Calculation of Fuel Consumption and Exhaust Emissions from Ship in Ice Conditions

Master Thesis

Student : Duong Quang Tan

Supervisor : Prof. Tadeusz Graczyk, ZUT

Dipl.-Ing. Nils Reimer, HSVA

EMship Advanced Design

Université de Liège

ECN Centrale Nantes

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

HSVA

Universität Rostock

Traditio et Innovatio

Universitas Galatiensis

UNIVERSITÀ DEGLI STUDI DI GENOVA

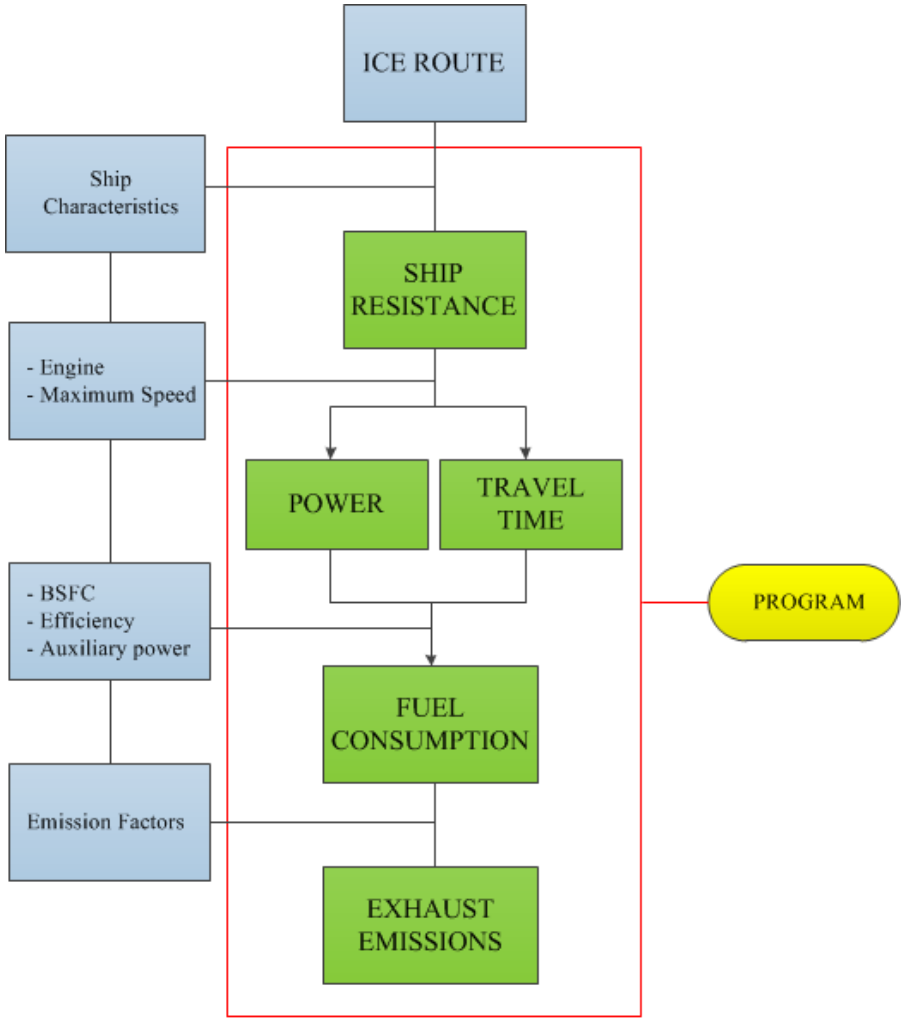
OUTLINE

- Introduction
- Methodology
- Considerations
- Calculation of Fuel Consumption and Exhaust Emissions
- Results
- Conclusions

INTRODUCTION

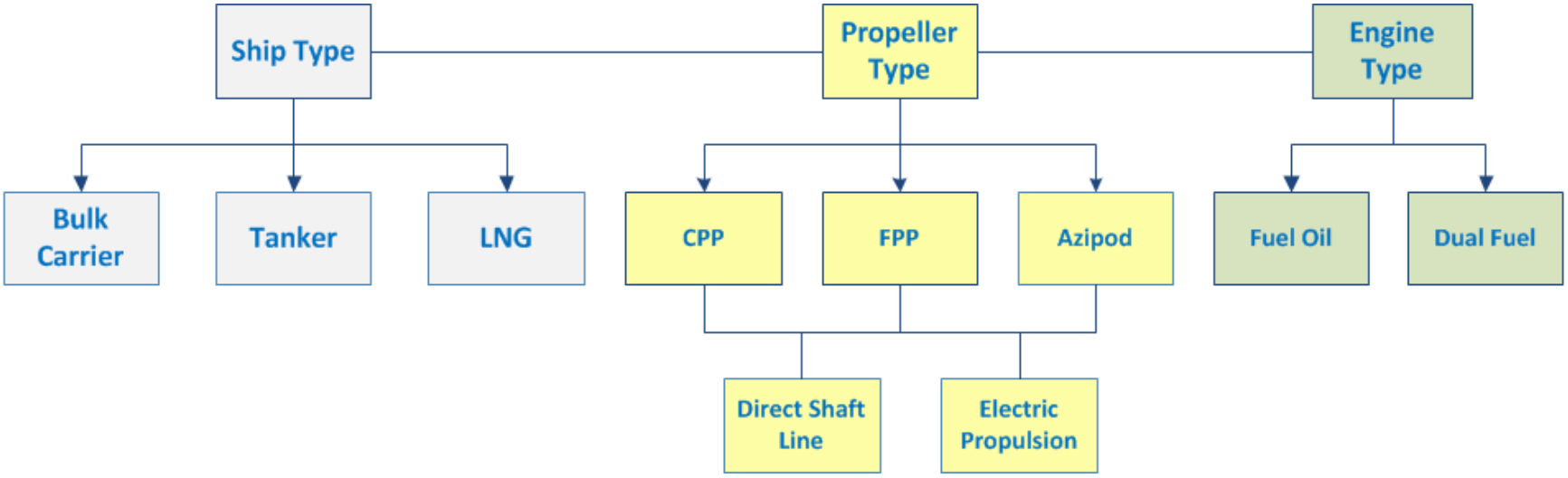
- The working topic is studied at the Hamburg Ship Model Basin – HSVA (Hamburg, Germany), and is part of the ACCESS project (Arctic Climate Change, Economy and Society), an European Project supported within the Ocean of Tomorrow call of the European Commission Seventh Framework Program
- Calculation of fuel consumption and exhaust emissions for various ship types as a function of power and speed in various ice conditions
- Arctic area condition, along the Northern Sea Route

METHODOLOGY



CONSIDERATIONS

- Ship type: Bulk carrier, Tanker, LNG carrier
- Propeller type: CPP, FPP, Podded Azimuth
- Transmission type: direct shaft line, electric propulsion
- Engine type: fuel oil

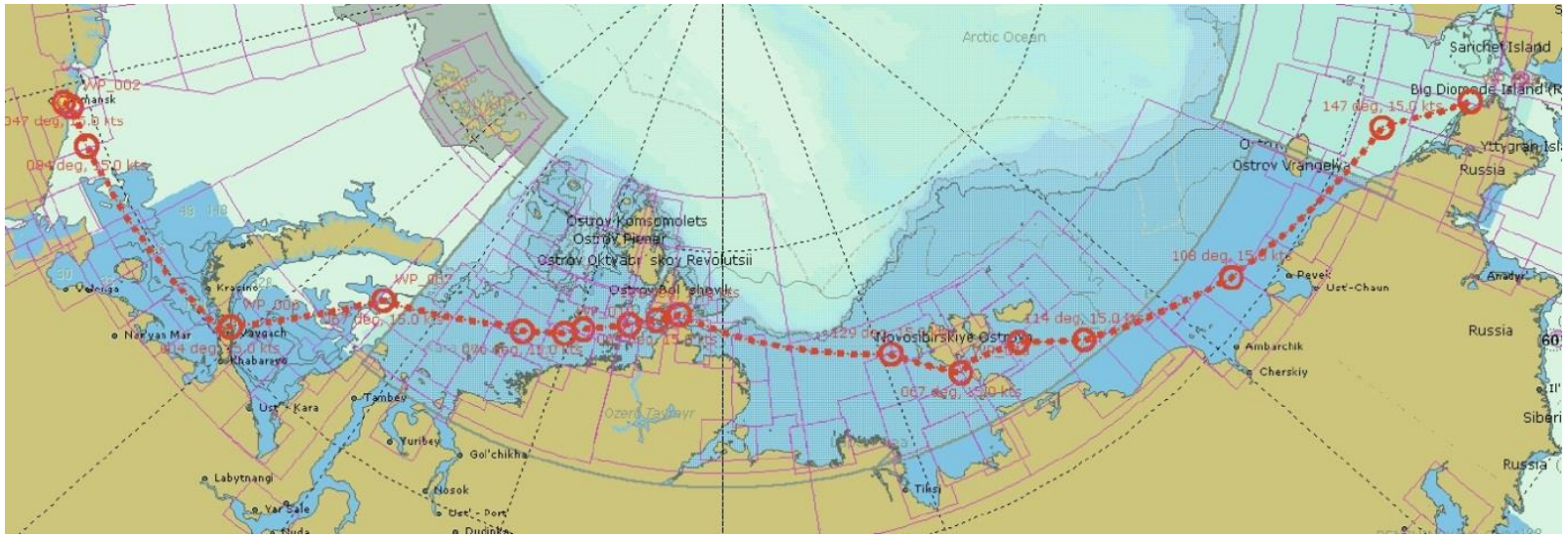


CONSIDERATIONS

- Four difference routes:
  - Murmansk to Bering Strait via Kara gate and south of Novosiberian Island
  - Murmansk to Bering Strait via Kara gate and north of Novosiberian Island
  - Murmansk to Bering Strait via north of Novaya Zemlya and south of Novosiberian Island
  - Murmansk to Bering Strait via north of Novaya Zemlya and north of Novosiberian Island
- Ice conditions:
  - September 2000
  - November 2000
  - September 2007
  - November 2007

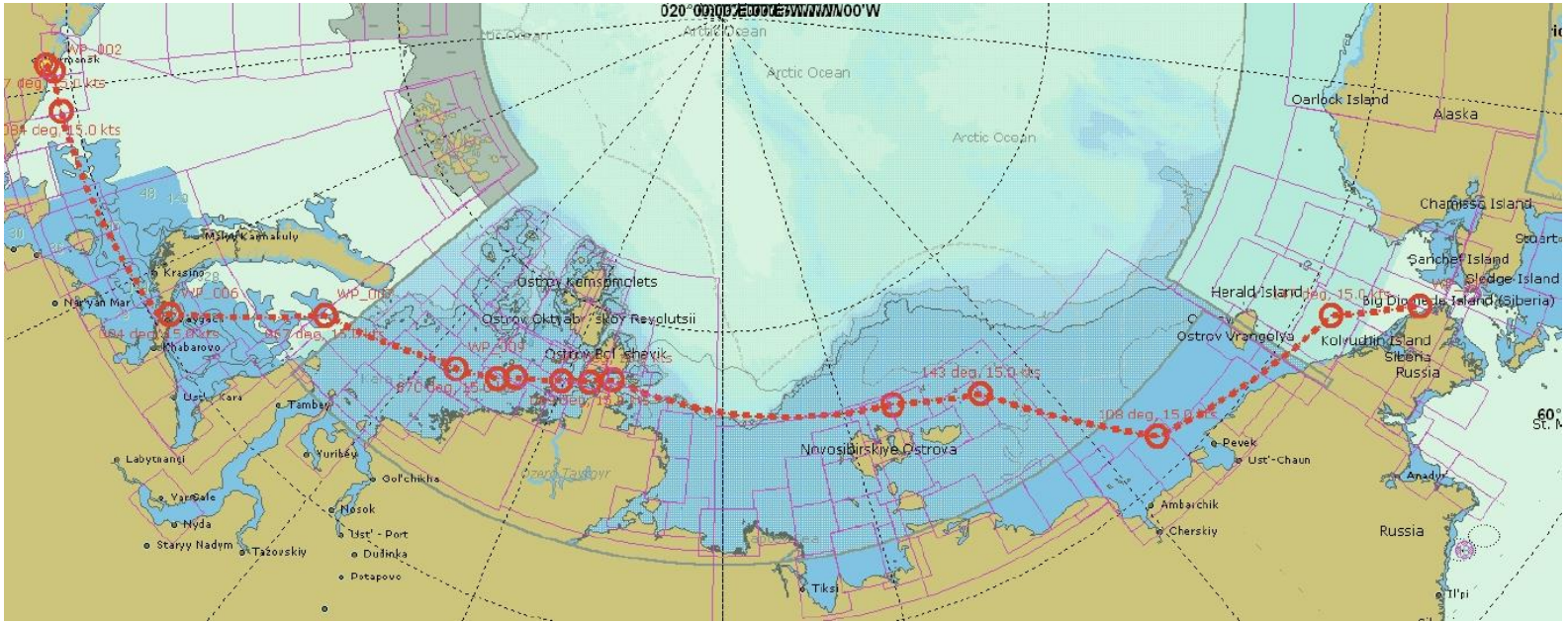
ROUTES

- Route 1: Murmansk to Bering Strait via Kara Gate and passing south of Novosiberian Island (total distance 3017.76 nm)



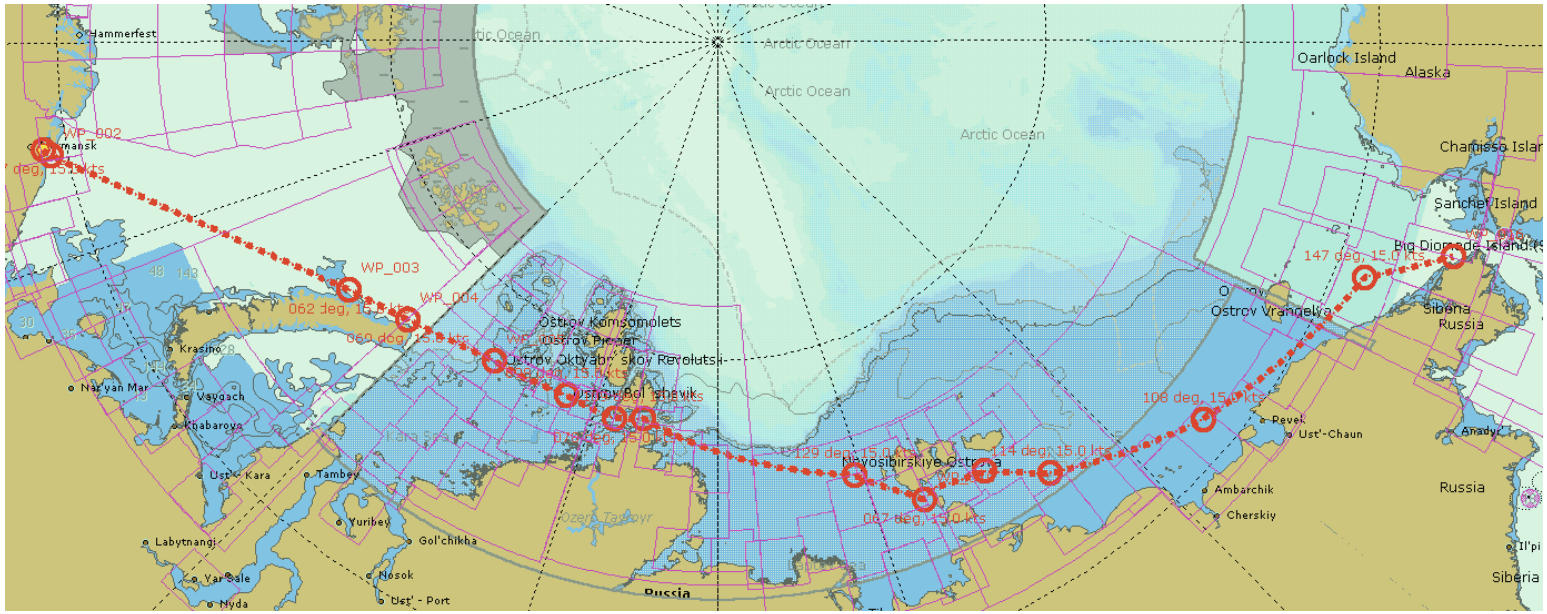
ROUTES

- Route 2: Murmansk to Bering Strait via Kara Gate and passing north of Novosiberian Island (total distance 2976.94 nm)



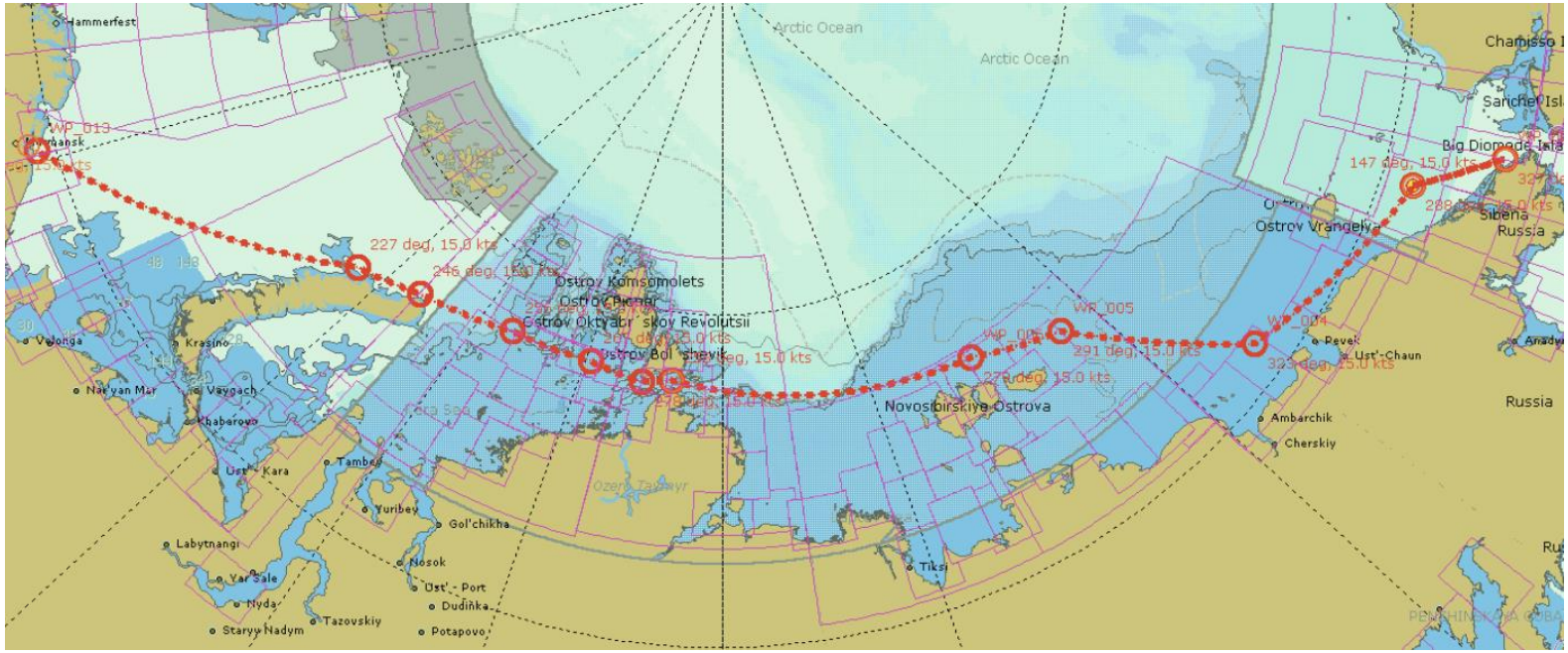
ROUTES

- Route 3: Murmansk to Bering Strait via north of Novaya Zemlya and passing south of Novosiberian Island (total distance 2842.60 nm)



ROUTES

- Route 4: Murmansk to Bering Strait via north of Novaya Zemlya and passing north of Novosiberian Island (total distance 2801.78 nm)



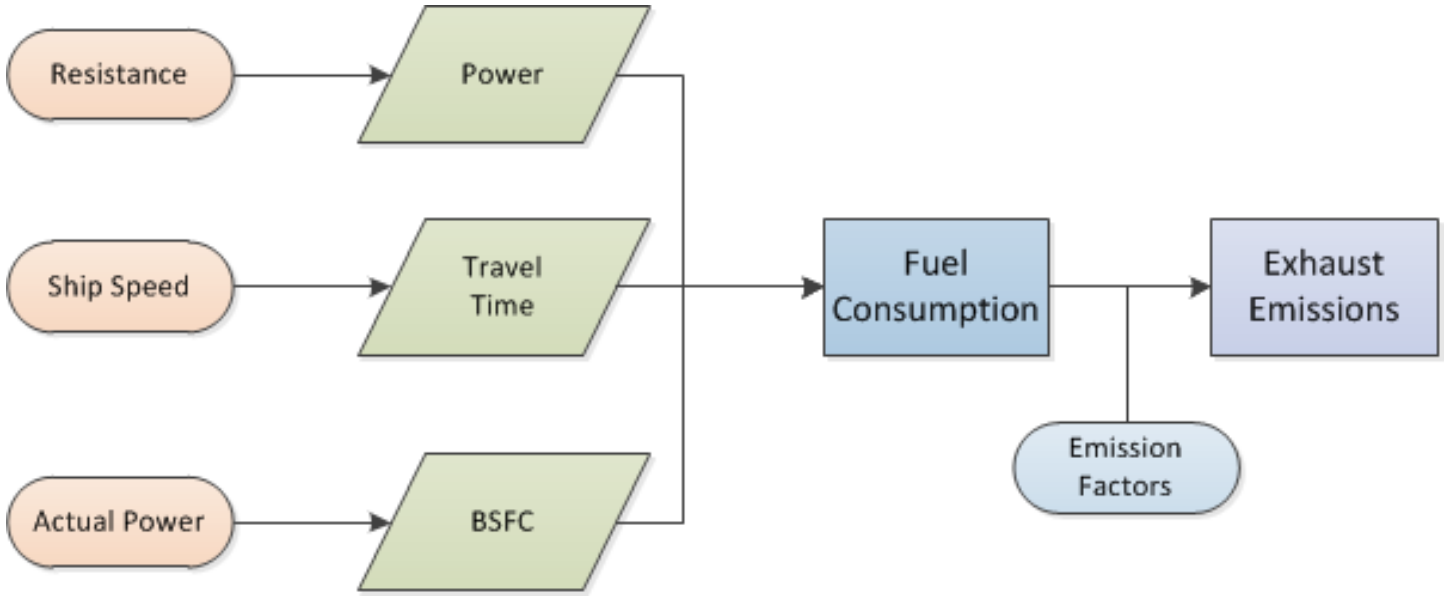
CONSIDERATIONS

- Emission factors are taken from IMO study 2009

Emission factors	g/kg fuel(*)	g/kWh	%
CO2	3206	561.05	6.467
CO	7.4	1.30	0.015
NOx	78	13.65	0.157
SOx	54	9.45	0.109
BC	0.35	0.06	0.001
OC	1.07	0.19	0.002
PM	5.3	0.93	0.011

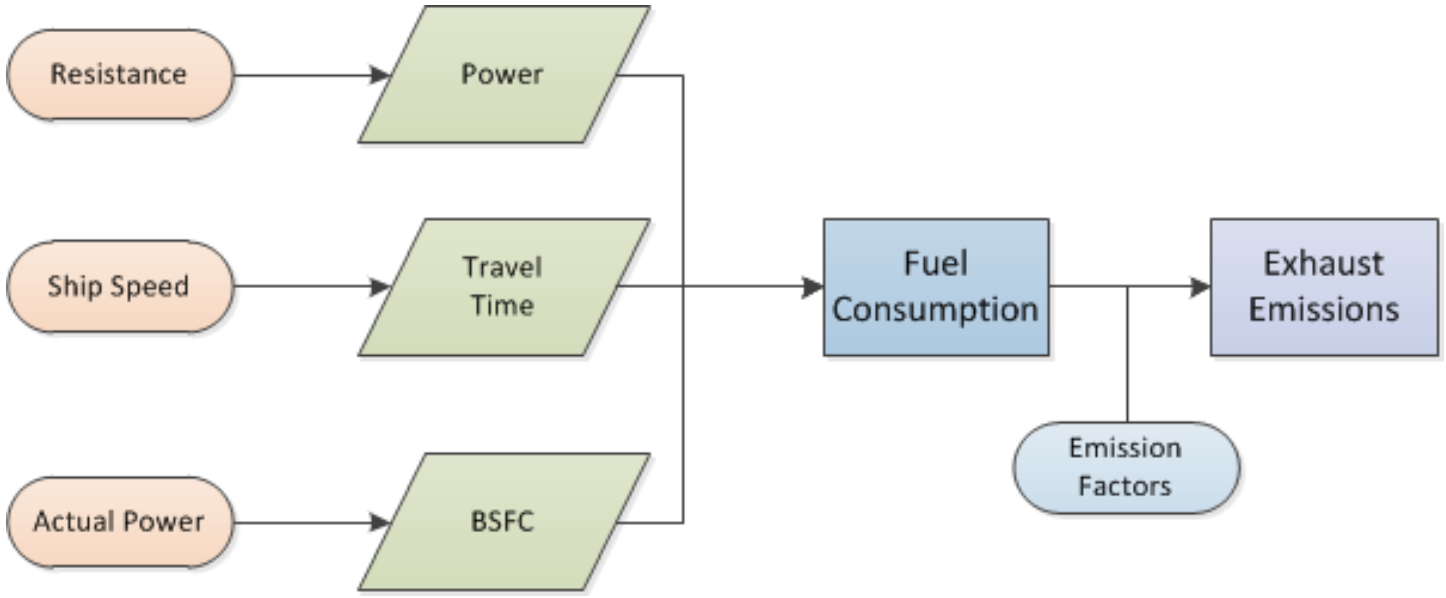
Fuel Consumption

- Total Fuel Consumption (tons) = Power (kW) x SFC (g/kWh) x Time (h) x 10^{-6}



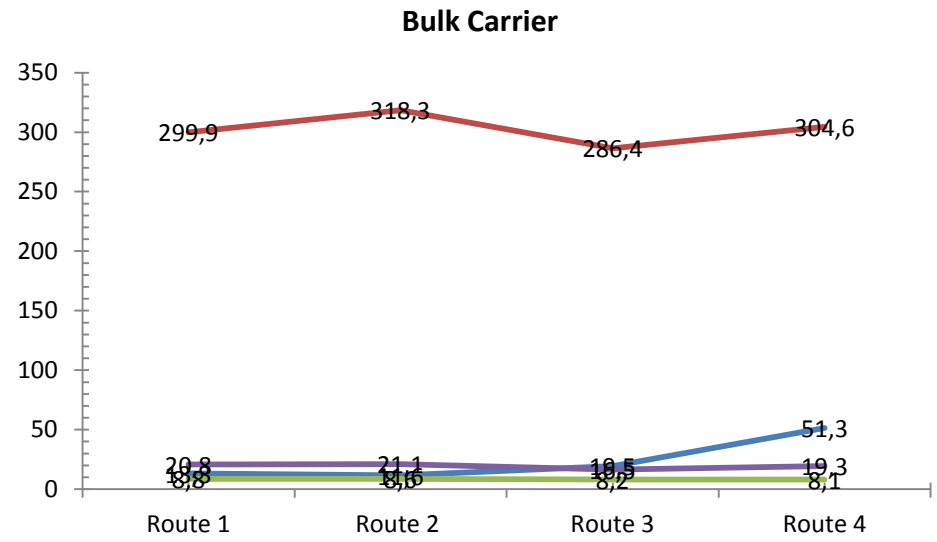
Exhaust Emissions

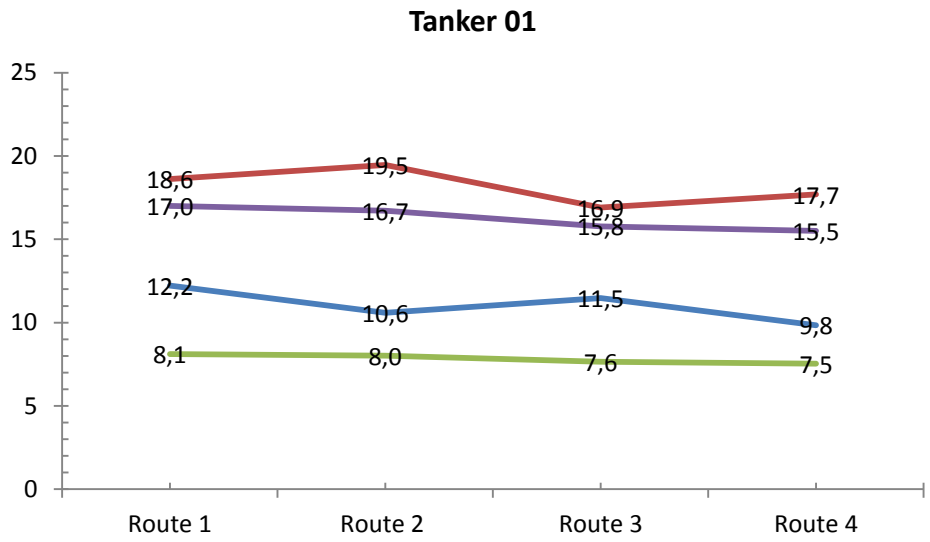
- Exhaust gas (kg) = Total fuel (kg) x Emission factor (g/kg fuel) x 10^{-3}

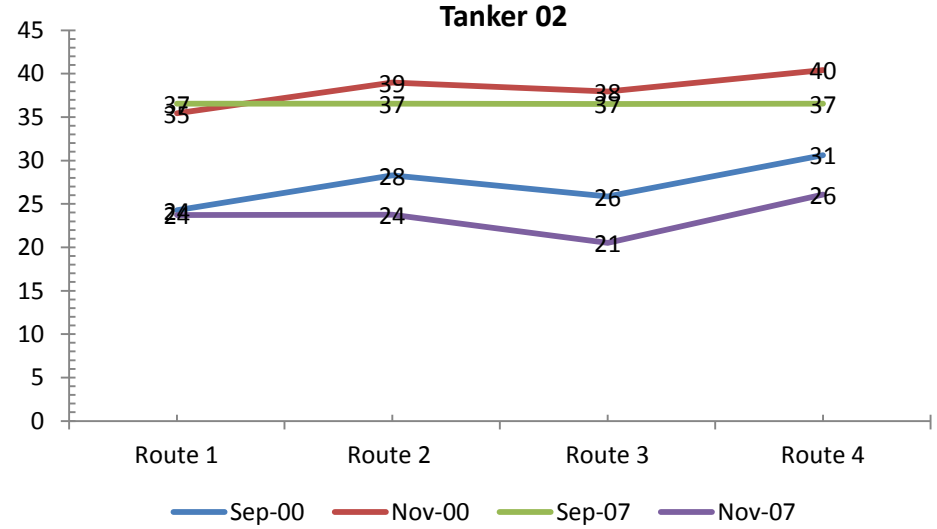


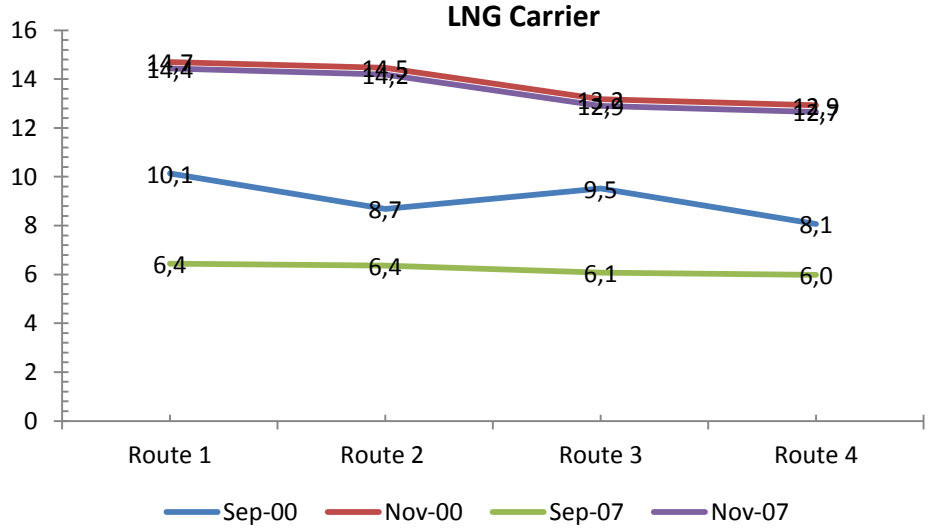
RESULTS

Result: Travel time (days)

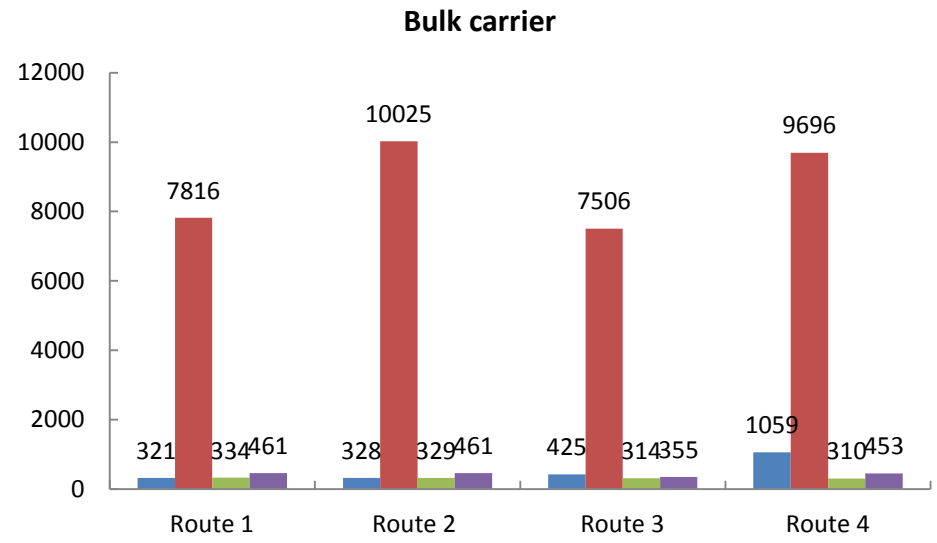


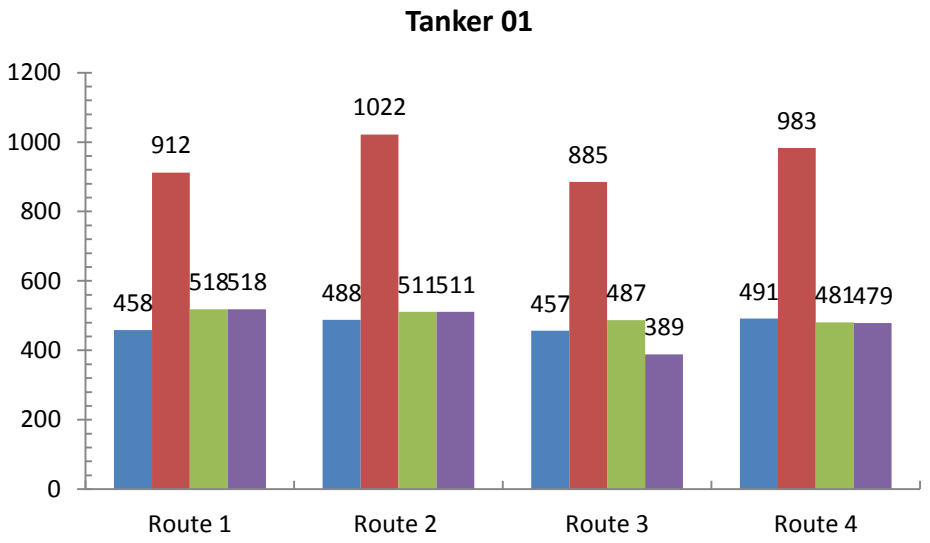


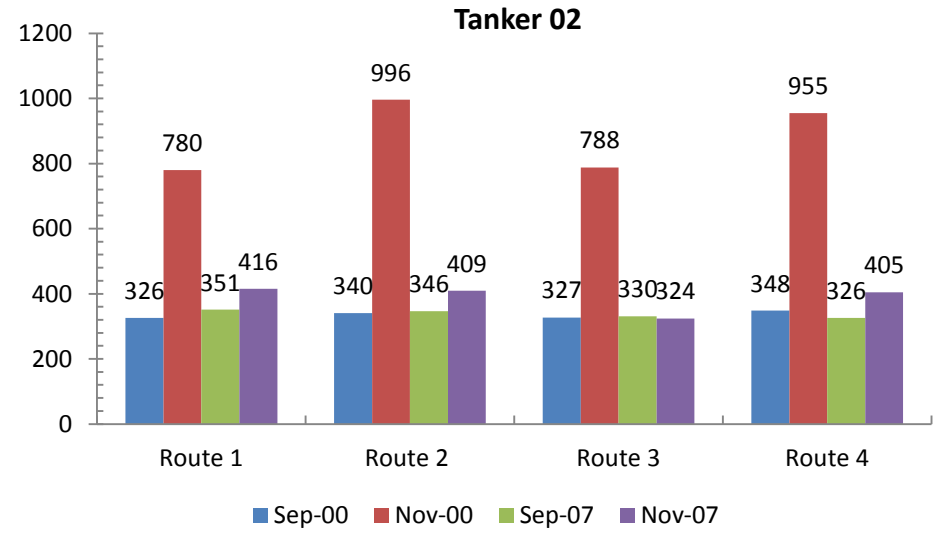


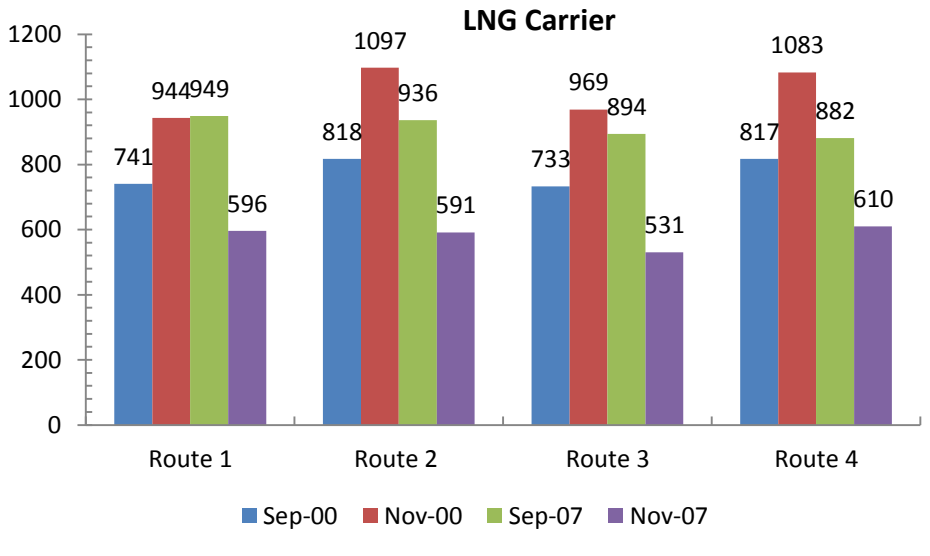


Result: Fuel consumption (tons)

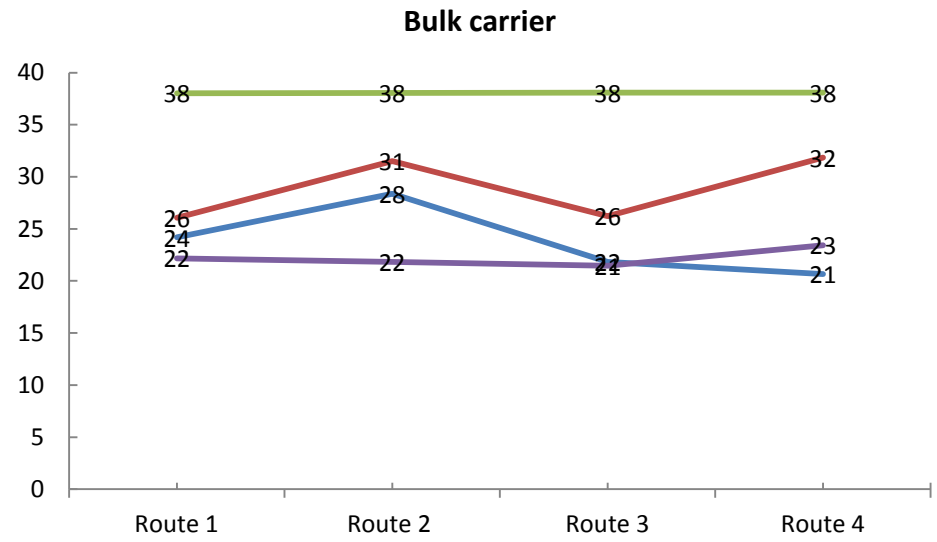


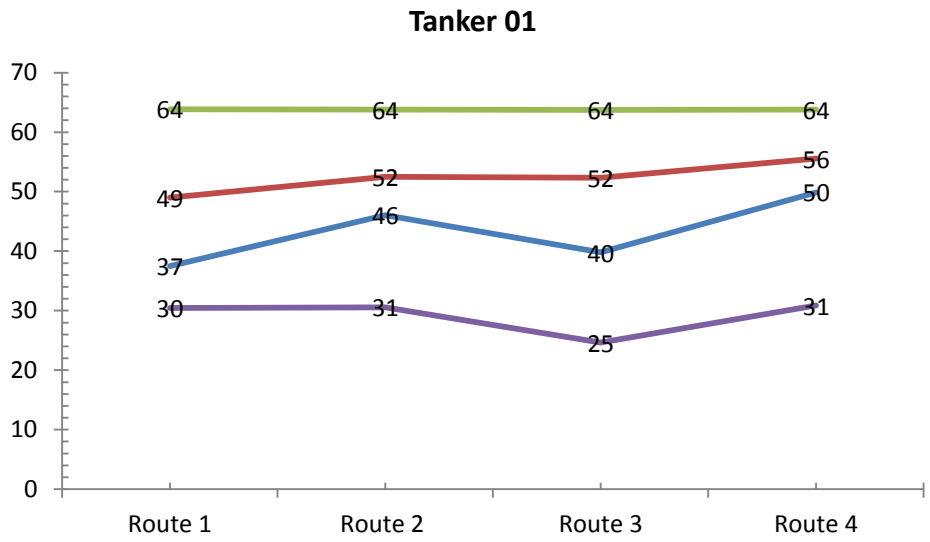


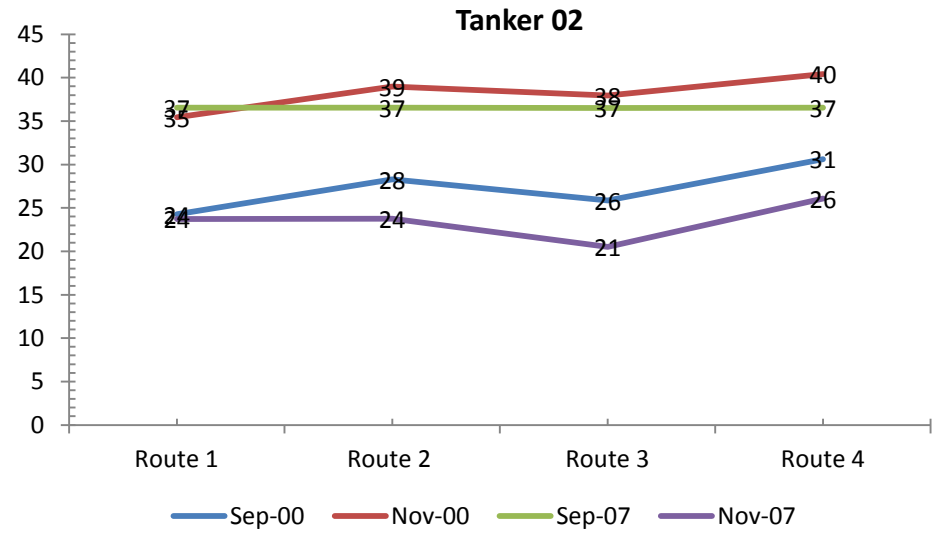


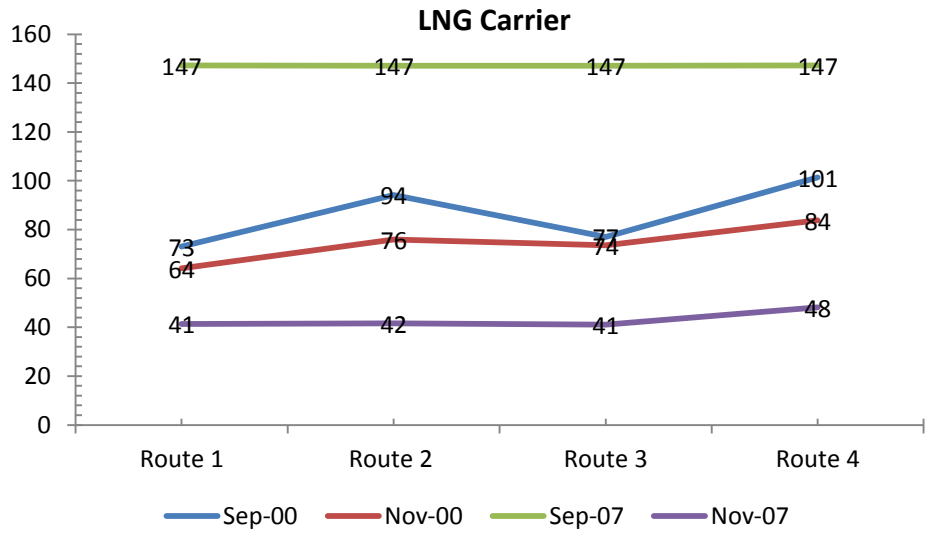


Result: Fuel per day (tons/day)









Exhaust Emissions

		CO_2	CO	NOx	SOx	BC	OC	PM
		(tons)	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
Sep-00	Route 1	1468.2	3.39	35.72	24.73	0.16	0.49	2.43
	Route 2	1563.3	3.61	38.03	26.33	0.17	0.52	2.58
	Route 3	1463.9	3.38	35.62	24.66	0.16	0.49	2.42
	Route 4	1574.8	3.63	38.31	26.53	0.17	0.53	2.60
Nov-00	Route 1	2923.8	6.75	71.13	49.25	0.32	0.98	4.83
	Route 2	3274.8	7.56	79.67	55.16	0.36	1.09	5.41
	Route 3	2837.6	6.55	69.04	47.79	0.31	0.95	4.69
	Route 4	3152.6	7.28	76.70	53.10	0.34	1.05	5.21
Sep-07	Route 1	1661.9	3.84	40.43	27.99	0.18	0.55	2.75
	Route 2	1637.4	3.78	39.84	27.58	0.18	0.55	2.71
	Route 3	1562.6	3.61	38.02	26.32	0.17	0.52	2.58
	Route 4	1541.1	3.56	37.49	25.96	0.17	0.51	2.55
Nov-07	Route 1	1661.2	3.83	40.42	27.98	0.18	0.55	2.75
	Route 2	1638.9	3.78	39.87	27.61	0.18	0.55	2.71
	Route 3	1246.2	2.88	30.32	20.99	0.14	0.42	2.06
	Route 4	1533.9	3.54	37.32	25.84	0.17	0.51	2.54

CONCLUSIONS

- Speed and ice condition are two main parameters which affect the fuel consumption.
- In tough ice the resistance is increased and the speed is reduced, the required power is higher than in open water.
- If there is no ice the ship will run faster and also consume more fuel.
- Higher fuel consumption might occur at high speed and low ice conditions as well as in tough ice at lower speed.

Further Works

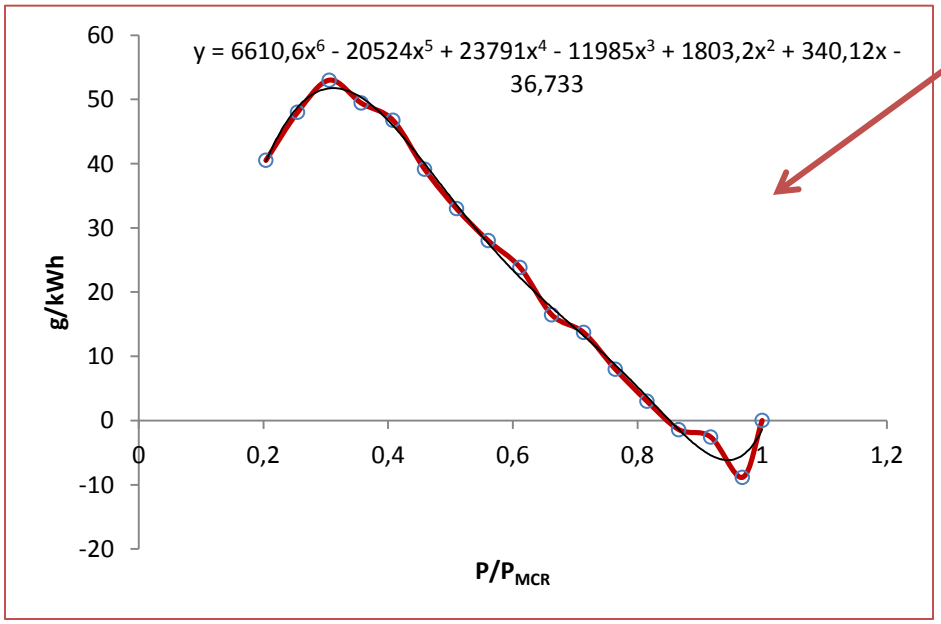
- Collect emission factors data
- Collect ship data: number of vessels, ship characteristics
- Develop a method to estimate the results with less parameters

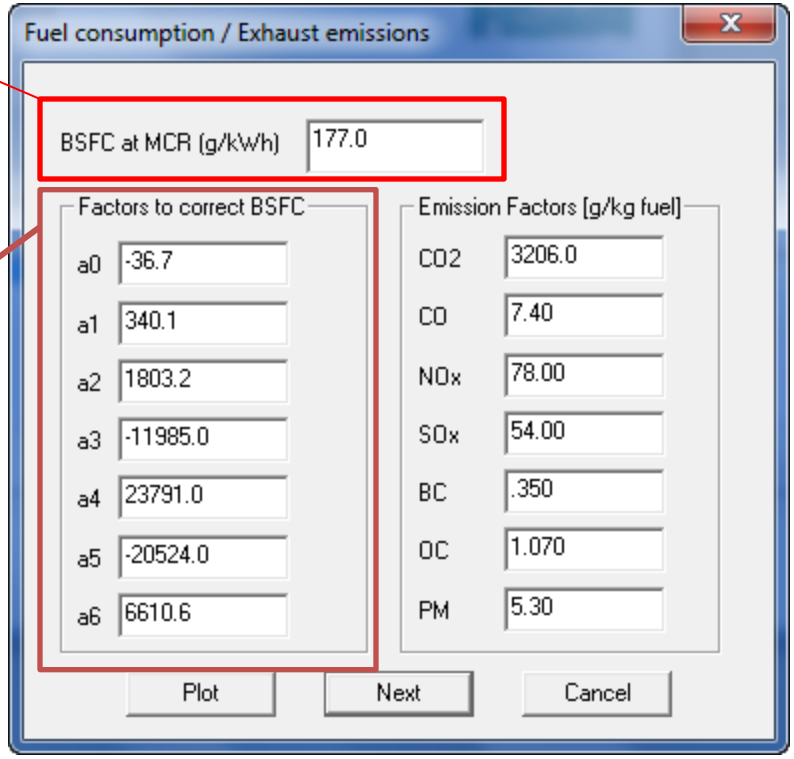
Thank you for your attention!

Improvement to the program

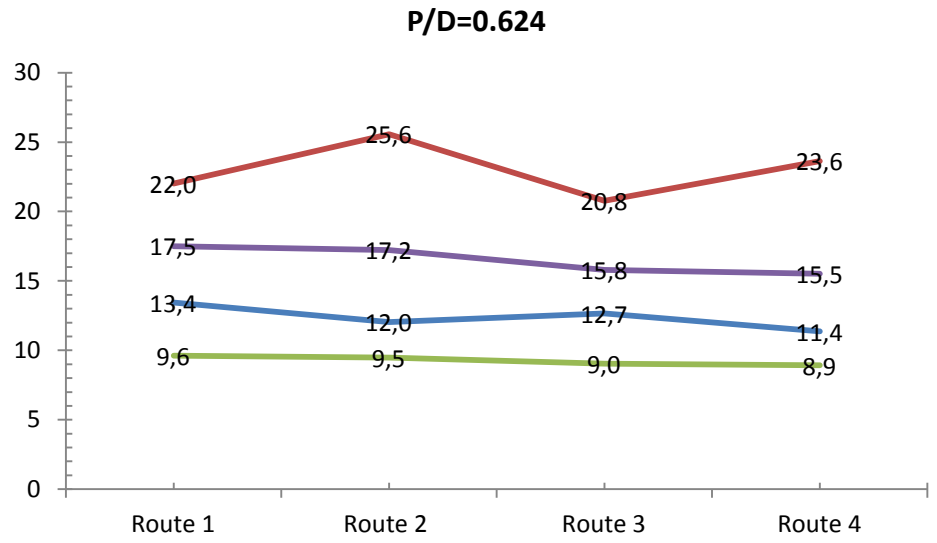
- Newly added input interface

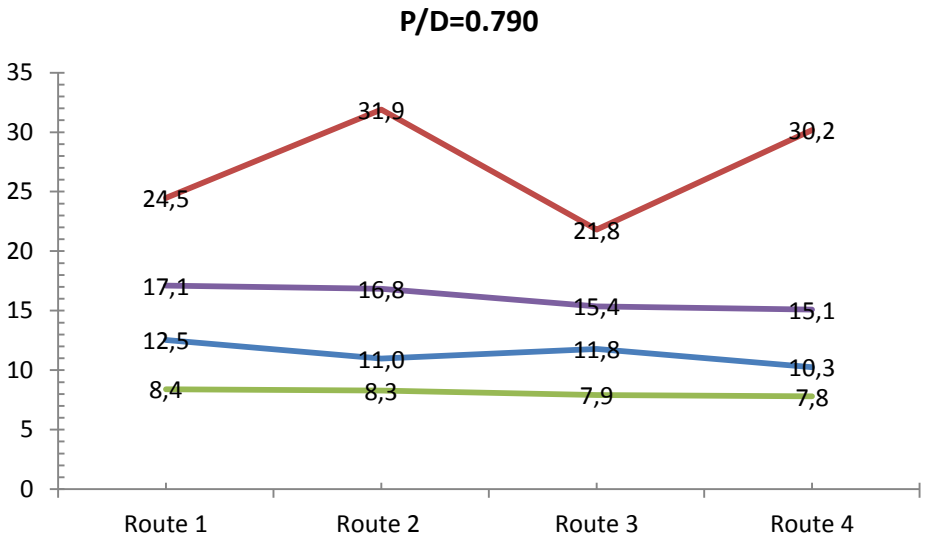
Standard BSFC at MCR

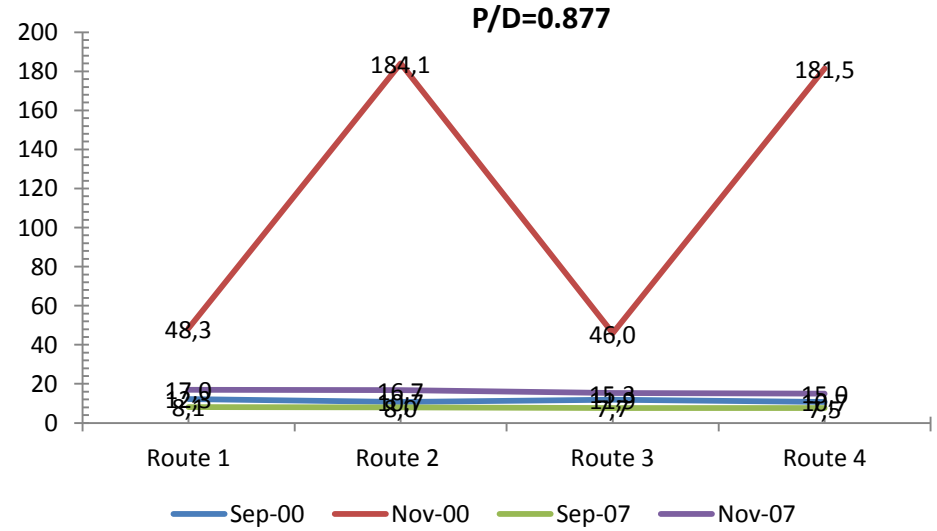




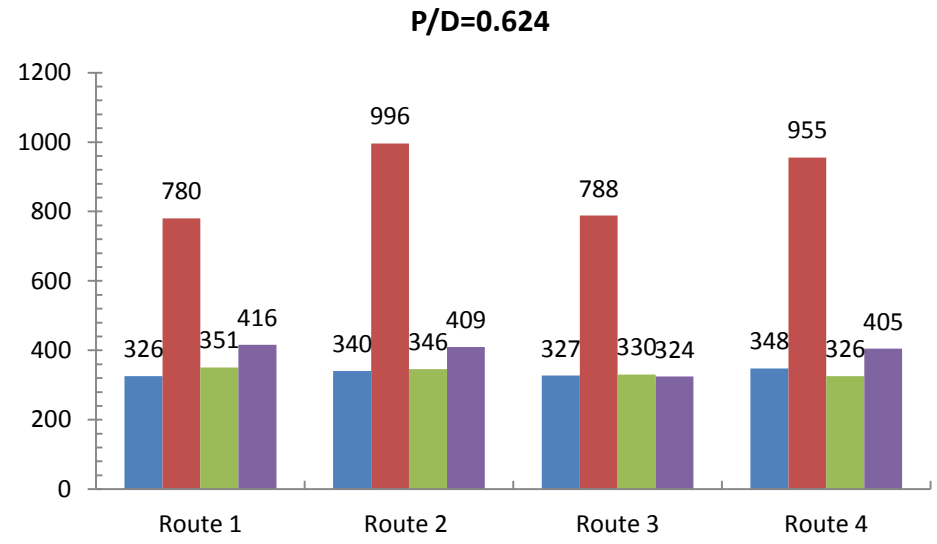
Travel times (Tanker 02: CPP)

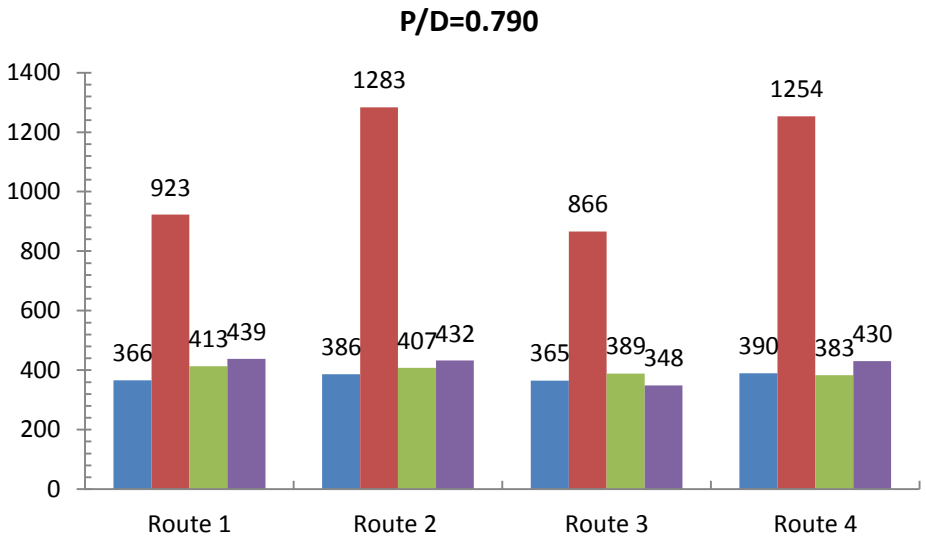


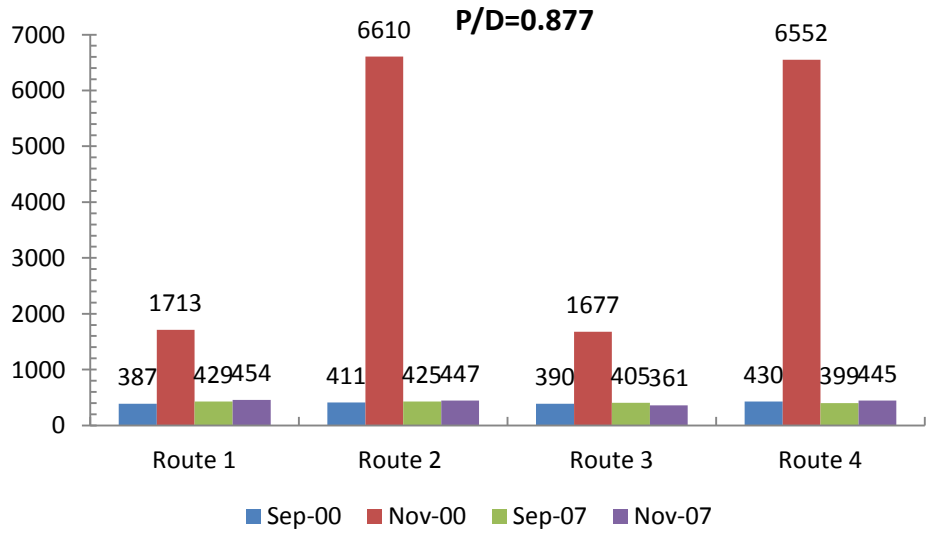




Fuel consumption (Tanker 02: CPP)







Fuel per day (Tanker 02: CPP)