiments: grid-based analysis

The area of interest in divided into 0.05° by 0.05° grids



(a) Baseline (b) IMO (c) GrossTonnage

Figure: Spatial distribution of CO_2 emissions by each model

Comparison of Vessel CO_2 Emission Models

Experiments: grid-based analysis

Comparison of absolute emissions by each model

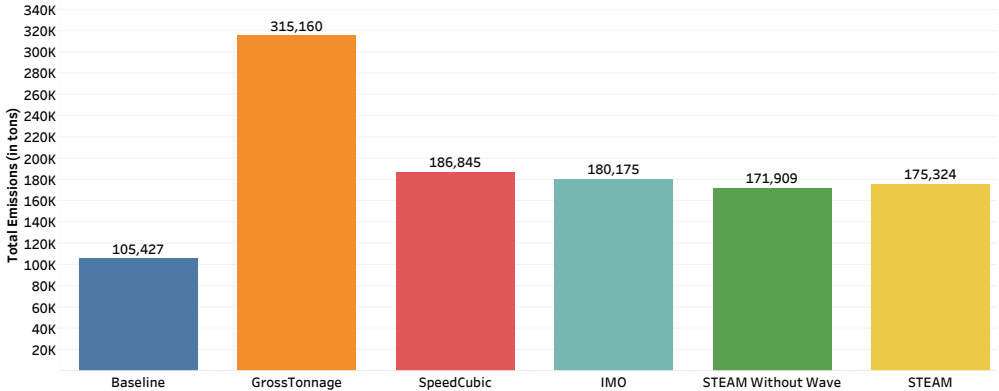
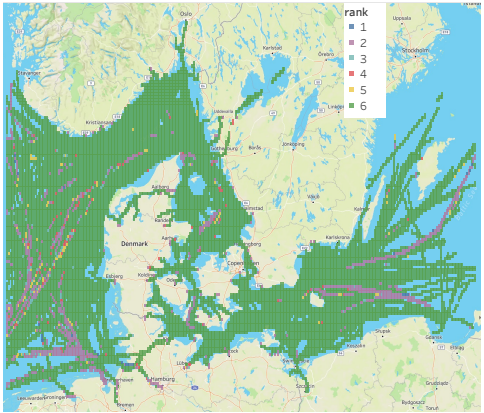


Figure: Total CO_2 emissions of the 1,571 ships by each model

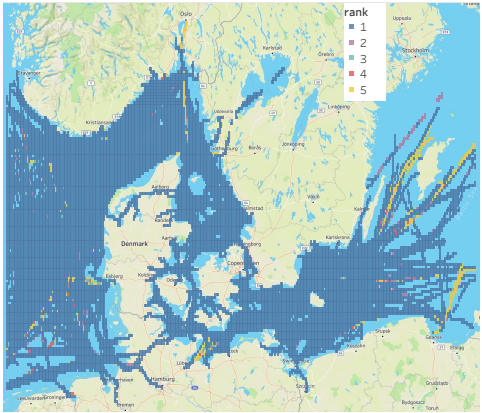
Comparison of Vessel CO_2 Emission Models

Experiments: grid-based analysis

Grid-level ranking of each model: "1" highest ("6" lowest) emissions



(a) Baseline

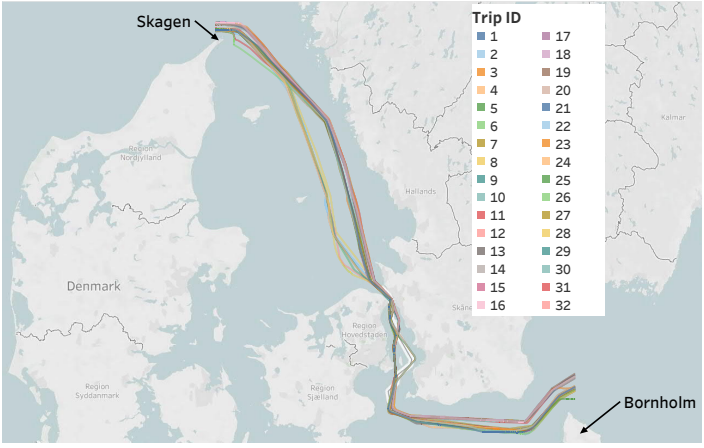


(b) GrossTonnage

Comparison of Vessel CO_2 Emission Models

Experiments: trajectory-based analysis

32 trips are selected travelling between Skagen and Bornholm



Comparison of Vessel CO_2 Emission Models

Experiments: trajectory-based analysis

Statistic of the 32 trips

min. / avg. / max. length (km)	482.56 / 490.92 / 504.66
min. / avg. / max. duration (hours)	15.7 / 20.5 / 25.4
min. / avg. / max. passing speed (knots/hour)	10.39 / 13.14 / 16.88

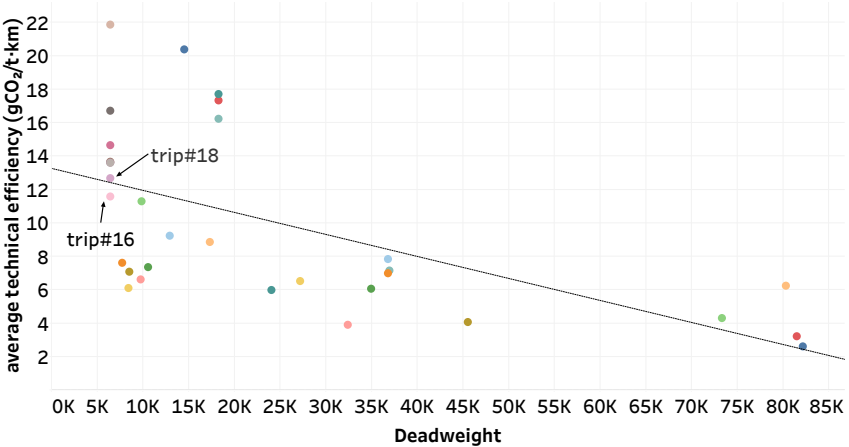
Equivalent CO_2 efficiency for each trip

$$E_{CO_2,i} = \frac{CO_{2\_IMO}}{Cargo_i * Length_i}, 1 \leq i \leq 32$$

Comparison of Vessel CO_2 Emission Models

Experiments: trajectory-based analysis

Equivalent CO_2 efficiency of the 32 trips



Comparison of Vessel CO_2 Emission Models

Experiments: trajectory-based analysis

trip#16 and trip#18 by the same ship (*DWT* = 6,410 t, *S* = 19 knots/h)

	trip#16	trip#18
length (km)	489.8	489.6
avg. passing speed (knots/hour)	13.17	14.15
CO_2 emissions (kg)	36,372	39,798
CO_2 efficiency ($gCO_2/t{\cdot}km$)	11.58	12.68

A 5.2% decrease in speed leads to a 8.7% increase in CO_2 efficiency

- it suggests that shipowners can probably improve CO_2 efficiency of their fleet by speed optimization.

Next Steps

Research Plan
1 to 2 publications on trajectory similarity measures

Secondment
1 June 2023 - 31 August 2023 at MarineTraffic, in Athens

Relocation
return to ULB on 1 Sep 2023

Thank for your attention! Feel free to ask any questions.

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DENMARK

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