International Maritime Statistics Forum

IMSF 2022 Meeting

Estimating, Modelling and Forecasting Shipping Emissions in Ports

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By

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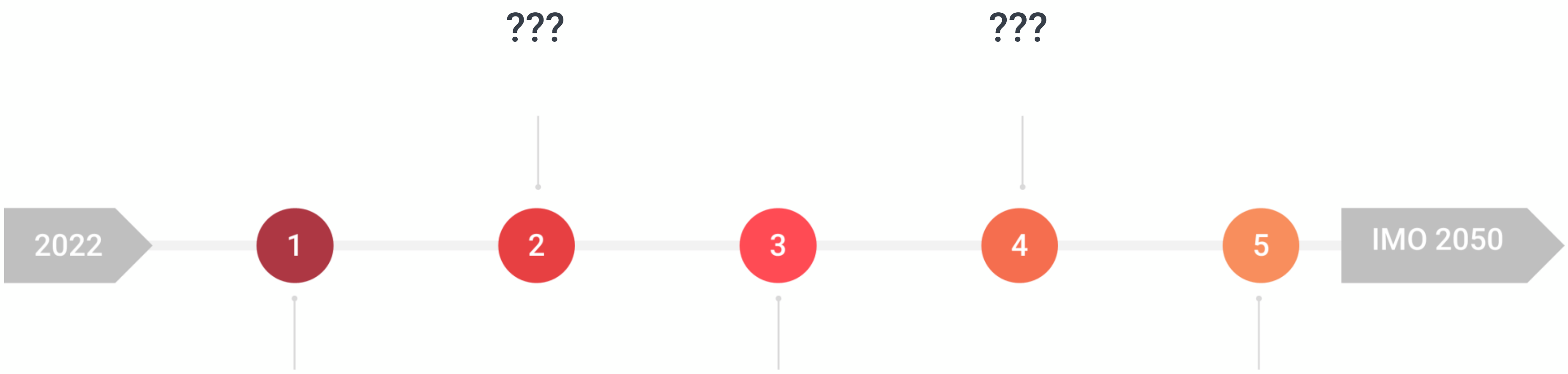
Agenda

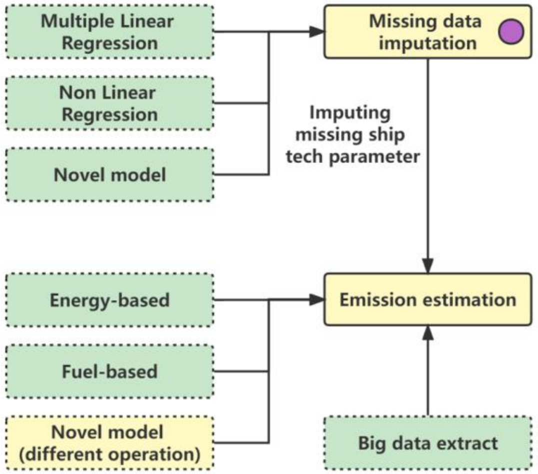
- Motivation
- Our research framework
- Emissions reporting by leading companies
- The mission data problem and solution
- The emissions estimation accuracy problem and solution
- Discussion

Is the IMO 2050 target realistic?

How can we use a data science approach to answer this question?



Accurate Estimates



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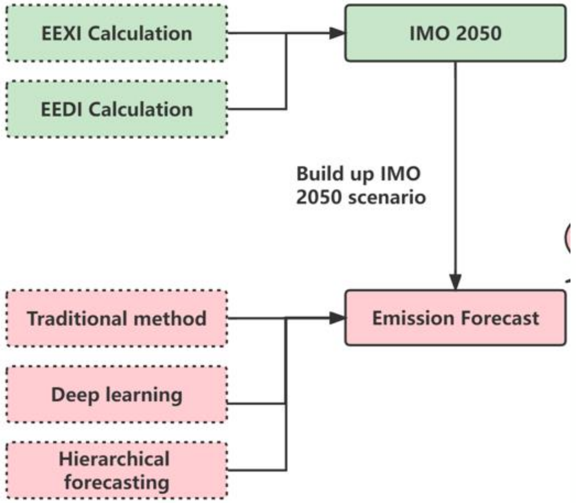
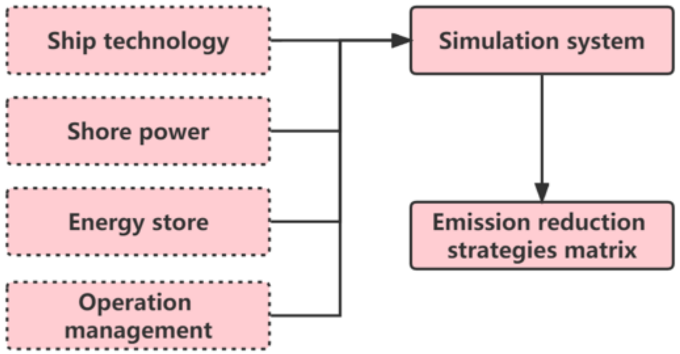


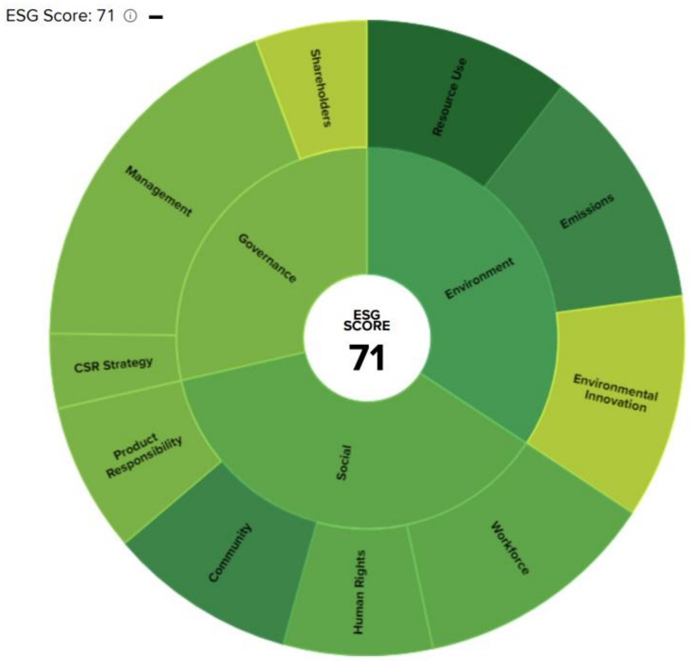
Forecast Scenarios

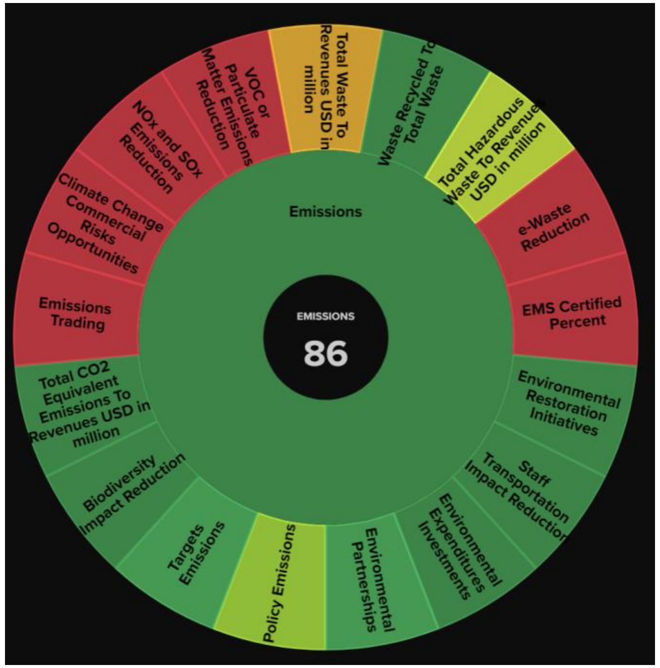


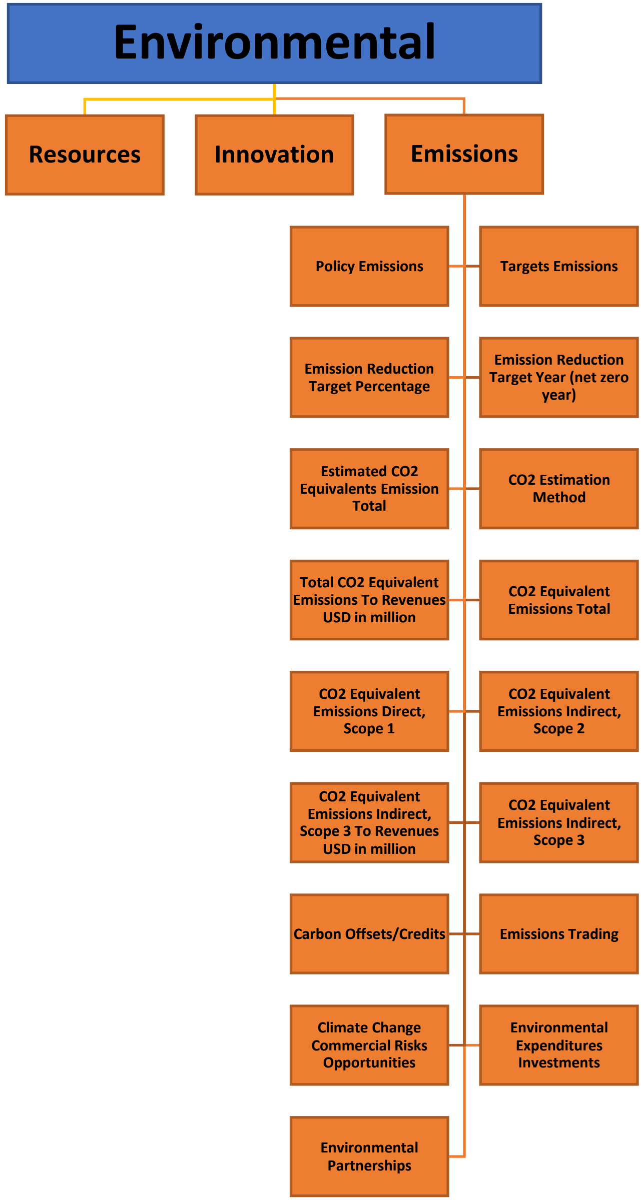
Emissions reporting by leading companies

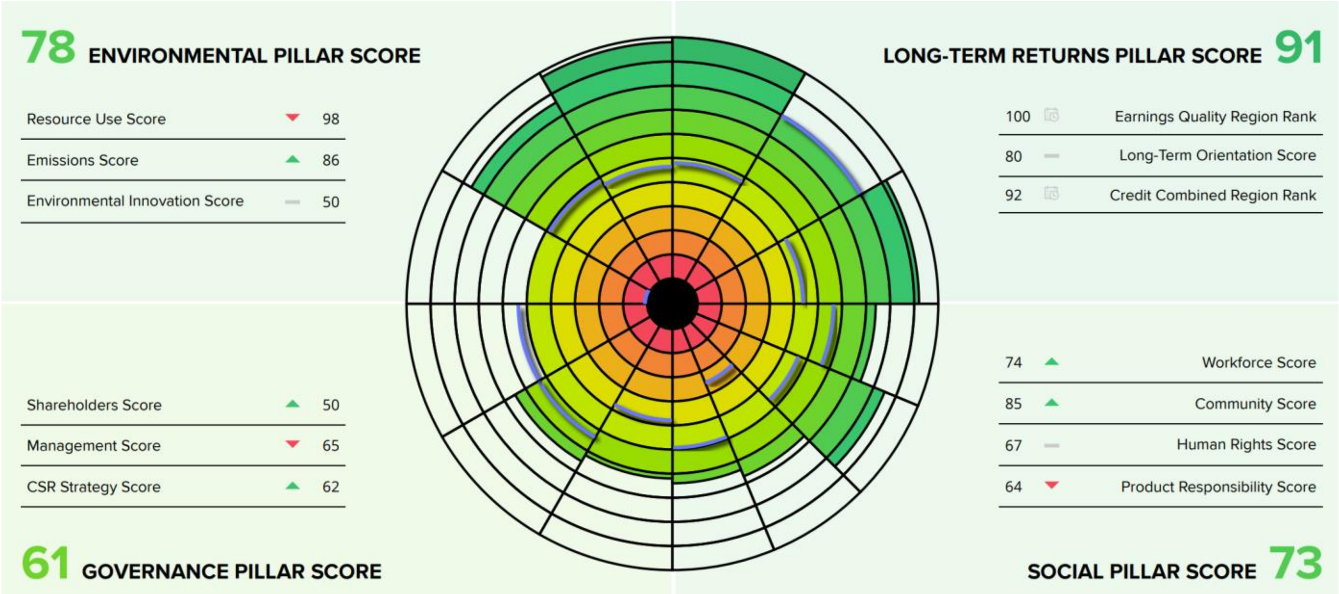
Environmental, Social, and Governance

KUEHNE UND NAGEL INTERNATIONAL AG

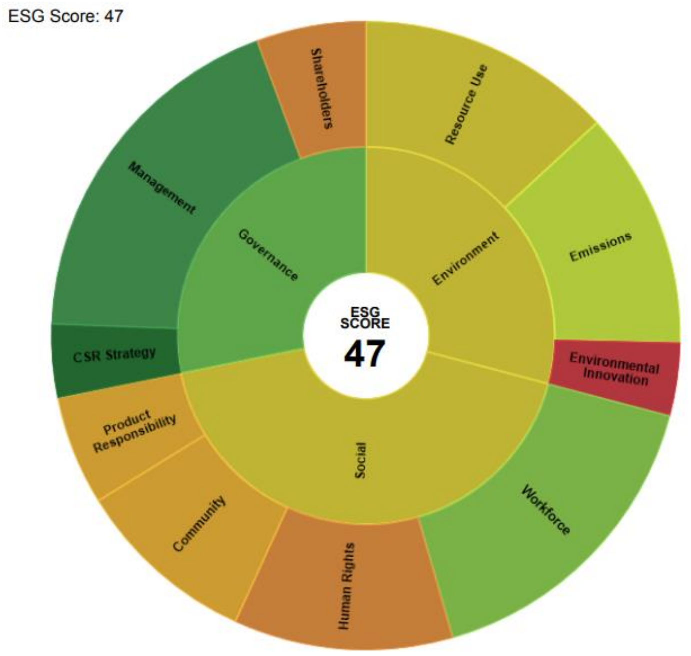


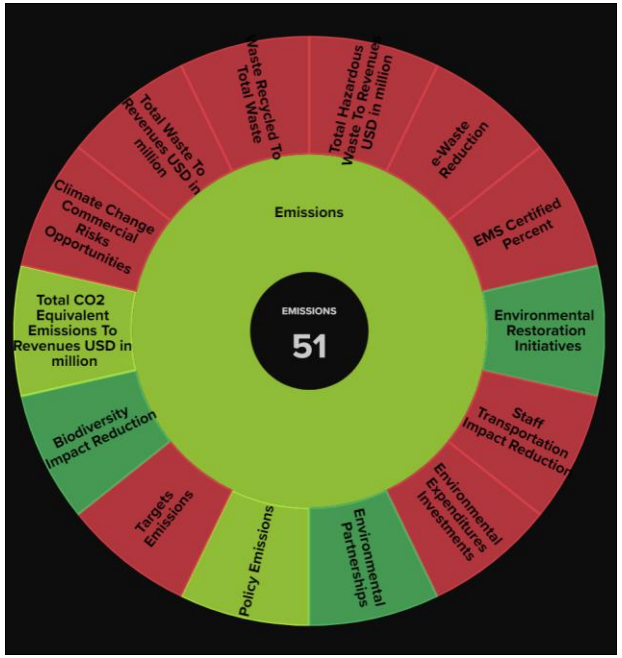


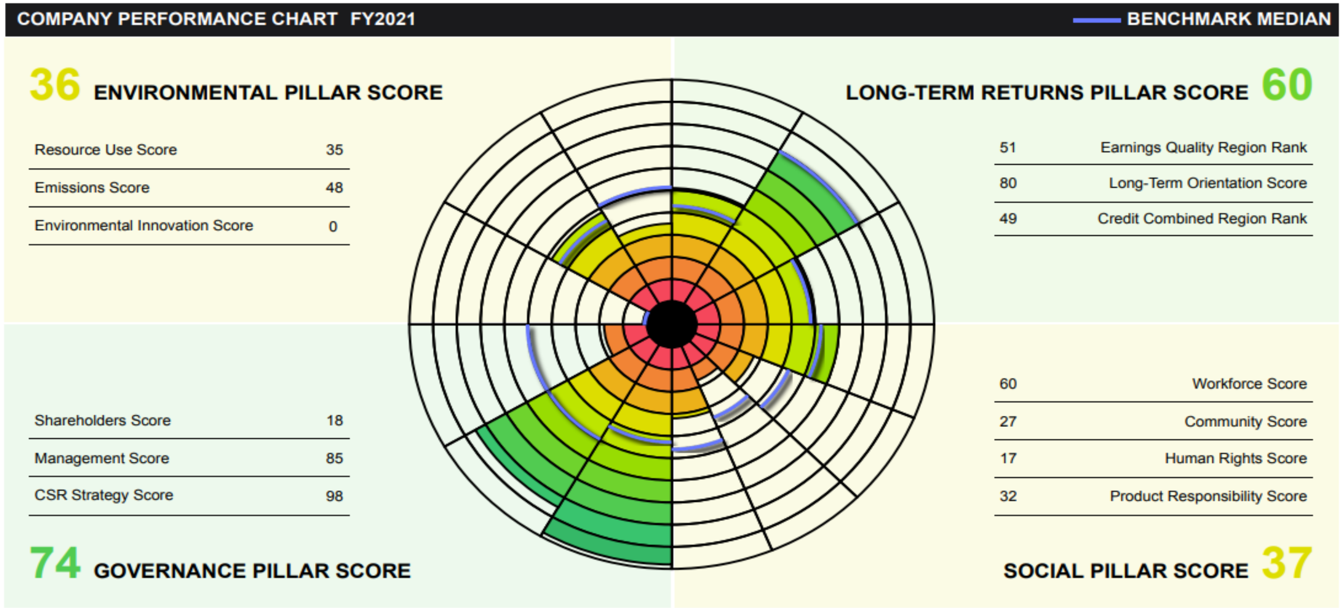


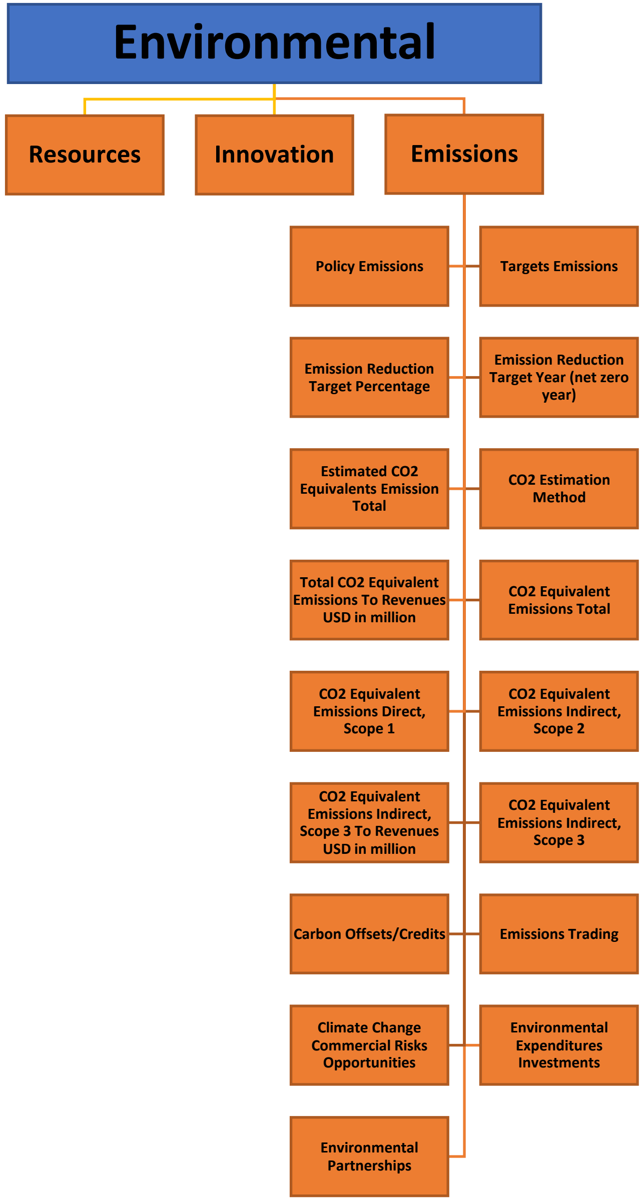


Shanghai International Port Group CO LTD









Missing Data

What does the literature say?

Source	Segment focus	Sample size	Method	Input parameter	Input parameter number	Output parameter	Benchmark	Method of Accuracy valid
Kim et al. (2022)	Container	6278 containers	curve fit + Backward linear regression	Basic + Advanced	7-13	Basic + Advanced	2: Abramowski et al., (2018)/ Random Forest	MSE, MAE, RMSE, R-squared, Adjusted R-squared
Cepowski and Chorab (2021)	Container	215 containers	multiple nonlinear regressions with randomly searched functions	Basic + Speed	3	Basic	2	RMSE, Correlation coefficient
Cepowski (2019a)	Tankers, Bulkers, Containers	1710 tankers, 1248 bulkers 442 containers	multiple nonlinear regressions	Basic + Speed	2	Advanced: ME power	2: Piko (1980); Żelazny (2015)	SE, R-squared
Cepowski (2019b)	Tanker	1723 tankers	multiple nonlinear regressions + group	Basic + Speed	2	Basic	3: Piko (1980); Kristensen (2012); Papanikolau (2014)	SE
Gurgen et al. (2018)	Chemical Tanker	100	artificial neural network	Basic + Speed	2	Basic	No benchmark	MAPE, Correlation coefficient
Abramowski et al. (2018)	Container	3573	multiple nonlinear regressions	Basic	2	Basic + Advanced: ME power / Speed	No benchmark	SE, R-squared
Adam Charchalis (2014)	Container	17	linear regression	Basic	2	Advanced: ME power	No benchmark	SE
Adam Charchalis (2013)	Tankers, Bulkers, Containers	14	linear regression	Basic	1	Basic	No benchmark	SE
Abramowski (2013)	Tankers, Bulkers, Containers	3200	artificial neural network	Basic + Speed	6	Advanced: ME power	No benchmark	Absolute error, Relative error, Correlation coefficient

Source	Segment focus	Sample size	Method	Input parameter	Input parameter number	Output parameter	Benchmark	Method of Accuracy valid
Our research	Bulkers	17980 tankers, 12374 bulkers 7664 containers	nonlinear regressions + forward linear regression	Basic	4	Advanced	4: IMO 2021; IMO 2020; Cepowski, (2019); Abramowski et al., (2018)	RMSE, MAE, Adjusted R-squared
Kim et al. (2022)	Container	6278 containers	curve fit + Backward linear regression	Basic + Advanced	7-13	Basic + Advanced	2: Abramowski et al., (2018)/ Random Forest	MSE, MAE, RMSE, R-squared, Adjusted R-squared
Cepowski and Chorab (2021)	Container	215 containers	multiple nonlinear regressions with randomly searched functions	Basic + Speed	3	Basic	2	RMSE, Correlation coefficient
Cepowski (2019a)	Tankers, Bulkers, Containers	1710 tankers, 1248 bulkers 442 containers	multiple nonlinear regressions	Basic + Speed	2	Advanced: ME power	2: Piko (1980); Żelazny (2015)	SE, R-squared
Cepowski (2019b)	Tanker	1723 tankers	multiple nonlinear regressions + group	Basic + Speed	2	Basic	3: Piko (1980); Kristensen (2012); Papanikolau (2014)	SE
Gurgen et al. (2018)	Chemical Tanker	100	artificial neural network	Basic + Speed	2	Basic	No benchmark	MAPE, Correlation coefficient
Abramowski et al. (2018)	Container	3573	multiple nonlinear regressions	Basic	2	Basic + Advanced: ME power / Speed	No benchmark	SE, R-squared
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A novel method for missing data imputation

Code	Name	Description
Name	Ship name	A proper noun chosen at the shipowner's discretion
ID	IMO number	The seven-digit number of the IMO ship identification number assigned to all ships when constructed.
TYP	Ship Type	The classification of ship
STYP	Ship Sub-Type	The sub classification of ship
SSTYP	Ship Sub-Sub-Type	The sub-sub classification of ship
DWT	Dead weight tonnage	Deadweight tonnage is a measure of how much weight a ship is carrying or can safely carry.
GT	Gross Tonnage	Gross tonnage is a nonlinear measure of a ship's overall internal volume.
LOA	Overall Length	Overall Length refers to the maximum length of a vessel from the two points on the hull measured perpendicular to the waterline.
Beam	Beam	The beam of a ship is its width at the widest point.
Draft	Draught	The draft or draught of a ship's hull is the vertical distance between the waterline and the bottom of the hull
Cubic	Cubic Capacity	Cubic capacity in cubic meters, the total capacity of goods a vessel can handle in its holds or tanks.
Speed	Service Speed	The average speed maintained by a ship under normal load and weather conditions
MEP1	Main Engine Power 1	The total power supplied by the main engine installed on a ship (Data source 1)
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MEP	Main Engine Power mixed	The total power supplied by the main engine installed on a ship (All data source)
MER	Main Engine Rpm	The revolutions per minute of main engine
MEY	Main Engine Built Year	The year in which main engine was constructed
AEP	Auxiliary Engine Power	The total power supplied by the auxiliary engine installed on a ship
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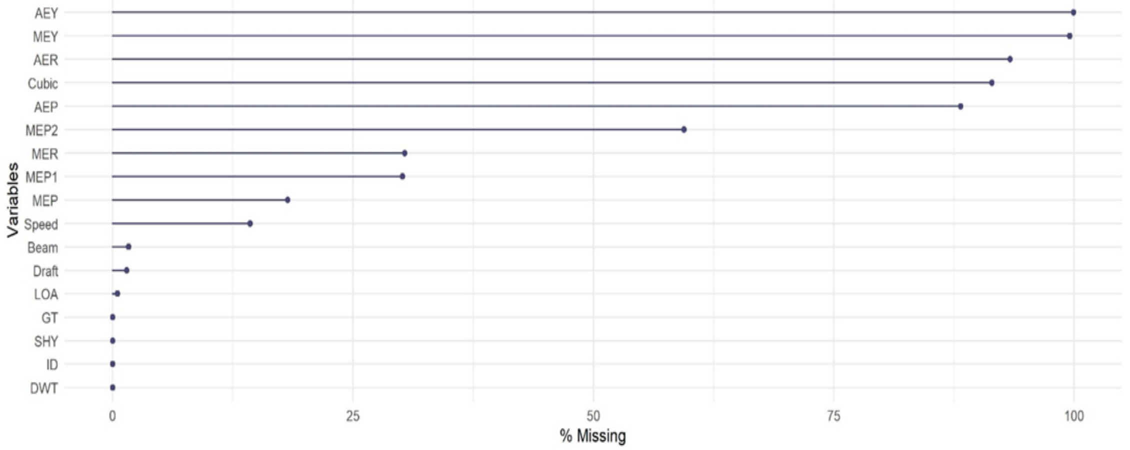

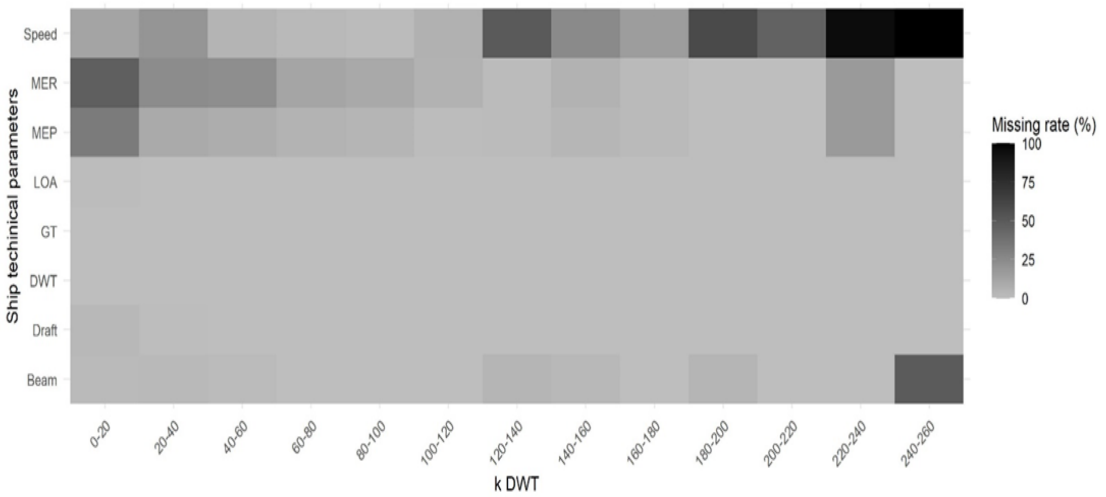

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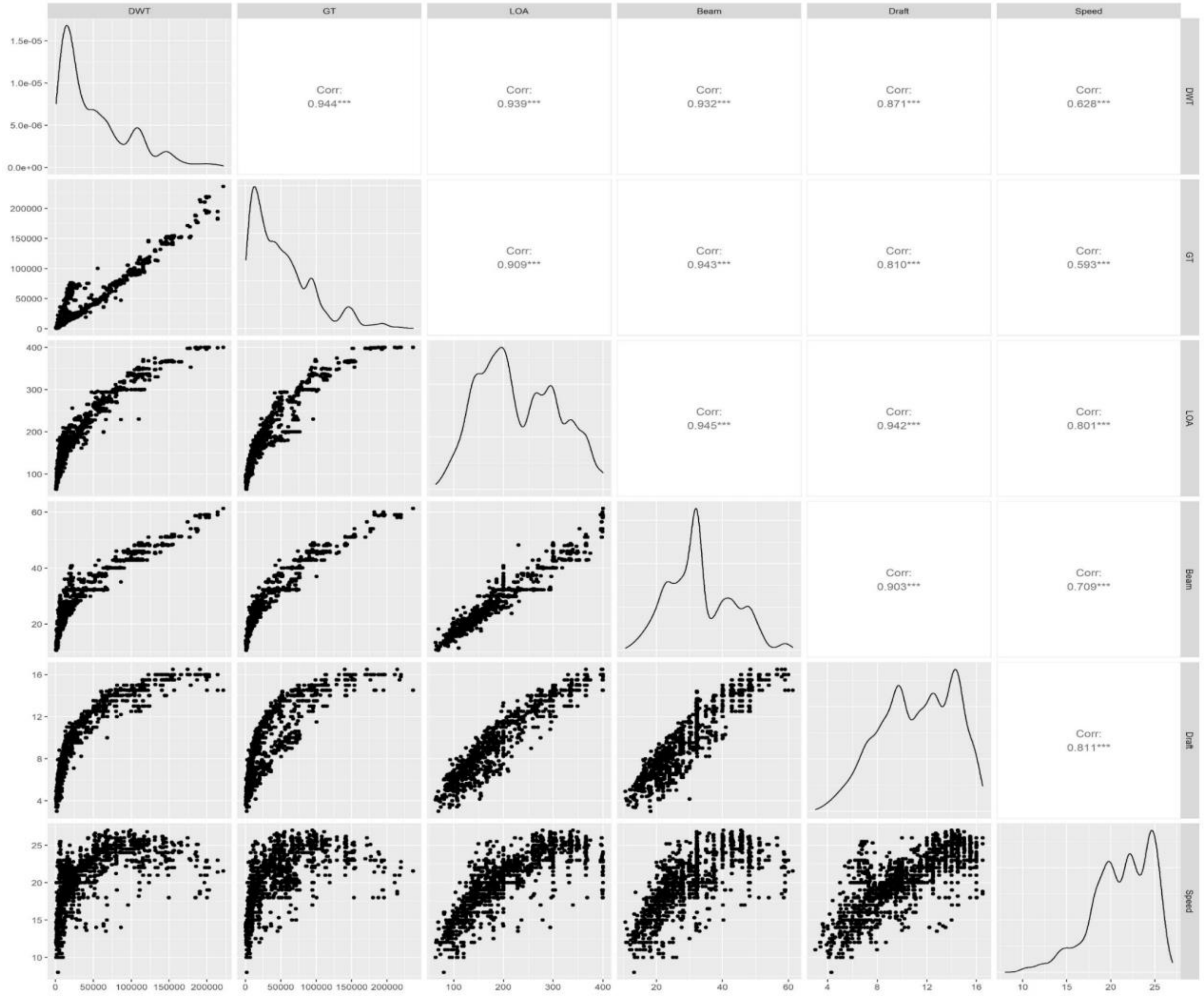

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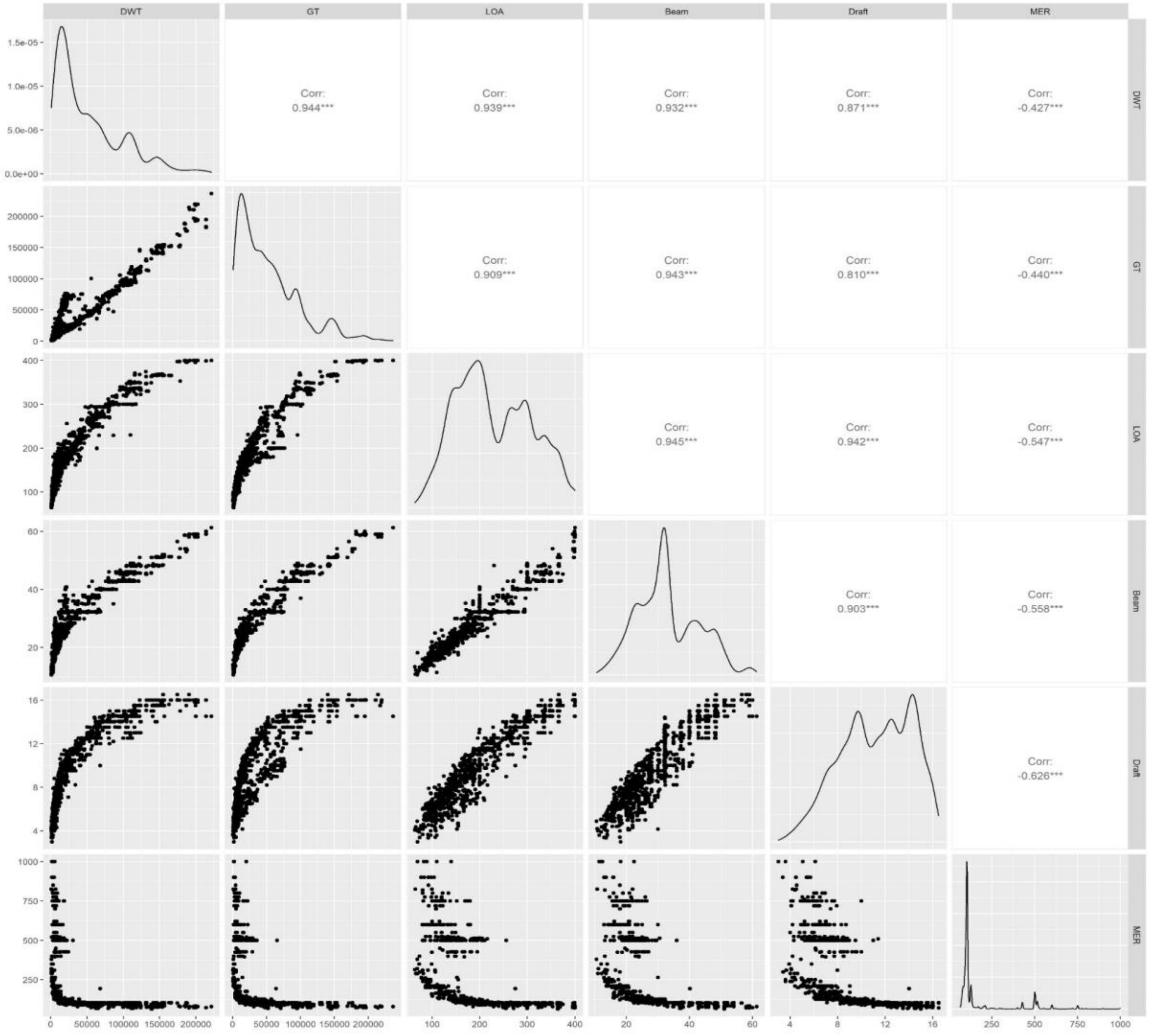

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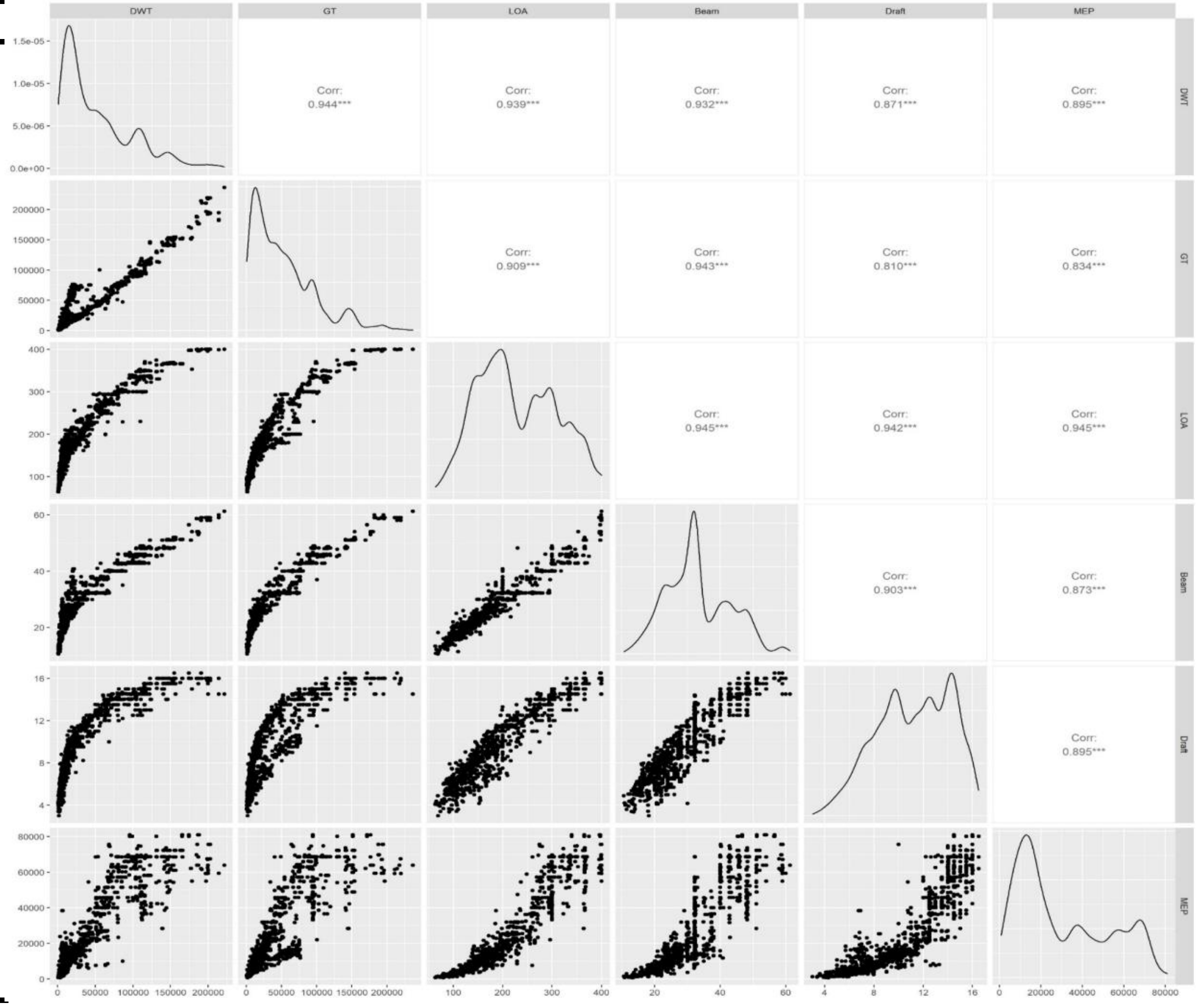
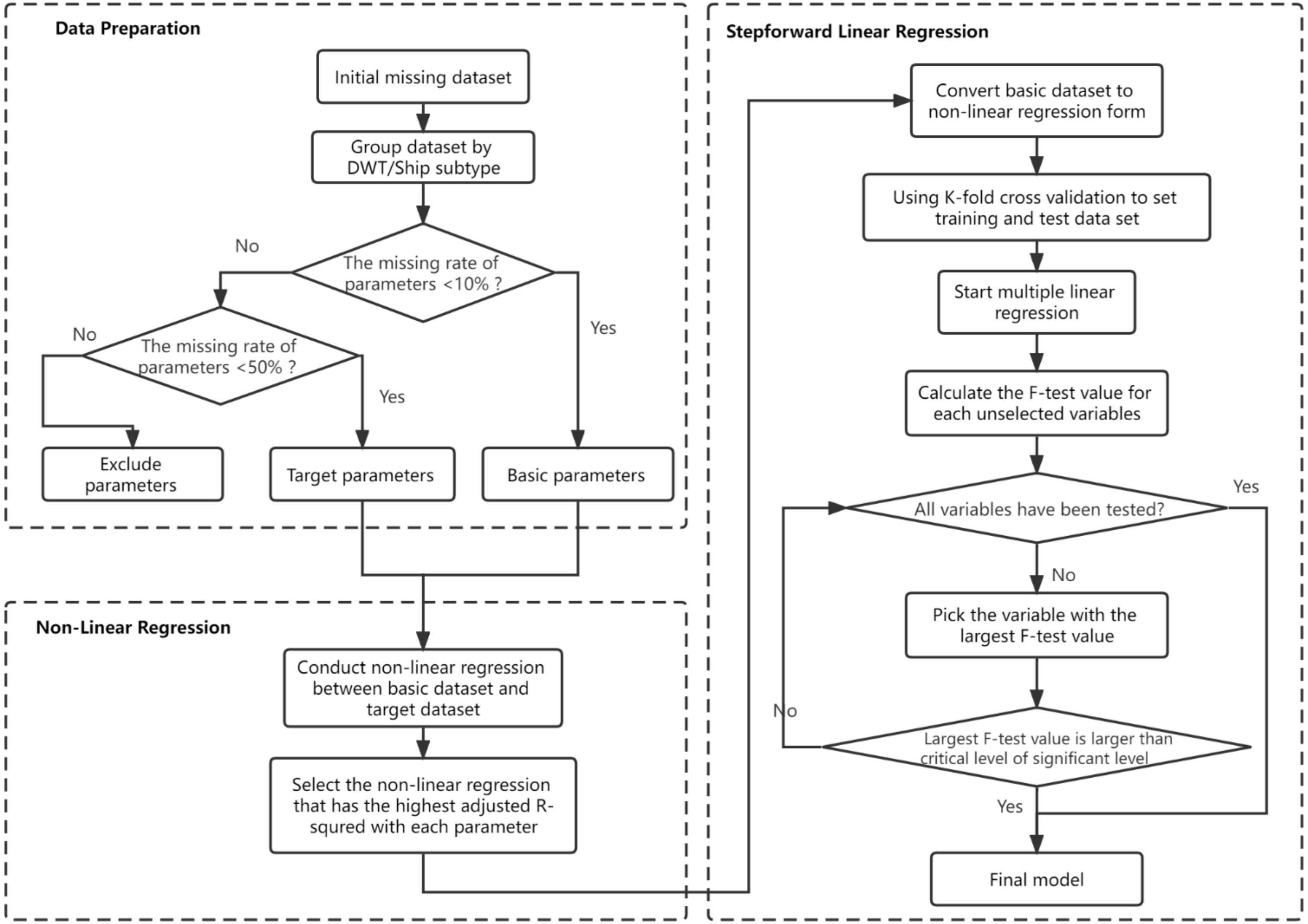


A novel method for missing data imputation



A novel method for missing data imputation

Speed	Ship type	RMSE	MAE	Adjusted-R	Cover rate
Method 1	Dry bulks	33.263	9.325	0.846	96.08%
	Containers	62.238	21.738	0.848	97.38%
	Tankers	105.766	50.002	0.845	91.59%
Method 2	Dry bulks	42.908	15.085	0.755	96.08%
	Containers	98.904	50.470	0.617	97.38%
	Tankers	165.941	105.606	0.616	91.59%
Method 3	Dry bulks	49.927	22.587	0.647	72.76%
	Containers	111.881	71.999	0.510	70.50%
	Tankers	182.780	131.588	0.535	57.47%
Method 4	Dry bulks	-	-	-	-
	Containers	-	-	-	-
	Tankers	-	-	-	-
Method 5	Dry bulks	-	-	-	-
	Containers	-	-	-	-
	Tankers	-	-	-	-
Method 6	Dry bulks	73.011	35.892	0.252	73.00%
	Containers	127.610	89.609	0.361	70.69%
	Tankers	210.682	170.647	0.382	57.52%
Method 7	Dry bulks	55.456	26.594	0.569	100.00%
	Containers	124.479	80.200	0.391	100.00%
	Tankers	206.520	160.420	0.405	100.00%
Method 8	Dry bulks	49.927	22.587	0.647	72.76%
	Containers	111.881	71.999	0.510	70.50%
	Tankers	182.780	131.588	0.535	57.47%
Method 9a	Dry bulks	51.809	26.736	0.628	96.20%
	Containers	114.764	84.322	0.481	97.38%
	Tankers	192.596	151.552	0.483	92.22%
Method 9b	Dry bulks	40.480	13.976	0.770	96.13%
	Containers	98.365	49.711	0.620	97.55%
	Tankers	187.783	127.609	0.523	86.99%
Method 9c	Dry bulks	38.124	13.407	0.796	74.72%
	Containers	97.424	49.438	0.627	72.66%
	Tankers	175.834	119.159	0.582	66.56%
Method 9d	Dry bulks	44.244	16.733	0.725	96.50%
	Containers	108.422	74.839	0.538	97.78%
	Tankers	181.580	135.496	0.540	91.60%
Method 9e	Dry bulks	42.119	16.076	0.725	73.94%
	Containers	103.446	68.207	0.538	67.51%
	Tankers	172.376	125.272	0.540	61.86%

ME RPM	Ship type	RMSE	MAE	Adjusted-R	Cover rate
Method 1	Dry bulks	33.263	9.325	0.846	96.08%
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	Containers	-	-	-	-
	Tankers	-	-	-	-
Method 5	Dry bulks	-	-	-	-
	Containers	-	-	-	-
	Tankers	-	-	-	-
Method 6	Dry bulks	73.011	35.892	0.252	73.00%
	Containers	127.610	89.609	0.361	70.69%
	Tankers	210.682	170.647	0.382	57.52%
Method 7	Dry bulks	55.456	26.594	0.569	100.00%
	Containers	124.479	80.200	0.391	100.00%
	Tankers	206.520	160.420	0.405	100.00%
Method 8	Dry bulks	49.927	22.587	0.647	72.76%
	Containers	111.881	71.999	0.510	70.50%
	Tankers	182.780	131.588	0.535	57.47%
Method 9a	Dry bulks	51.809	26.736	0.628	96.20%
	Containers	114.764	84.322	0.481	97.38%
	Tankers	192.596	151.552	0.483	92.22%
Method 9b	Dry bulks	40.480	13.976	0.770	96.13%
	Containers	98.365	49.711	0.620	97.55%
	Tankers	187.783	127.609	0.523	86.99%
Method 9c	Dry bulks	38.124	13.407	0.796	74.72%
	Containers	97.424	49.438	0.627	72.66%
	Tankers	175.834	119.159	0.582	66.56%
Method 9d	Dry bulks	44.244	16.733	0.725	96.50%
	Containers	108.422	74.839	0.538	97.78%
	Tankers	181.580	135.496	0.540	91.60%
Method 9e	Dry bulks	42.119	16.076	0.725	73.94%
	Containers	103.446	68.207	0.538	67.51%
	Tankers	172.376	125.272	0.540	61.86%

ME Power	Ship type	RMSE	MAE	Adjusted-R	Cover rate
Method 1	Dry bulks	1365.249	814.092	0.911	96.04%
	Containers	2816.732	1340.234	0.984	97.36%
	Tankers	1569.999	745.444	0.965	90.91%
Method 2	Dry bulks	1495.832	1034.263	0.892	96.08%
	Containers	4875.996	3181.496	0.951	97.38%
	Tankers	2171.868	1186.840	0.934	91.59%
Method 3	Dry bulks	1556.337	1098.806	0.883	80.77%
	Containers	6471.498	4849.304	0.914	59.53%
	Tankers	2426.194	1466.653	0.917	71.87%
Method 4	Dry bulks	1588.655	1109.549	0.879	81.11%
	Containers	-	-	-	-
	Tankers	4010.062	1826.743	0.775	72.66%
Method 5	Dry bulks	1972.149	1333.989	0.813	99.96%
	Containers	-	-	-	-
	Tankers	3251.380	2003.988	0.852	72.66%
Method 6	Dry bulks	1574.385	1150.759	0.881	81.11%
	Containers	6916.712	5155.351	0.903	85.70%
	Tankers	3086.737	1870.446	0.867	72.61%
Method 7	Dry bulks	3508.338	2051.481	0.409	100.00%
	Containers	7785.551	4679.507	0.875	100.00%
	Tankers	6573.405	3378.763	0.394	100.00%
Method 8	Dry bulks	1556.337	1098.806	0.883	80.77%
	Containers	6471.498	4849.304	0.914	59.53%
	Tankers	2426.194	1466.653	0.917	71.87%
Method 9a	Dry bulks	1560.453	1098.252	0.883	96.08%
	Containers	6641.510	4874.096	0.910	97.38%
	Tankers	2505.398	1524.374	0.912	91.59%
Method 9b	Dry bulks	1513.255	1046.646	0.890	96.19%
	Containers	4865.068	3158.699	0.951	97.48%
	Tankers	2238.039	1187.495	0.897	86.76%
Method 9c	Dry bulks	1475.209	986.331	0.895	82.03%
	Containers	4092.121	2656.507	0.966	73.49%
	Tankers	2090.247	1066.919	0.910	65.67%
Method 9d	Dry bulks	1519.056	1060.753	0.889	96.31%
	Containers	6126.747	4173.564	0.923	97.51%
	Tankers	2189.027	1196.692	0.933	93.90%
Method 9e	Dry bulks	1475.561	991.335	0.889	79.16%
	Containers	5825.487	4077.273	0.923	78.28%
	Tankers	2102.583	1137.193	0.933	72.31%

Target Parameters	Only missing target parameter	Not missing basic parameters	Other
Service speed	Combined Model - All parameter - DWT Group	Combined Model - Basic parameter - DWT Group	IMO - Power curve fit
ME rpm	Combined Model - All parameter - DWT Group	Combined Model - Basic parameter - DWT Group	IMO - Power curve fit
ME power	Combined Model - All parameter - Ship subtype	Combined Model - Basic parameter - Ship subtype	IMO - Power curve fit

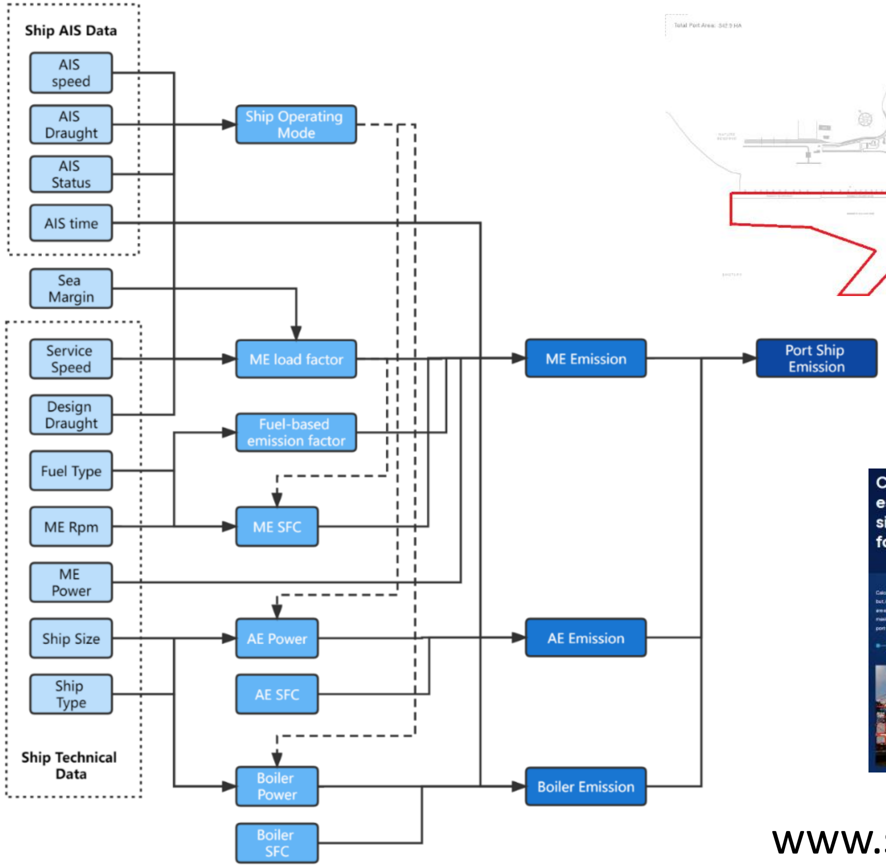
To sum up, our main contributions are:

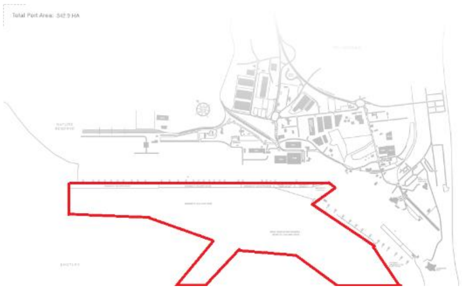
1） The technical parameters of ships in the carbon emission calculation equations for ships are prone to be missing in the actual collection, and there are few models to impute in the missing data for these parameters. We are proposing a new idea to improve the data integrity in carbon emission calculations, thus making the results of ship carbon emission calculations more accurate.

2） Previous imputing models have focused on model accuracy, with little research on the input variables' missing rate and how much the final model can cover data. Therefore, the combined model constructed in this paper requires input variables with few missing parameters, and the coverage rate of imputing in missing data is greatly improved compared with the previous models. At the same time, the model's accuracy is also higher or similar.

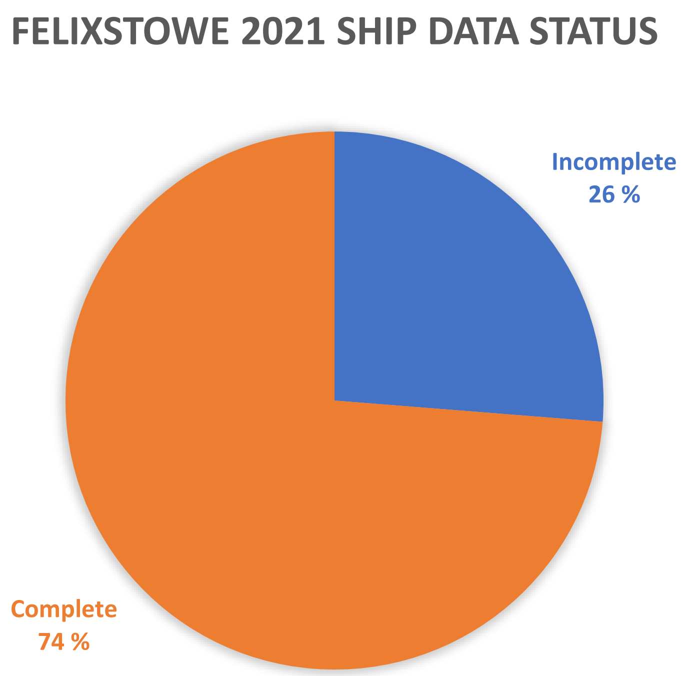
3） A decision matrix for the impute model is developed to provide a basis for using the model in different states. The accuracy of the imputing is further improved, and the imputing rate is 100%.

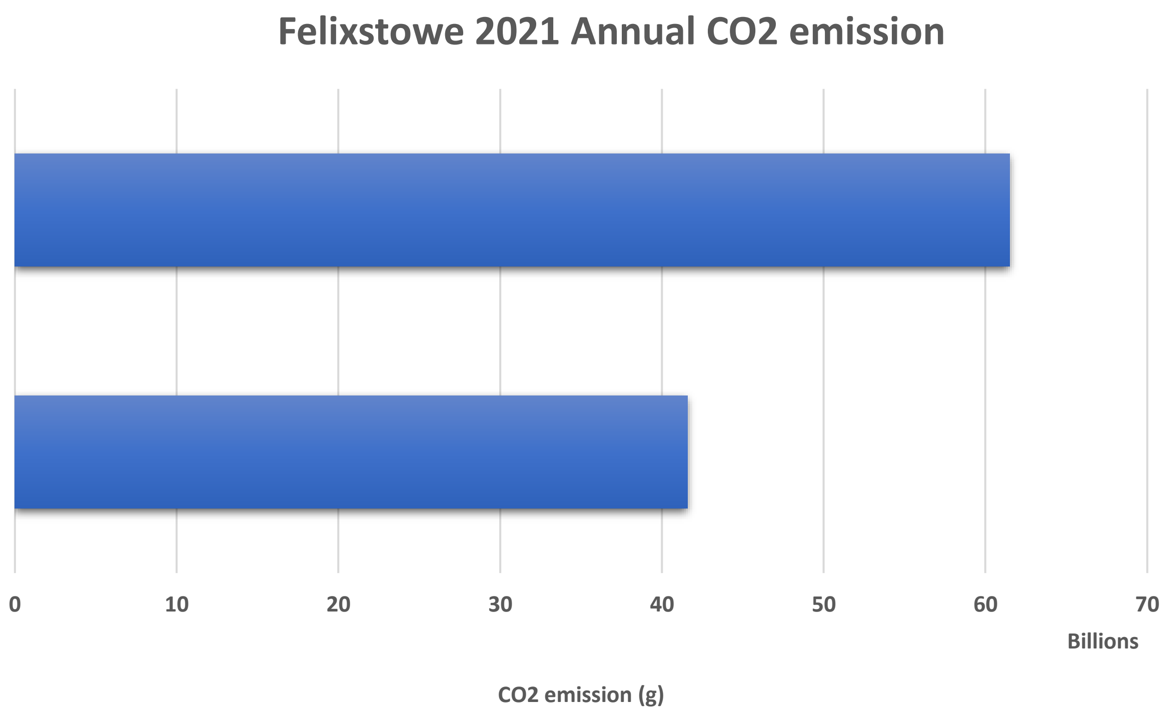
Estimating Emissions for Felixstowe





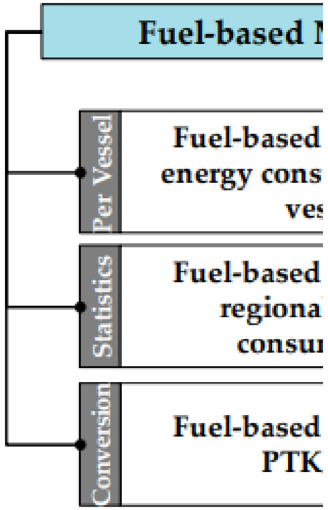
www.seaedge.global


FELIXSTOWE 2021 SHIP DATA STATUS
Incomplete
26 %
Complete
74 %


Felixstowe 2021 Annual CO2 emission
0
10
20
30
40
50
60
70
Billions
CO2 emission (g)

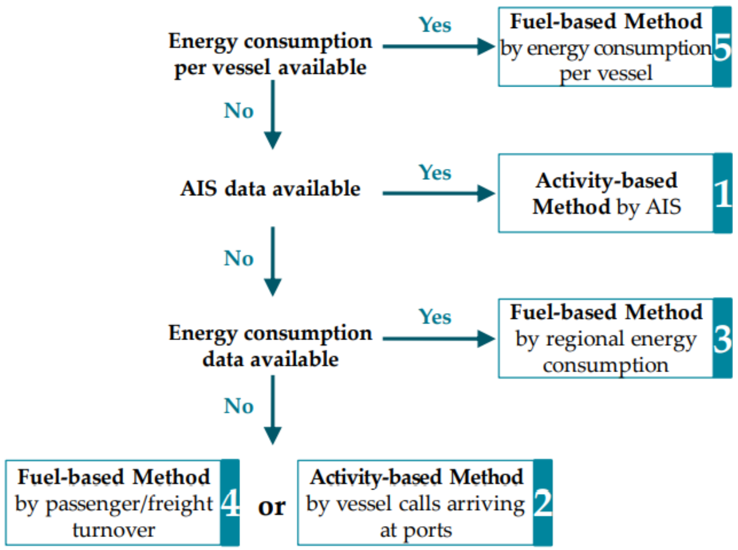
Emissions Estimation Accuracy

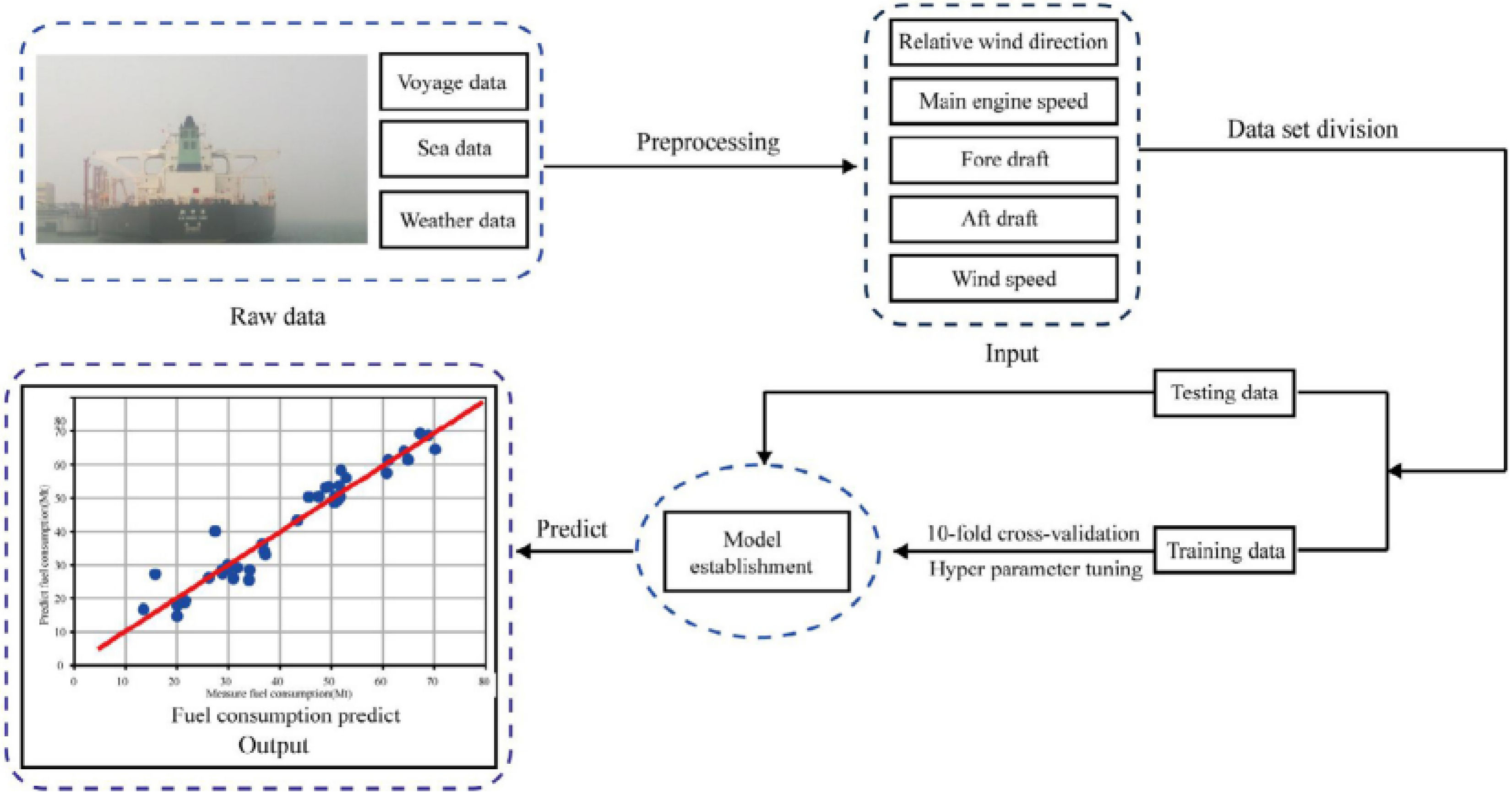
What does the literature say?



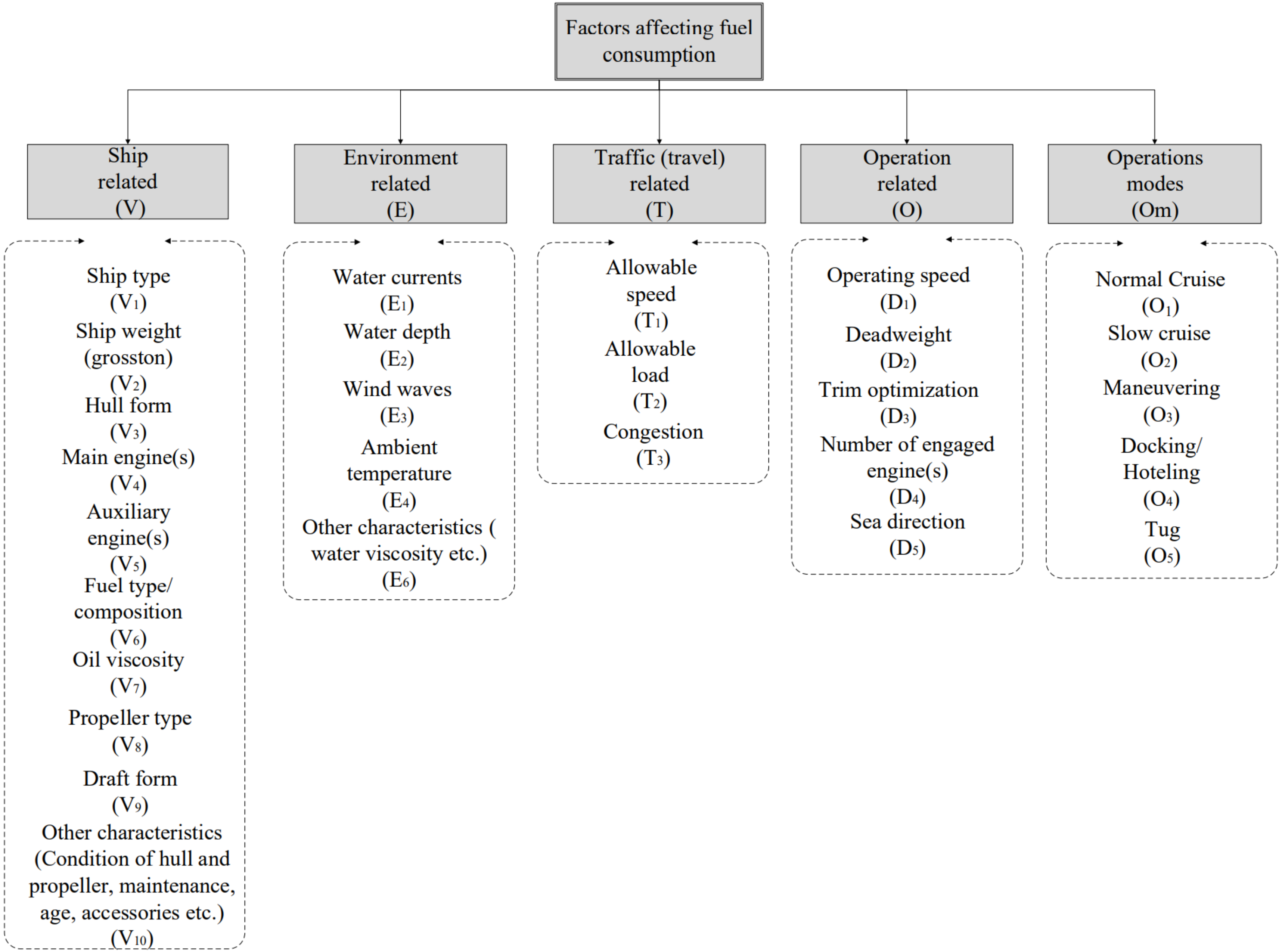
Name	Method 1 Activity-Based Method by Dynamic Vessel Data	Method 2 Activity-Based Method by Vessel Calls	Method 3 Fuel-Based Method by Regional Energy Consumption	Method 4 Fuel-Ba Method PTK/F	Method 5 Fuel-Based
Applicability for Different Scales	Large scale = Medium scale = Small scale	Small scale > Medium scale > Large scale	Large scale > Medium scale > Small scale	Large sca Medium s Small sc	
Complexity and Time of Calculation	★ High and long	★★ Medium and medium	★★★ Low and short	★★★ Low and	
Accuracy of Results	★★★★ Moderately high	★★★ Average	★★ Moderately low	★ Low	
Temporal Resolution of Results	★★ Fine	☆ No	☆ No	☆ No	
Spatial Resolution of Results	★★ Fine	☆ No Resolution by region/country depends on activity level data	☆ No Unclear scope of calculation	☆ No Unclear scope of calculation	
		etc.	etc.		

Emission Factor	Power-based emission factor (g/kW·h)	Power-based emission factor (g/kW·h)	Fuel-based emission factor (g/kg fuel), etc.	Fuel-based emission factor (g/kg fuel), etc.	Fuel-based emission factor (g/kg fuel), etc.




Voyage data
Sea data
Weather data
Raw data
Preprocessing
Relative wind direction
Main engine speed
Fore draft
Aft draft
Wind speed
Input
Data set division
Testing data
Training data
10-fold cross-validation
Hyper parameter tuning
Model establishment
Predict
Fuel consumption predict
Output

A comparative analysis of several ship emission models for maritime freight transportation



What are the variables?

Ship Technical

Notation	Term	Description	Unit
F_m	main engine fuel consumption	vessel's main engine specific fuel consumption per tonne-kilometre	g/t-nm
F_A^S	auxiliary engine fuel consumption at sea	vessel's auxiliary engine specific fuel consumption per tonne-kilometre at sea	g/t-nm
F_A^p	auxiliary engine fuel consumption in port	vessel's auxiliary engine specific fuel consumption per tonne-kilometre in port	g/t-nm
F_{jk}	daily consumption of fuel	daily consumption of fuel type j in ship class k as a function of GT	g
ME_{MCR}	main engine maximum continuous rating	the maximum power output main engine can produce while running continuously at safe limits and conditions	kWh
AE_{MCR}	auxiliary engine maximum continuous rating	the maximum power output auxiliary engine can produce while running continuously at safe limits and conditions	kW
SFC_{ME}	main engine specific fuel consumption	the amount of fuel consumed by main engine for each unit of power output	g/kWh
SFC_{AE}	auxiliary engine specific fuel consumption	the amount of fuel consumed by auxiliary engine for each unit of power output	g/kWh
SFC_{m2}	amount of fuel used per work unit produced	the amount of fuel consumed by vessels for each unit of power output	g/kWh
DWT	dead weight tonnage	a measure of how much weight a ship can carry	DWT
V_d	design speed	design speed for which the vessel is optimized (this speed is usually 90–95% of the maximum speed)	knots
S	wetted surface of the vessel	total surface area of the hull and appendages below the waterline	m2
L	LOA	the maximum length of a vessel's hull measured parallel to the waterline	m
B	Beam	distance between planes passing through the outer extremities of the ship	m

Ship Movement Status

Notation	Term	Description	Unit
LF	load factor	the ratio of mass of weight and payload capacity	%
LF_{DWT}	the average engine loading factor	average value of actual power output of the engine relative to its Maximum Continuous Rating	%
M	mass of freight	The quantity of cargo carried by the ship	net tonne
CP	payload capacity	Maximum mass of freight allowed	tonne
CU	capacity utilisation	Additional distance the vehicle/vessel runs empty related to loaded distance allocated to the transport	%
$H_{1/3}$	significant wave height	the average wave height, from trough to crest, of the highest one-third of the waves	m
ET	empty trip factor	Additional distance the vehicle/vessel runs empty related to loaded distance allocated to the transport	%
D	roundtrip distances	the length of the space between departure and destination points	nm
D_{empty}	distance empty	distance travelled when the vessel is empty	nm
D_{loaded}	distance loaded	distance travelled when the vessel is loaded	nm
ME_{load}	main engine load factor	actual power output of the main engine relative to its Maximum Continuous Rating	%
AE_{load}^{s}	auxiliary engine load factor at sea	actual power output of auxiliary engine relative to its Maximum Continuous Rating at sea	%
AE_{load}^{s}	auxiliary engine load factor in port	actual power output of auxiliary engine relative to its Maximum Continuous Rating in port	%
V	vessel speed	actual speed of the vessel while in motion	nm/h
V_{fleet}	average speed of fleet	average speed of multiple vessels	nm/h
P_M	power required for main engine	power required for main engine	kWh
P_A	power required for auxiliary engine	power required for auxiliary engine	kWh
P_s	power required for still water	power required for still water	kWh
P_w	additional power required for waves	additional power required for waves	kWh
P_{fleet}	the specific power of fleet	the specific power of fleet	kWh/tonne
$P_{p\&s}$	power requirement in port and slow zones	power requirement in port and slow zones	kWh
u	wave speed	wave speed in relation to vessel speed	knots
T_s	sailing time	time spent during sailing per roundtrip	hr
$T_{p\&s}$	in port and slow zones time	time spent in port and slow zones per roundtrip	hr
t_{jl}	number of days in navigation	number of days in navigation of ships of class k with engine type l using fuel j	day
E_{CO2}	CO2 emission amount	amount of CO2 emitted by vessels	g
$E_{g,i,k,s}$	amount of pollutant	amount of pollutant emitted of type g for ships of type i in size category k with engine type s	kg

Coefficients

Notation	Term	Description	Unit
K	propeller efficiency	power produced (propeller power) divided by power applied (engine power)	%
η	efficiency at design speed	efficiency at design speed	%
η_e	engine efficiency	ratio of the useful work done to the heat provided	%
j	propeller constant independent	propeller constant that is speed independent	non-dimensional
k	propeller constant dependent	propeller constant that is speed dependent	non-dimensional
ρ	density of water	the weight of the water per its unit volume	kg/m3
ρ_f	mass density of diesel fuel	the weight of the fuel per its unit volume	g/gal (kg/m3)
C_T	total drag coefficient	total resistance of vessels in the sea	non-dimensional
C_{aw}	drag coefficient for the wave resistance	wave resistance of vessels in the sea	non-dimensional
g	gravity force	an universal force of attraction acting between all matter	m/s2
K_e	CO2 coefficient	amount of CO2 emitted per ton nautical mile	g/ton-nm
$K_{hph-BTU}$	conversion from hp-h to BTU	conversion from hp-h to BTU	non-dimensional
C_F	carbon fraction of the fuel	carbon content of the fuel as a percentage of its mass	g C/g fuel
μ	carbon to CO2e conversion factor	carbon to CO2e conversion factor	non-dimensional
ϵ_{ijl}	average emission factor	average emission factor of pollutant i from fuel j in engines type l	non-dimensional
$N_{i,k}$	number of vessels	number of vessels of type i in size category k	non-dimensional
$F_{i,k}$	fraction of vessels	fraction of vessels of type i in size category k with engine type s	non-dimensional

Operation Type	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Manoeuvring	↓64.3%	↑167.7%	↓87.1%	↓41.1%	↑166.7%	↑61.0%	↑149.1%	↑30.0%	↑51.0%	↑17.1%	↓43.7%
Sea	↓11.1%	↑78.4%	↓30.8%	↑13.4%	↑79.9%	↓66.4%	↑68.1%	↑68.3%	↑95.5%	↑56.7%	↓24.1%
At Anchorage	↓55.6%	↑330.0%	↓94.3%	↓19.3%	↑337.2%	↑29.5%	↑308.4%	↑13.8%	↑32.2%	↑58.4%	↓24.2%
At berth	↓9.9%	↑348.9%	↓95.5%	↓16.9%	↑362.2%	↑45.9%	↑331.8%	↑7.9%	↑25.4%	↓28.3%	↓66.5%
Total	↓19.2%	↑153.9%	↓49.6%	↑3.9%	↑157.7%	↓36.1%	↑140.7%	↑51.6%	↑76.2%	↑47.3%	↓28.9%

Operation Type	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Manoeuvring	↓47.2%	↑300.8%	↓82.5%	↓18.9%	↑440.9%	↓20.6%	↑334.8%	↑163.8%	↑193.0%	↑114.3%	↑7.3%
Sea	↓14.8%	↑123.9%	↓33.7%	↑7.6%	↑134.9%	↓56.5%	↑88.8%	↑130.0%	↑155.5%	↑91.9%	↓2.7%
At Anchorage	↓61.3%	↑260.3%	↓95.4%	↓51.5%	↑339.9%	↑28.4%	↑253.6%	↑13.0%	↑25.5%	↑28.0%	↓36.5%
At berth	↓44.2%	↑358.0%	↓98.0%	↓50.5%	↑383.3%	↓26.7%	↑288.4%	↑8.3%	↑20.3%	↓54.7%	↓78.9%
Total	↓24.0%	↑179.1%	↓50.7%	↓7.9%	↑198.5%	↓44.2%	↑139.9%	↑98.1%	↑120.1%	↑59.3%	↓19.7%

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Manoeuvring	↓64.3%	↑167.7%	↓87.1%	↓41.1%	↑166.7%	↑61.0%	↑149.1%	↑30.0%	↑51.0%	↑17.1%	↓43.7%
Sea	↓11.1%	↑78.4%	↓30.8%	↑13.4%	↑79.9%	↓66.4%	↑68.1%	↑68.3%	↑95.5%	↑56.7%	↓24.1%
At Anchorage	↓55.6%	↑330.0%	↓94.3%	↓19.3%	↑337.2%	↑29.5%	↑308.4%	↑13.8%	↑32.2%	↑58.4%	↓24.2%
At berth	↓9.9%	↑348.9%	↓95.5%	↓16.9%	↑362.2%	↑45.9%	↑331.8%	↑7.9%	↑25.4%	↓28.3%	↓66.5%
Total	↓19.2%	↑153.9%	↓49.6%	↑3.9%	↑157.7%	↓36.1%	↑140.7%	↑51.6%	↑76.2%	↑47.3%	↓28.9%

↓4.4%

Operation Type	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Manoeuvring	↓47.2%	↑300.8%	↓82.5%	↓18.9%	↑440.9%	↓20.6%	↑334.8%	↑163.8%	↑193.0%	↑114.3%	↑7.3%
Sea	↓14.8%	↑123.9%	↓33.7%	↑7.6%	↑134.9%	↓56.5%	↑88.8%	↑130.0%	↑155.5%	↑91.9%	↓2.7%
At Anchorage	↓61.3%	↑260.3%	↓95.4%	↓51.5%	↑339.9%	↑28.4%	↑253.6%	↑13.0%	↑25.5%	↑28.0%	↓36.5%
At berth	↓44.2%	↑358.0%	↓98.0%	↓50.5%	↑383.3%	↓26.7%	↑288.4%	↑8.3%	↑20.3%	↓54.7%	↓78.9%
Total	↓24.0%	↑179.1%	↓50.7%	↓7.9%	↑198.5%	↓44.2%	↑139.9%	↑98.1%	↑120.1%	↑59.3%	↓19.7%

↑0.6%

International Maritime Statistics Forum

IMSF 2022 Meeting

Thank you for your attention

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