다변적 물리요소를 고려한 인천항 정박지 개선 방안

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Introduction

- ✓ Ongoing port development in Incheon waters has led to changes in water depth and current velocity, affecting anchorage areas in Incheon Port. These changes raise safety and efficiency concerns for ships, necessitating operational improvements.
- ✓ Due to the complexity of Gyeonggi Bay's waters, environmental conditions vary significantly by location. Therefore, data observed at specific points may not be representative of the entire area.
- ✓ In this study, numerical model results were used to analyze total external forces, considering spatial and temporal characteristics, and to calculate the appropriate total tonnage for each anchorage area.

Data gathering and analysis

◆ Model component analysis

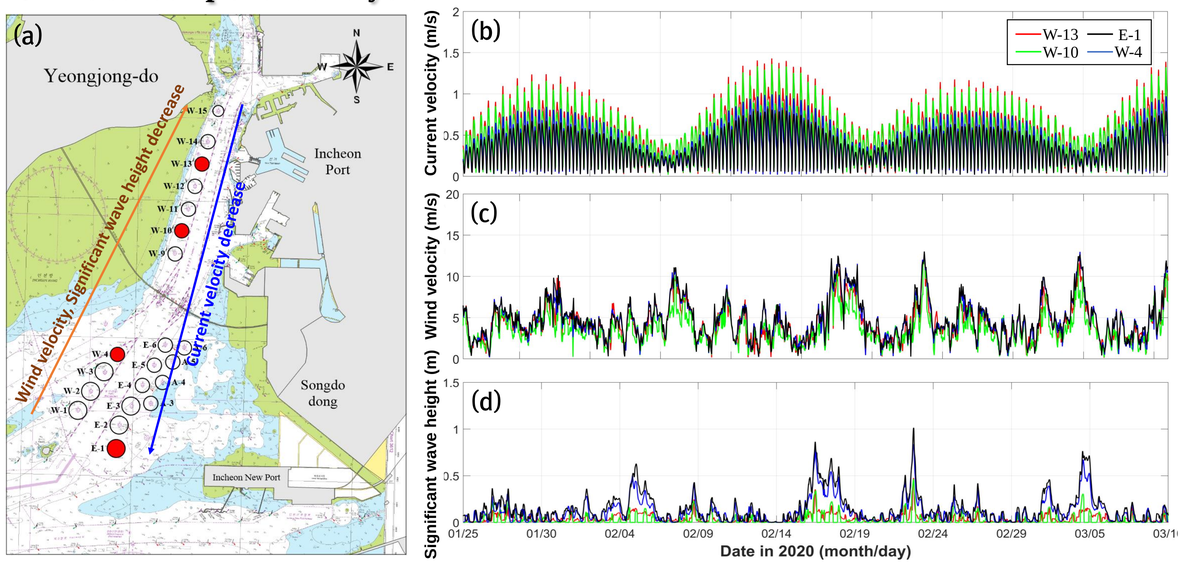


Figure 1. Incheon Port anchorage map (a), time series of current velocity (a), wind velocity (b), and significant wave height (d) at E-1, W-4, W-10, and W-13 from January 21 to March 10, 2020.

● Analyzing model data

- ✓ The model data used in the study were driven by the Finite Volume Community Ocean Model (FVCOM).
- ✓ Among the data for 21 anchorages, 4 anchorages showing distinct characteristics were selected and their components were compared.
- ✓ The significant wave height and wind speed decreased as the anchorage moved from the south to the north, which is believed to be a result of the weakening of waves as they propagate from the outer sea toward the coast.
- ✓ The current velocity decreased as the anchorage moved from the north to the south. This phenomenon appears to be a result of the narrow waterway widening after the Incheon Bridge.

◆ Analysis of Incheon Port ship data

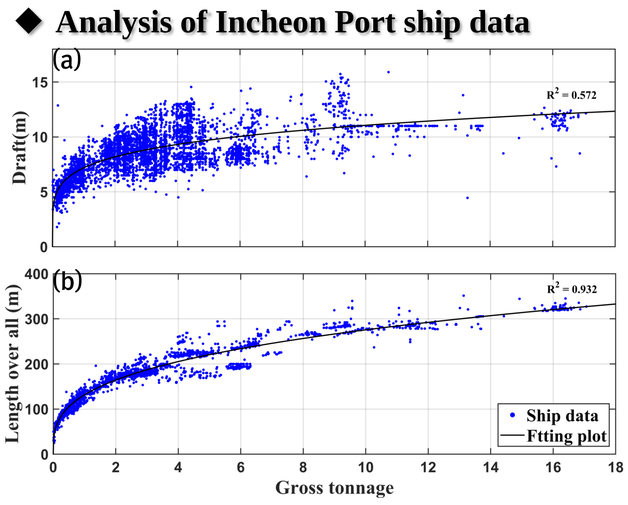


Figure 2. Correlation analysis of draft(a) and length(b) to gross tonnage of ships at Incheon Port from 2018 to 2022.

● Correlation Analysis

- ✓ The analysis of total tonnage and draft resulted in a low R-squared value of 0.572, suggesting that the ship is not always in a full-loaded state when using the facilities
- ✓ The analysis of total tonnage and LOA resulted in a high R-squared value of 0.932, which was used to calculate total tonnage based on ship length.

Table 1. Length in relation to gross tonnage

Gross tonnage (ton)	10K	20K	30K	40K	50K	60K	70K	80K	90K	100K	110K	120K	130K	140K	150K
Length over all (m)	131	164	187	205	220	234	246	256	266	275	284	292	300	307	314

◆ Collecting ship specifications

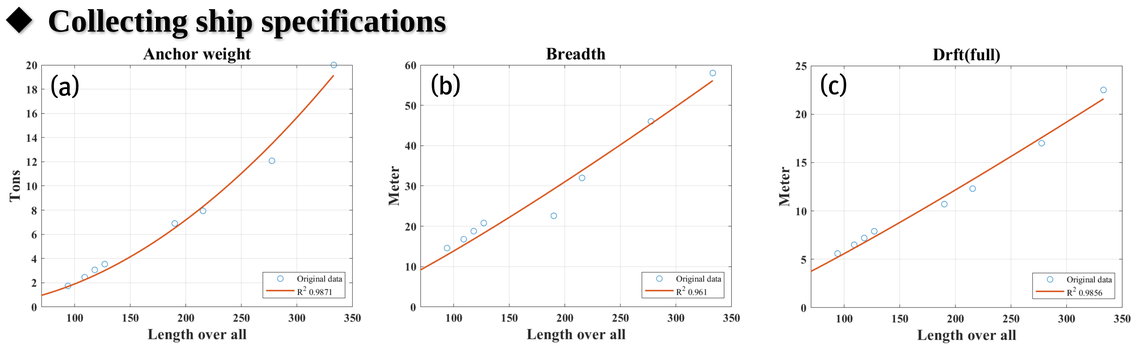


Figure 3. Correlation analysis between anchor weight (a), breadth (b) and draft (c) for 8 ships' lengths

- ✓ Prior studies involving 8 ships' specifications allowed us to define vessel parameters within the range of 10,000 to 150,000 tons.

Table 2. Ship specifications from 10,000 to 150,000 tons.

Length over all(m)	131	164	187	205	220	234	246	256	266	275	284	292	300	307	314
Gross Tonnage(ton)	10k	20k	30k	40k	50k	60k	70k	80k	90k	100k	110k	120k	130k	140k	150k
AT(m^2)	380	457	532	604	673	740	804	865	923	979	1032	1083	1130	1175	1218
AL(m^2)	470	582	694	805	914	1022	1129	1234	1339	1442	1544	1645	1744	1842	1940
Draft(m)	9	11	12	13	14	15	16	17	18	19	20	20	21	22	22
Breadth(m)	22.5	26.7	30.7	34.4	37.8	41	43.9	46.5	48.9	51	52.8	54.4	55.6	56.7	57.4
Anchor Weight(ton)	5.3	6.4	7.5	8.6	9.6	10.7	11.7	12.7	13.6	14.6	15.5	16.4	17.3	18.2	19.0
Chain Weight(ton)	0.073	0.095	0.115	0.134	0.152	0.169	0.184	0.198	0.211	0.223	0.233	0.242	0.25	0.257	0.263

External forces by anchorage

◆ Total external force calculation

$$F_a = \frac{1}{2}\rho_a C_a V_a^2 (A cos^2\theta + B sin^2\theta)$$

$$F_d = \frac{1}{2}\rho_c C_d g L h_d^2$$

$$F_c = \rho_c \lambda_c S\, V_c^{-1.825}$$

$$F_t = F_c + F_a + F_w$$

F_t: Total external force	V_a: Wind velocity	C_a: Wind force coefficients
F_a: Wind force	V_c: Current velocity	C_d: Drift force coefficients
F_c: Current force	h_d: Significant wave height	ρ_c: Density of seawater
F_d: Drifting force	g : Gravitational acceleration	ρ_a : Density of air
L : Length overall	λ_c: Friction coefficient	S : Wetted surface area
$A cos^2\theta + B sin^2\theta$: Projected wind area		

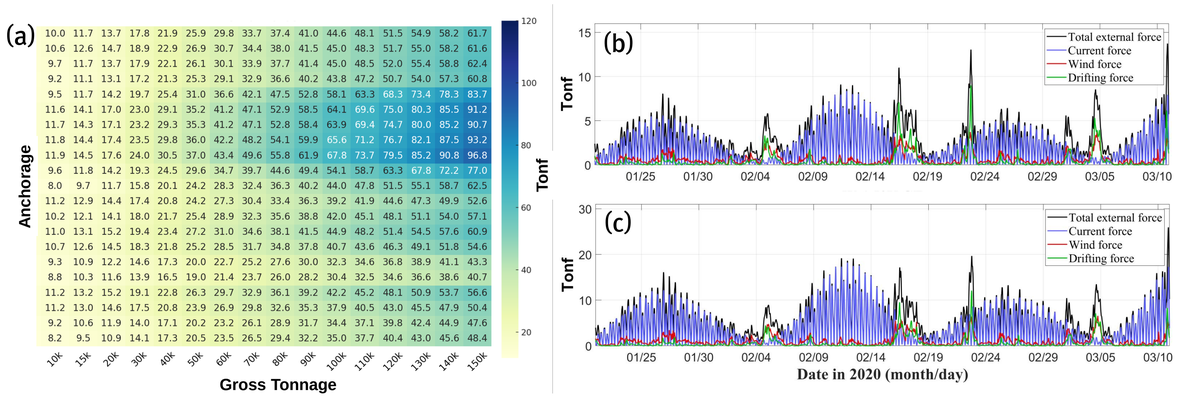


Figure 4. The total external force chart (a) displays gross tonnage on the x-axis, anchorage names on the y-axis, with color changing from yellow to navy blue based on force magnitude. It represents the time series of external forces (current force, wind pressure force, drifting force) for E-1, 100,000 tons (a), and W-1, 50,000 tons (b) Anchorage.

● Analysis of total external force results

- ✓ The analysis indicates that as ship size increases, the external forces on the hull also rise.
- ✓ In high current velocity regions like W-9 to W-13, there was a significant increase in external force magnitude
- ✓ At W-15, all external forces increased, resulting in the highest total external force.

Length overall by anchorage

◆ Calculation of anchor chain veering length

$$F_t <= F_h \qquad C = \sqrt{h(h + 2F_t/W_c)}$$

$$F_t <= \lambda_a w_a + \lambda_c w_c\, l$$

$$l = (F_t - \lambda_a w_a)/\lambda_c w_c$$

Ex) when the anchorage radius is 400 meters

$$\text{Length over all(Loa)} = 400 - (l + C)$$

F_h : holding power	
λ_a : holding power coefficient of anchors	
λ_c : holding power coefficient of chain	
w_a : Submerged weight of the anchor	
w_c : Submerged weight of the chain	
l : length of anchor chain laid on the seabed	
C : Catenary	
h : height from the hawse pipe to the seabed	

- ✓ To prevent anchor dragging, the holding power should be greater than the total external force. This condition can be used to calculate the length overall (Loa)

◆ Calculation of new seedlings and estimation of tonal class

Table 3. Loa eligible for anchorage use

Name	Standard	Result	Increadse	Percentage(%)
W-1	50000	120000	70000	140
W-2	50000	120000	70000	140
W-3	50000	120000	70000	140
W-4	30000	40000	10000	33
W-9	30000	30000	-	0
W-10	30000	20000	-	0
W-11	20000	20000	-	0
W-12	15000	20000	5000	33
W-13	15000	20000	5000	33
W-14	15000	30000	15000	100
W-15	2000	-	-2000	-100
E-1	100000	110000	10000	10
E-2	10000	120000	110000	1100
E-3	10000	120000	110000	1100
E-4	5000	30000	25000	500
E-5	50000	30000	-20000	-40
E-6	20000	40000	20000	100
A-3	2000	40000	38000	1900
A-4	2000	40000	38000	1900
A-5	2000	40000	38000	1900
A-6	4000	40000	36000	900

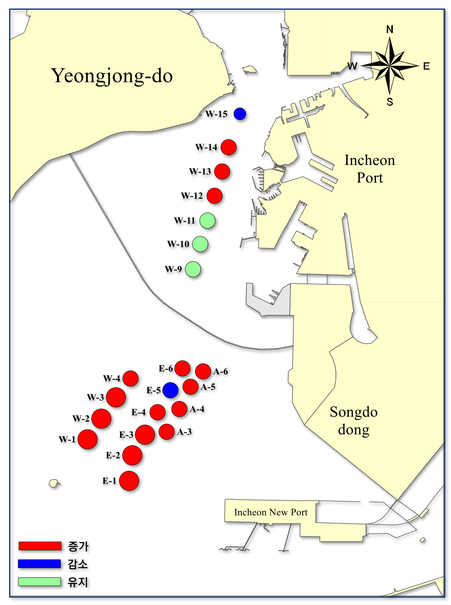


Fig 5. The anchorage layout diagram indicates that the red indicate an increase in tonnage, the blue indicate a decrease, and the green indicate the maintenance of gross tonnage

- ✓ When applying the eligible Length overall for anchorage use to Table 1, we expect an increase in available tonnage at 16 anchorages, a decrease at 2 sites, and no change at 3 locations. The most significant increase is anticipated at A-3, A-4, and A-5, while W-15 is expected to yield unsuitable results for usage.

Conclusions

- ✓ The analysis results suggest an overall increase in gross tonnage at anchorages. However, due to the relatively short duration of the numerical simulation, these results may not fully represent the entire period.
- ✓ In the future, I will compare these results with long-term observational data or extend the numerical simulation period to calculate external forces applied to anchorages, aiming to derive results that can better represent the region