Ecological Benefit and Navigational Safety Study based on S-10X Data

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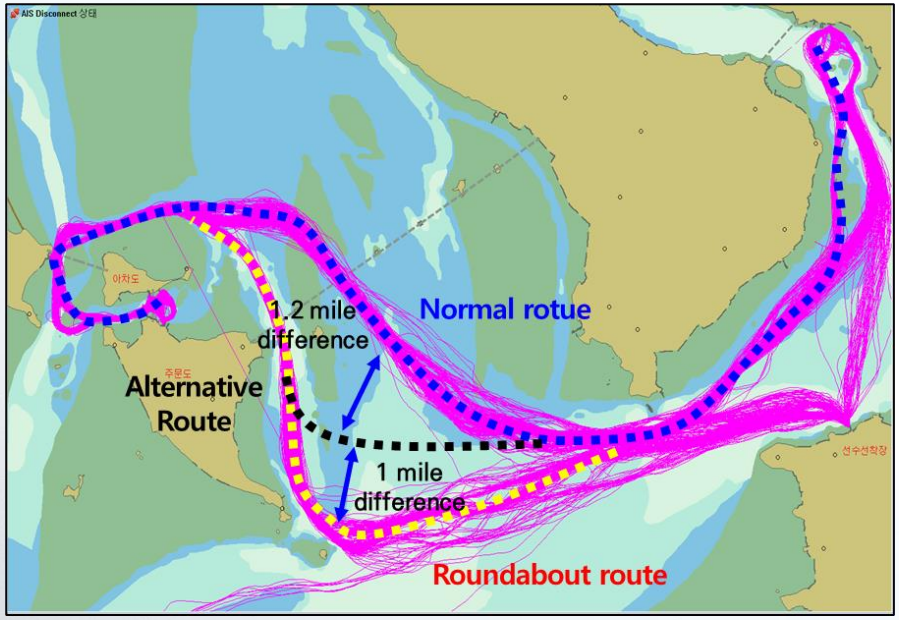
I Previous Research

Economic Efficiency with Route Planning

- KHOA reported “Evaluation of the economic feasibility with S-10X data” at the IHO 6th Council (October 2022) with 2 topics (Economic, Usability)
- With S-102/104 data, new alternative route for passenger ship was produced for existing normal route and roundabout route as a part of economic study
- Alternative route was 55% shorter than the roundabout route and the fuel consumption 45.5% saved, 124,186 USD saved annually.



Passenger ship Route	Roundabout route	Alternative route explored using S-100 data service
Estimated distance (m)	4,157	2,306
Distance difference between normal and roundabout/ alternative(NM)	2.2	1.2
Total number of navigation	2,190 rounds	
Expected number of roundabout/alternative route	1,196 rounds	
Fuel consumption per hour	1,000 liters	
Fuel cost per liter	$1.25 per liter (include 0.01% MGO tax)	
Economics analysis of coastal passenger ships	(Route distance) X (Numbers of Roundabout/Alternative route navigation) / (Vessel speed – 12kn) X (Fuel consumption per hour) X (Fuel cost per liter)	
	(A) **$273,209**	(B) **$149,023**
	(A) - (B) = **$124,186 (45.5% savings)** Total annual cost savings of $124,186 (45.5% savings) would occur when the alternative route was used	

I Previous Research

Usability Test of S-100 Service

- Usability test shows that the quantitative evaluation results (Duration Time, Number of Fixation, Number of Saccades) of the S-100 test bed system were excellent compared to the use of traditional products.
- The usability of the S-100 test bed system provides a higher usability compared to the traditional products in updating nautical products, navigational warning, and checking surface current in arrival port.

Test equipment

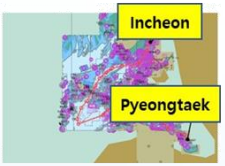

S-57 ECDIS

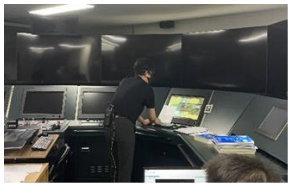

S-100 testbed system

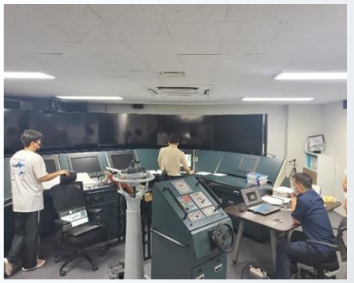

Eye tracker

Test scenario

- Task 1. Update of nautical products
- Task 2. Navigational warning
- Task 3. Route planning
- Task 4. Check the surface current
- Task 5. Confirmation of route and save










Ⅱ Ecological Benefit Study – Intro

Simulation Overview

- Time: Departure MokPo **(am 01:00)** -> Enter to JeJu **(am 05:30)**, around 5hr trip
- Sailing range: 148 km (approximately 92 miles)
- Tidal currents: **Maximum ebb** (predicted S-111 surface currents data)
- Ship: Passenger ship (ferry)
- Wave height: 0.2m (2yr average)

Ⅱ Ecological Benefit Study – Intro

Simulation Scenario

- **Normal Route Planning** : Only the changing time of falling and rising currents
  - After departing from Mokpo, proceed at full speed and adjust speed near Jeju
- **Optimal Route Planning with S-100** : When establishing a sailing plan, the operator can check the predicted currents (direction, current speed) on an hourly basis.
  - After checking the dynamic waterway information for each time zone provided by S-100, set the target speed for each section and arrive at Jeju.
- **S-111 Surface Currents with 1hr interval :** During sailing, there will be RPM differences under the influence of the flow.

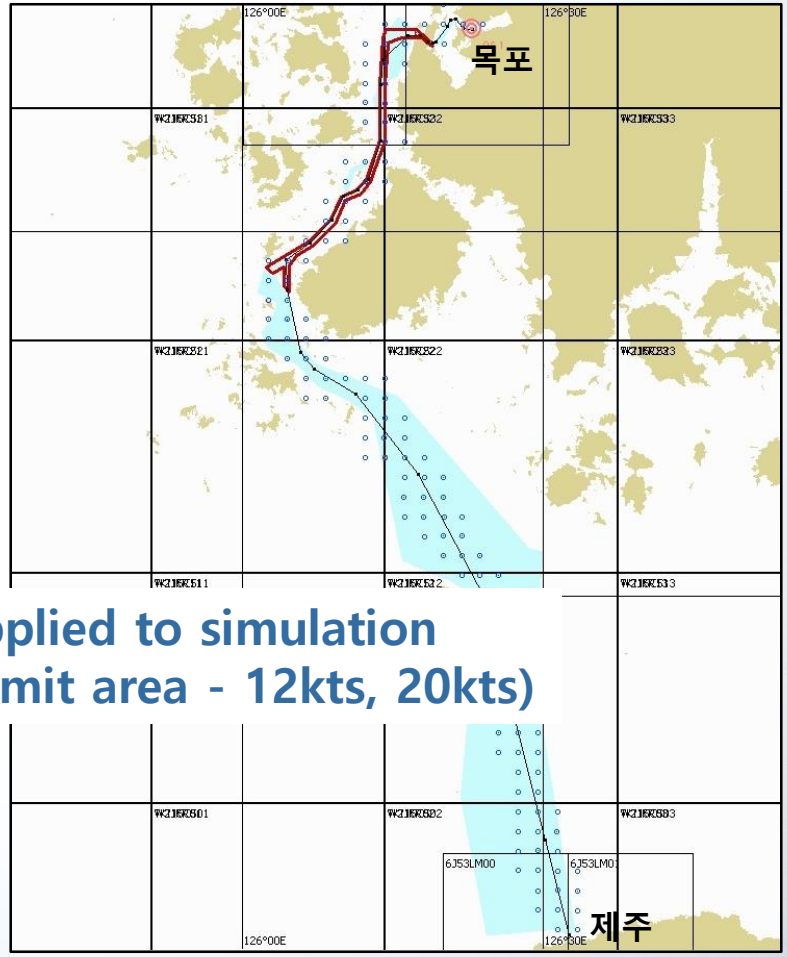
Ⅱ Ecological Benefit Study - Intro

Route Planning and Target Area

MokPo~JeJu Route Planning

W/P	Waypoint	Position		Course		Dist	To Go
		Lat.	Long,	of mokpo	of jeju		
1	국제 여객선(2부두)	34-46.50 N	126-22.90 E			0	92.5
2		34-46.60 N	126-22.02 E	098	278	0.8	91.7
3	목포대교	34-47.40 N	126-21.30 E	140	320	1.9	90.6
4		34-47.30 N	126-20.80 E	076	256	2.4	90.1
5	장좌도	34-46.80 N	126-20.50 E	026	206	3.1	89.4
6		34-45.50 N	126-19.30 E	037	217	4.8	87.7
7		34-45.40 N	126-19.00 E	068	248	5.2	87.3
8		34-45.53 N	126-18.54 E	108	288	5.4	87.1
9	목포등대	34-46.00 N	126-17.80 E	127	307	6.2	86.3
10		34-46.00N	126-16.50 E	090	270	7.4	85.1
11		34-44.00 N	126-14.00 E	045	225	10.3	82.2
12	시하도	34-42.00 N	126-13.80 E	005	185	12.3	80.2
13	마진도	34-37.40 N	126-13.80 E	000	180	17	75.5
14	율도	34-34.23 N	126.12.60 E	017	197	20.3	72.2
15		34-33.40 N	126-11.60 E	030	210	21.3	71.2
16		34-32.85 N	126-10.05 E	065	245	22.8	69.7
17	저도	34-30.90 N	126-09.00 E	030	210	26.1	66.4
18	양덕도						
19							
20	각흘도						
21	장죽도						
22		34-18.65 N	126-07.20 E	321	141	39.6	52.9
23	독거도	34-16.60 N	126-11.35 E	190	120	43.6	48.9
24		34-10.00 N	126-17.60 E	325	145	51.4	41.1
25	망도	33-59.80 N	126-24.20 E	329	149	63.2	29.3
26	제주 방파제	33-32.00 N	126-32.60 E	346	166	91.7	0.8
27		33-31.70 N	126-32.40 E			92.3	0.2
28	제주항 44번석	33-31.47 N	126-32.58 E			92.5	0

Target Area in Simulation



Official ferry route was applied to simulation including regulations (speed limit area - 12kts, 20kts)

Ⅲ Ecological Benefit Study – Results

Economical Comparison

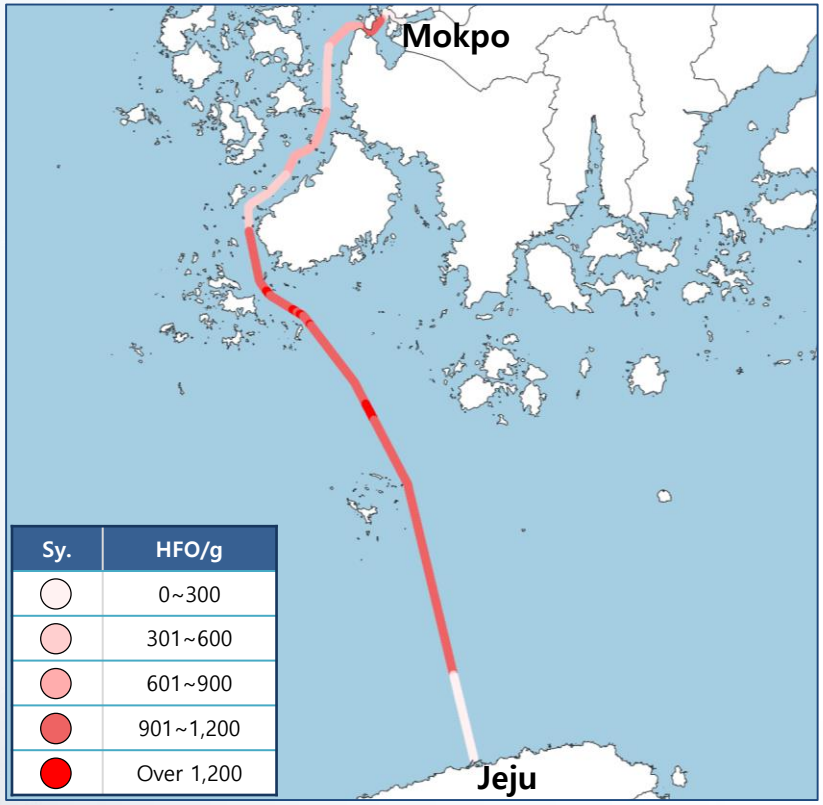
- Total sailing range was same for both scenarios; 148 km (approximately 92 miles)
- Both scenarios sailing took approximated 4hr 30min to satisfy real sailing schedule
- As the scenario 1 sailing with fixed speed, fuel consumption shows 13.02 ton
- However scenario 2 was designed for optimal routing plan, it saved 14.6% of fuel consumption

구 분	Scenario 1	Scenario 2
Total sailing range	148 km (92 miles)	148 km (92 miles)
Total sailing time	4hr 24min	4hr 26min
Average RPM	102.3	100.3
Average speed	STW 19.4kts / SOG 20.7kts	STW 19.0kts / SOG 20.5kts
Fuel Consumption	**13.02ton**	**11.12ton (▽ 14.6%)**

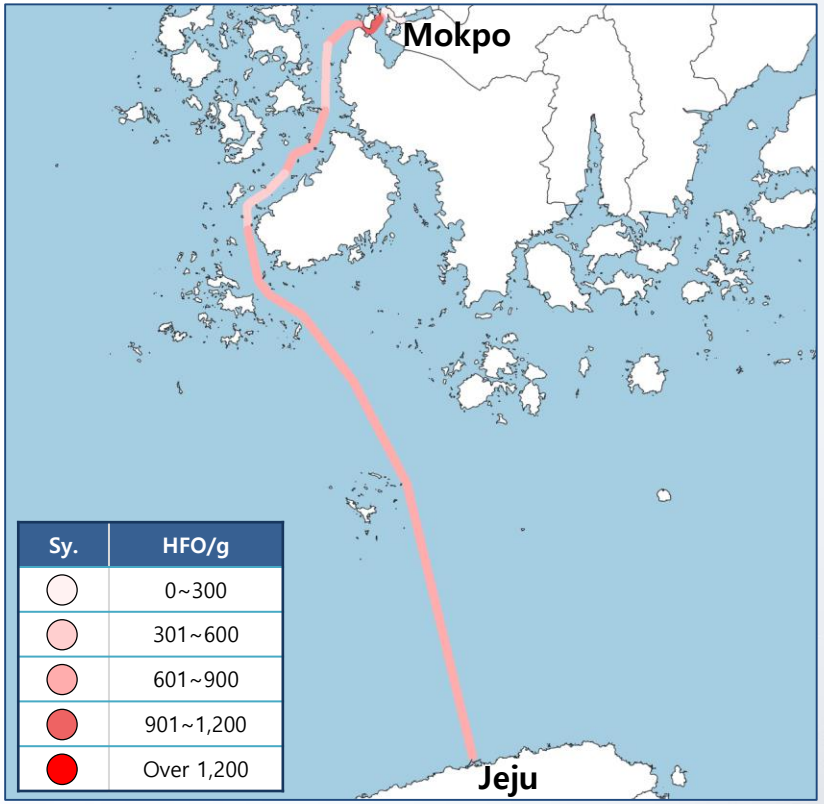
Ⅲ Ecological Benefit Study – Results

Fuel Consumption Map

Scenario 1



Scenario 2



Ⅲ Ecological Benefit Study – Results

Economic Analysis

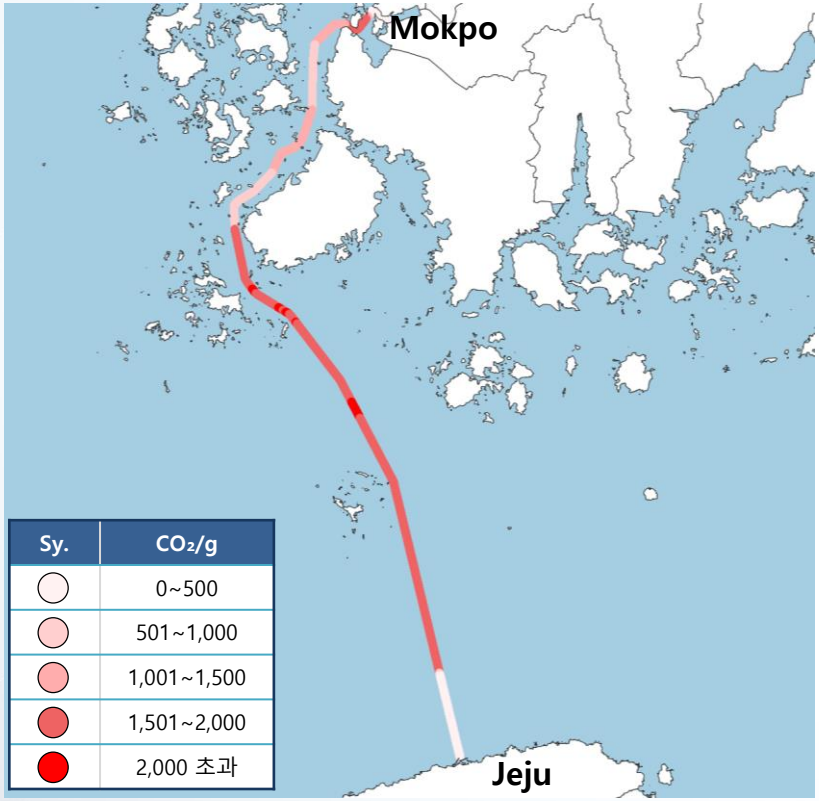
- Pollutant emissions were calculated using fuel consumption
- Air pollutants also decreased **similarly to a 14.6%** decrease in fuel consumption

	Scenario 1	Scenario 2
Fuel Consumption	13.02	11.12 (▽)
Carbon(CO_2)	40.54	34.64 (▽)
Nitrogen Oxide(NOx)	1.006	0.859 (▽)
Sulfur Oxides(SOx)	0.621	0.531 (▽)
Dust(PM)	0.094	0.081 (▽)
Methane(CH_4)	0.00065	0.00056 (▽)

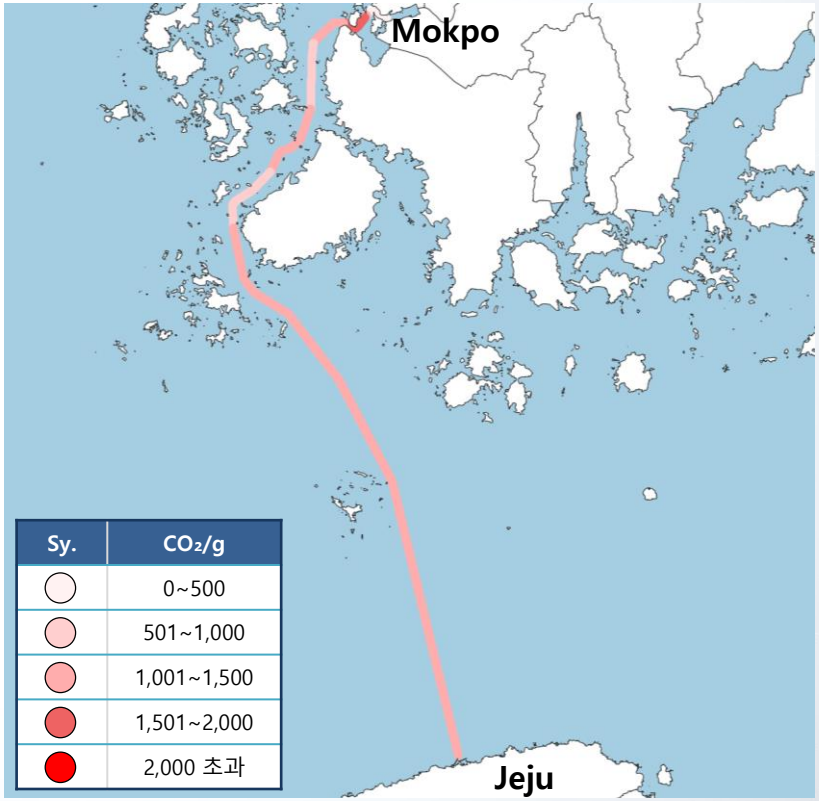
Ⅲ Ecological Benefit Study - Results

Carbon(CO_2) Emission Map

Scenario 1



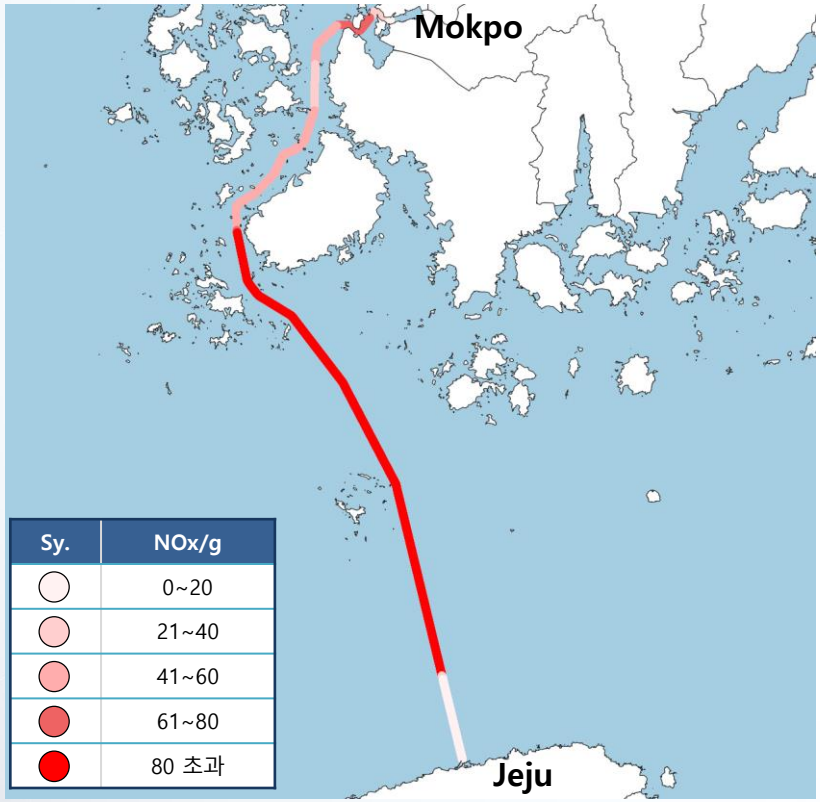
Scenario 2



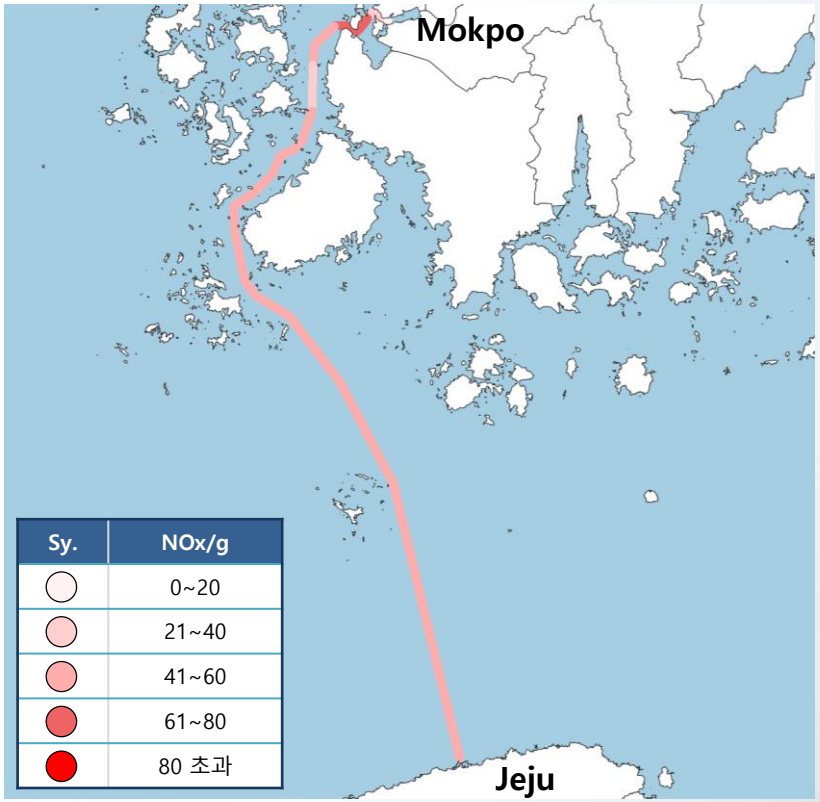
Ⅲ Ecological Benefit Study - Results

Nitrogen Oxide(NOx) Emission Map

Scenario 1



Scenario 2

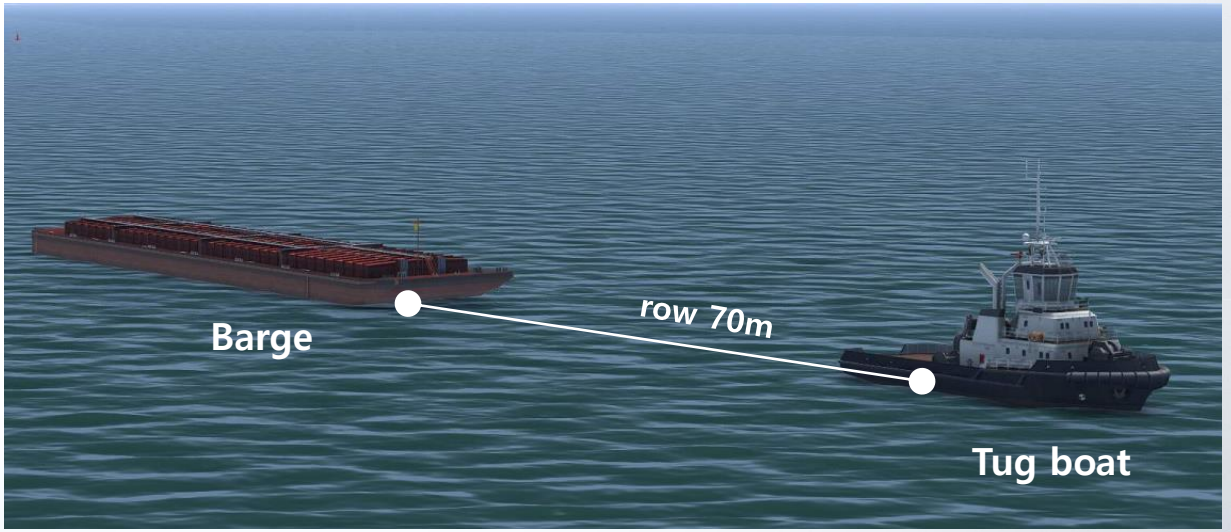


IV Navigational Safety Study – Intro

Simulation Scenario

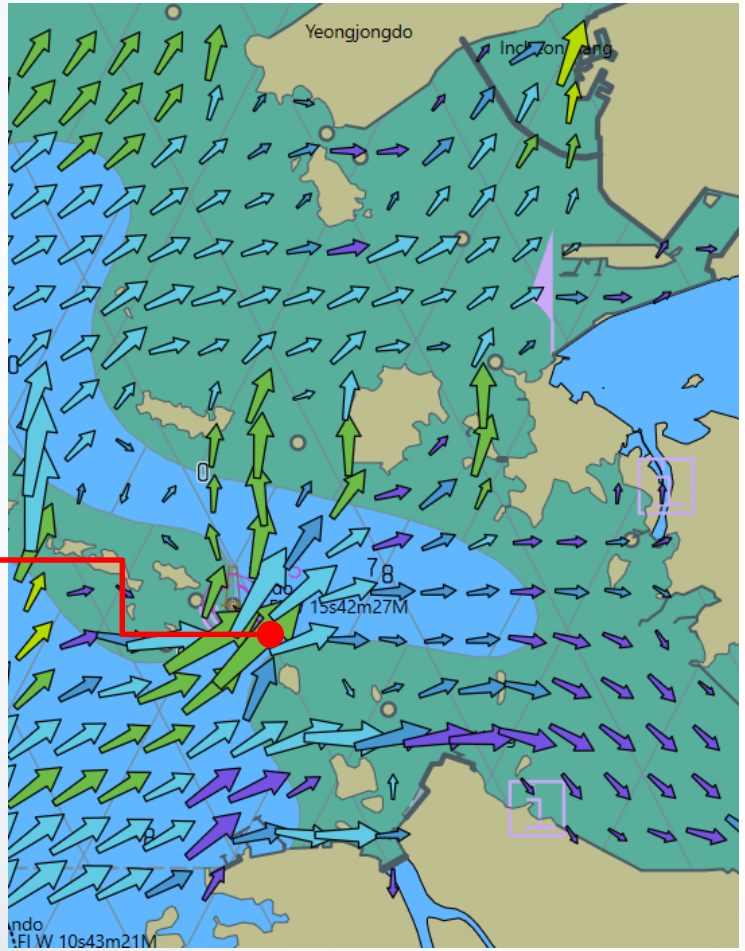
- Timeline : Max.flood('23. 1. 23. 3pm, 6.2kts), Max.ebb('23. 1. 23. 9am, 4.3kts)
- Target Area : Pyeongtaek ~ Incheon
- Ship : The tugboat row (tug boat with barge)

	Information	
Ship	Tug boat	Barge
Length	33.1m	76.2m
Width	12.0m	23.2m
Draft	4.4m	0.8m

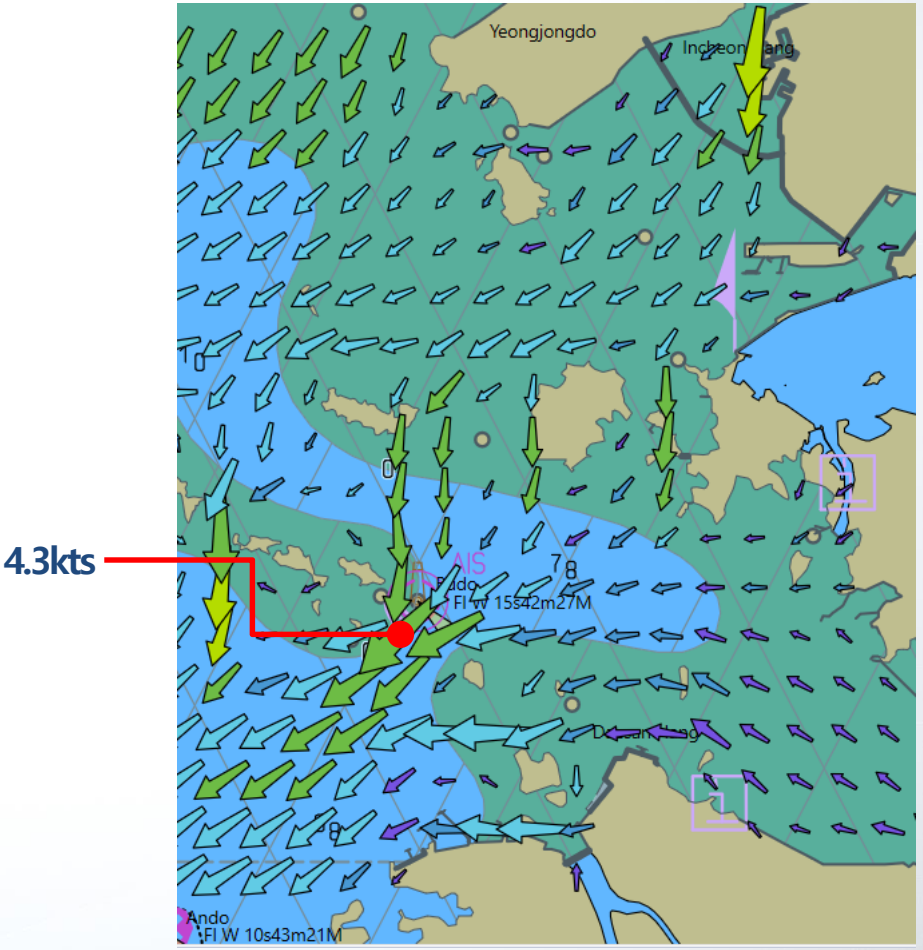


IV Navigational Safety Study – Intro

Simulation Scenario



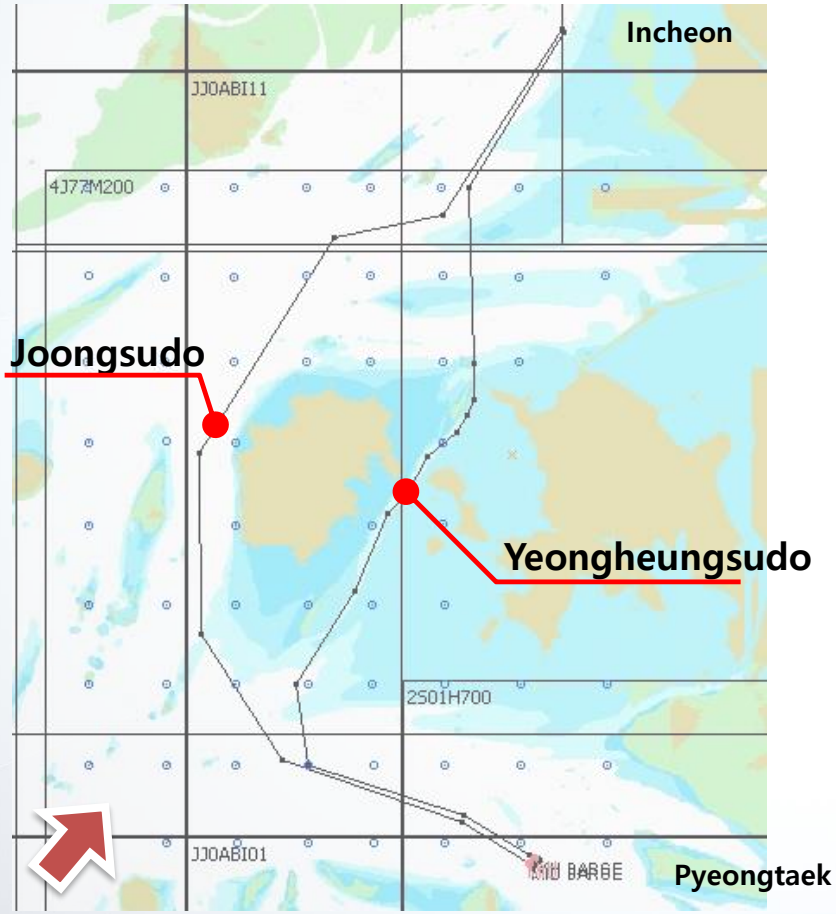
Max.flood ('23. 1. 23. 3pm, **6.2kts**)



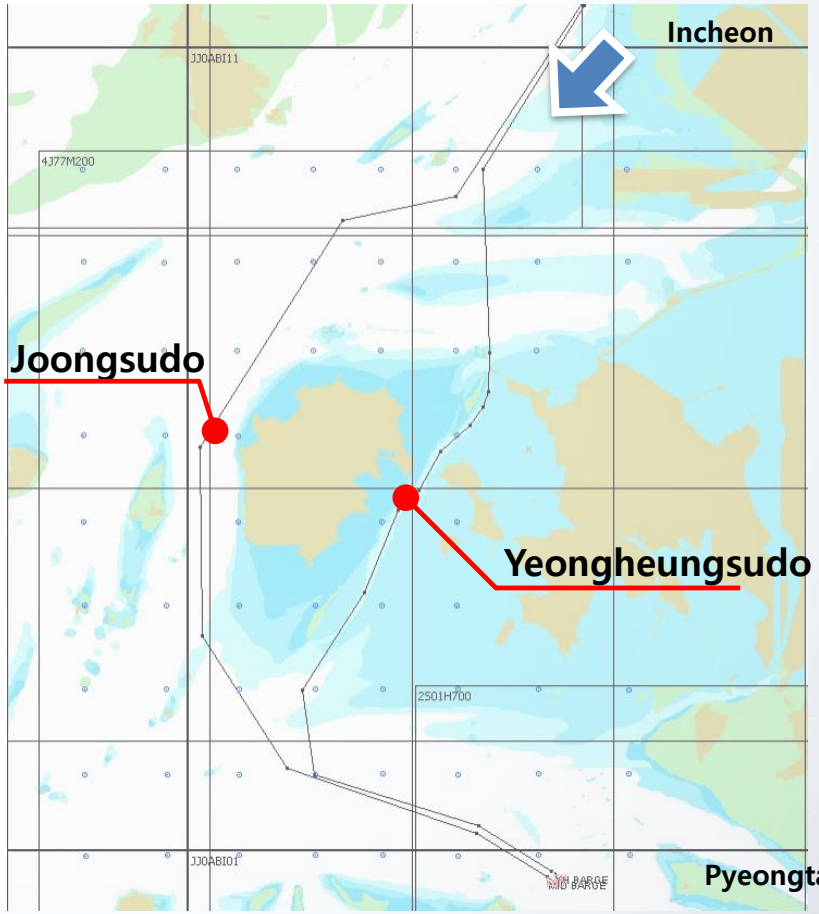
Max.ebb ('23. 1. 23. 9am, **4.3kts**)

IV Navigational Safety Study – Intro

Simulation Scenario



Max.flood



Max.ebb

V Navigational Safety Study – Results

Navigational Safety Comparison

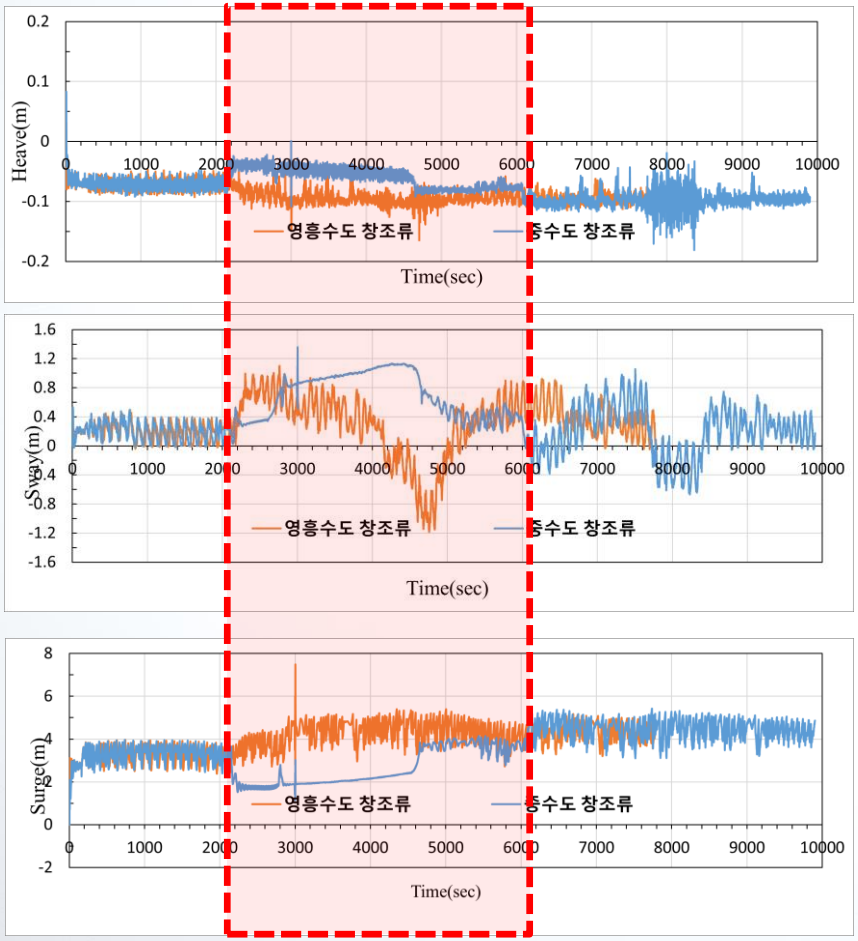
- In case of Max.flood, yaw movement is about **24% larger** than that of the Yeongheungsudo(waterway) when passing through the Joongsudo(waterway)
- Therefore, if the steering performance of the vessel operation is poor, it is judged that passage safety can be improved if the S-100 dynamic waterway information is provided to make route planning through the Joongsudo(waterway)

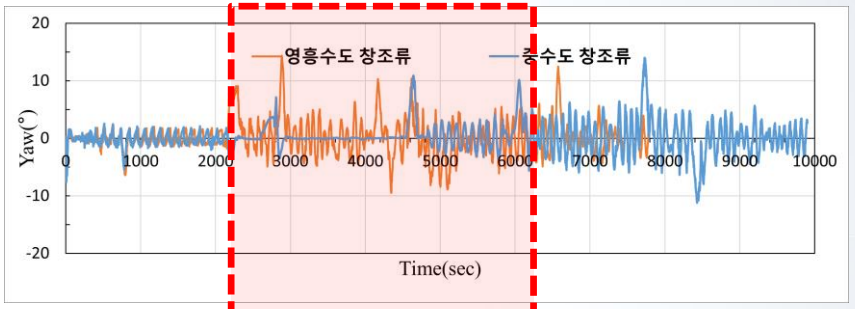
	Maximum flood		Maximum ebb	
	Yeongheung	Joong	Yeongheung	Joong
Surge	4.00m	3.47m	4.08m	4.04m
Sway	0.38m	0.44m	0.29m	0.26m
Heave	0.09m	0.08m	0.08m	0.08m
Yaw	2.07°	1.66°	1.07°	0.80°
Roll	0.51°	0.46°	0.31°	0.30°
Pitch	1.27°	1.25°	1.15°	1.15°

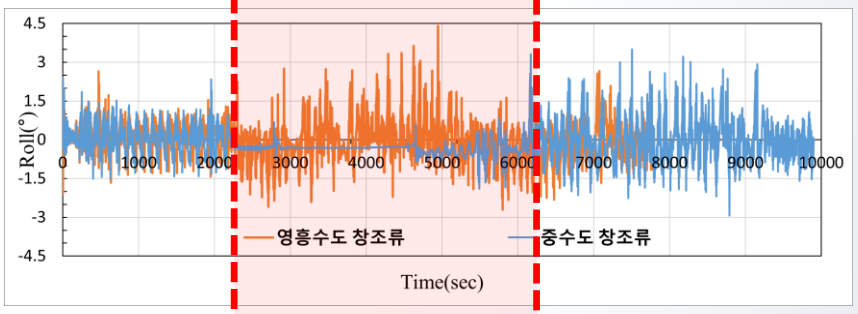
V Navigational Safety Study - Results

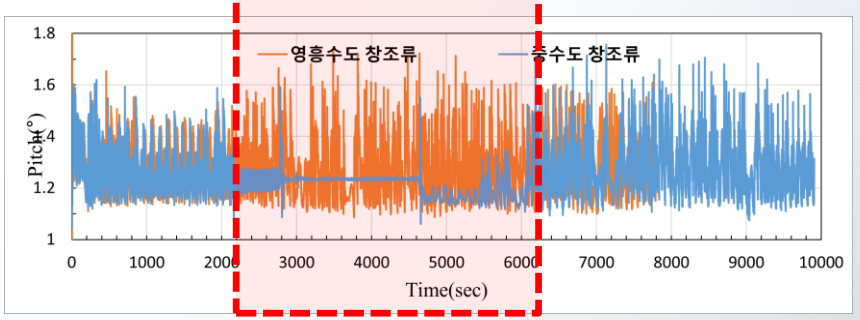
Navigational Safety Comparison

■ Yeongheungsudo(waterway)
■ Joongsudo(waterway)









VI Conclusion

Optimal Routing Plan with S-100 Data

- A ship's **optimal routing plan** is to minimize fuel consumption, which increases operation efficiency and lowers CO2 emission of the vessels.
- Establishing a ship's optimal routing plan is a major interest not only for shipping companies but also around the world.
- Currently, it is possible for shipping companies to use efficient engines that match the ship's engine performance, but there are limitations in establishing a perfect optimal route plan due to variables depending on the weather, current and any other circumstances of the navigation area.
- We expect that some of the limitations we face now can be overcome with the predicted/ realtime dynamic hydrographic information provided by the S-100 hydrological data.