Document Version: v1.0.0 (Technical & Strategic Integration English, Published)
Project Code: MaeBara-100B-NSR

MaeBara: Seizing Global Maritime Leadership through AI-Native Infrastructure

Intelligent Logistics Integration Framework for Global Maritime Leadership in the Northern Sea Route Era

Strategic Necessity & Impact

- **Protection of Maritime Sovereignty:** Eliminates the risk of national wealth leakage (approx. 55.1 billion KRW annually) and secures independent maritime data sovereignty.
- **Busan Port as an AI Hub:** Pre-emptively transforms Busan Port into an AI-driven intelligent port to solidify its position as a global transshipment hub.
- **Maximization of Logistics Capacity:** Increases Busan Port's CAPA by **+9.3M TEU** through AI optimization alone.

Technical Moat

- **Proven Efficiency:** 32.4% reduction in container rehandling via T-CAG TYO.
- **Route Optimization:** 459.3km reduction and 12.8hr time saving on the Busan-Rotterdam route (NSR-OptiNav v0.3.0).
- **Execution Power:** Proven AI full-stack development through OpenAI Hackathon victory and 15-day MVP implementation.

Technical White Paper

1. Introduction: Shifting Paradigms in Global Logistics

1.1 Maritime Logistics Bottlenecks and Economic Losses

Maritime transport, the backbone of global trade, faces immense inefficiencies due to aging operational systems. Specifically, the "Container Stacking Problem" is an **NP-hard** complexity, where existing heuristics fail to find global optimal solutions [1]. Busan Port currently suffers annual losses of over 50 billion KRW due to rehandling inefficiencies.

1.2 Northern Sea Route (NSR) and Proactive AI Infrastructure

The opening of the NSR is a new global logistics artery. Following the **Digital Twin** concept proposed by Grieves (2014) [2], MaeBara aims to secure data sovereignty and lead global standards by converting Busan Port into an intelligent AI hub.

2. Core Technical Architecture: Intelligent Hybrid System

2.1 PDDL-based Intelligent Digital Twin (T-CAG Digital Twin)

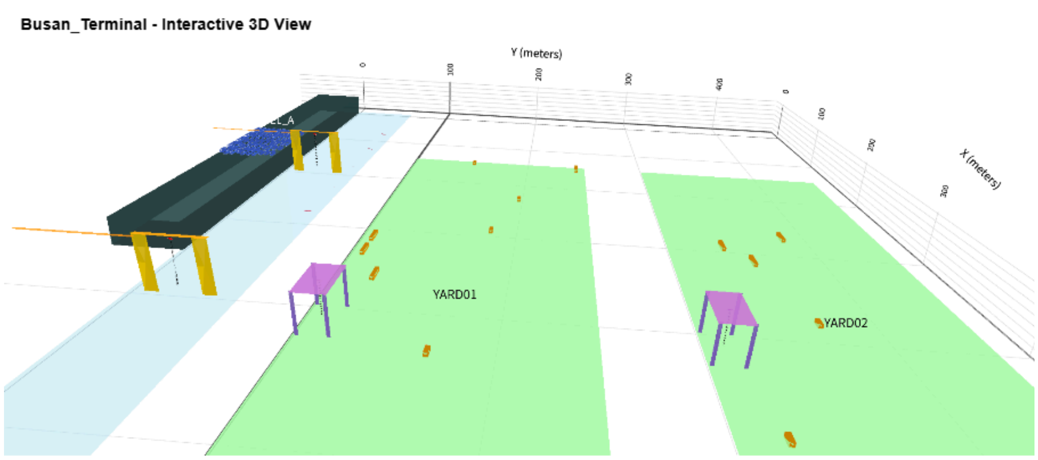

Figure 1. Screenshot of T-CAG Digital Twin port

We define port rules using **PDDL (Planning Domain Definition Language)** to build an integrity-verified virtual environment [3].

- **Symbolization of State (Predicates):** Logical symbolization of container positions for maximum computational efficiency.
- **Action Masking:** Filtering impossible actions based on physical constraints.

2.2 T-CAG Yard Orchestrator (TYO): Predictive Stacking Engine

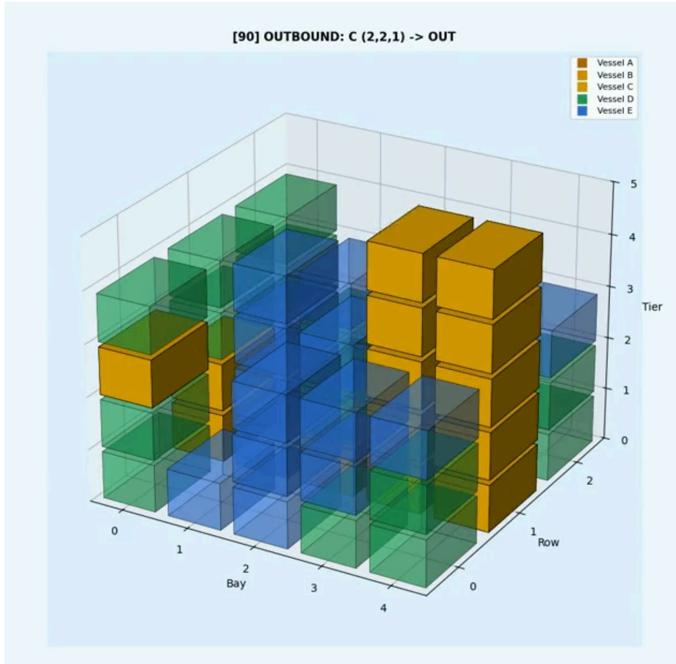

Figure 2. Screenshot of T-CAG Yard Orchestrator (TYO)

TYO utilizes Deep Reinforcement Learning (DRL) to link real-time yard states with future schedules [4].

Cost Function:

$$Total\_Cost = \sum(C_{in} + C_{out} + C_{rehandle})$$

To prevent inefficiency, we apply a powerful weight to 'rehandling' operations:

$$10 + (Source\_Tier + Dest\_Tier) \times 2$$

2.3 NSR-OptiNav: Intelligent Route Optimization Engine

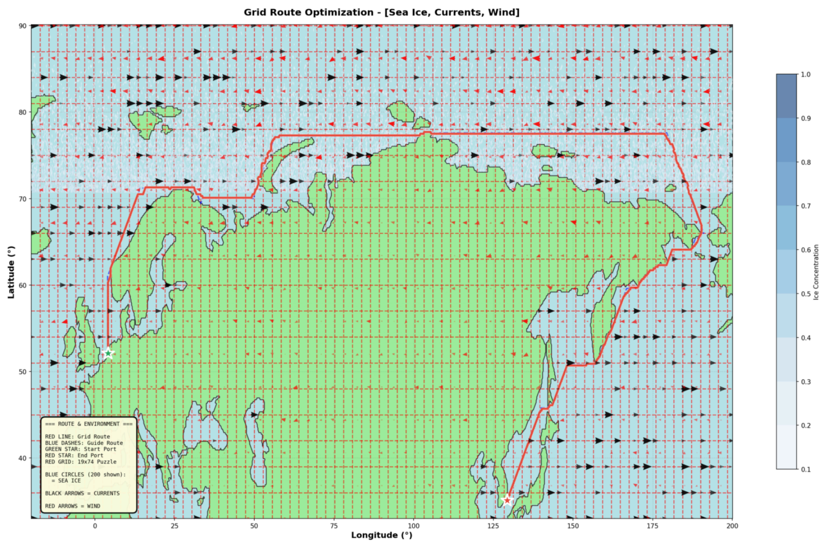

Figure 3. Screenshot of NSR-OptiNav navigating result

- **Ocean Digitization:** Integrating NSIDC and NOAA data (Ice, Current, Weather) into a layered grid.
- Hierarchical Routing: 1. Strategic Guide (Theta*): Line-of-sight optimization to overcome grid constraints [6].
  2. Tactical Fitting: Micro-path fitting based on high-resolution grid analysis.
- **Vessel Digital Twin:** Numerical modeling of non-linear resistance based on vessel Ice Class.

3. Empirical Results: Value Proven by Data

3.1 Port Operational Efficiency (T-CAG TYO)

Simulation results in a **3x5x5 standard environment** show that the TYO engine outperforms existing Greedy Rule-based stacking [5].

Table 1. Simulation results based on terminal operational data

Algo	Steps	Inbound	Outbound	Rehandle	Total Cost	Rehandle
T-CAG	**175**	80	72	**23**	**841**	**31.9 %**
GREEDY	186	80	72	34	1017	47.2 %

- **Rehandling Count (Rehandle):** Achieved a **32.4% reduction** compared to the existing Greedy policy (34 times → 23 times).
- **CAPA Expansion:** Confirmed the potential to secure an additional **9.3M TEU** of processing capacity for Busan Port by reducing unnecessary equipment downtime.

3.2 Route Optimization (NSR-OptiNav v0.3.0)

Table 2. Busan-Rotterdam route simulation results

Metrics	Traditional Guide Route	MaeBara (NSR-OptiNav)	Saved
Total Distance (km)	15,399.4 km	14,940.1 km	-459.3 km
Total Time (Days)	18.00 Days	17.46 Days	-0.54 Days (-12.8h)
Fuel Consumption (Tons)	2,757.2 tons	2,674.9 tons	-82.3 tons
Overall Efficiency (%)	Baseline	-	2.98% ↑

- **Route Efficiency:** Achieved a **459.3km reduction** compared to the simple shortest path through environment-integrated optimization.
- **Voyage Time:** Secured the possibility of a **12.8-hour reduction** through sea ice avoidance and current-riding strategies.

4. Integrated Vision: The 'Tesla Model' of Maritime Logistics

- **Data Virtuous Cycle:** Continuous AI model enhancement through platform data accumulation.
- **AI-Native Infrastructure:** Reverse-engineering where software defines hardware specifications.
- **Digital Twin Control Center (DTCC):** A single neural network connecting ships and ports.

5. Financial and Ecosystem Expansion Strategy

- **Data-driven Maritime Insurance:** Usage-Based Insurance (UBI) models based on real-time risk analysis.
- **Ship Finance Risk Management:** Providing AI-predicted profitability and asset value data to financial institutions.

6. Sustainable Competitive Advantage (The Moat)

- **6.1 Unrivaled Technical Barriers:** Deep research capabilities and the ability to implement MVPs at overwhelming speed (15 days).
- **6.2 National Strategic Value:** Transforming Busan Port into the world's most efficient AI port to lead the NSR era.

7. Conclusion: Setting a New Standard

MaeBara aims to be the "brain" of Korea's maritime logistics. Planting AI in Busan Port is the most certain investment to stand at the forefront of the upcoming logistics revolution.

References

[1] Gharehgozli, A. H., et al. (2014). "A review of real-time scheduling of container terminal operations." European Journal of Operational Research.
[2] Grieves, M. (2014). "Digital Twin: Manufacturing Excellence through Virtual Factory Replication." White Paper.
[3] McDermott, D., et al. (1998). "PDDL - The Planning Domain Definition Language." Yale Center for Computational Vision and Control.
[4] Mnih, V., et al. (2015). "Human-level control through deep reinforcement learning." Nature.
[5] Kim, K. H., & Hong, G. P. (2006). "A heuristic rule for relocating blocks." Computers & Industrial Engineering.
[6] Daniel, K., et al. (2010). "Theta*: Any-angle path planning on grids." Journal of Artificial Intelligence Research.

Document History

- v1.0.0: Technical & Strategic Integration, Published (2025.12)
- Author: Han Sang-do (MaeBara Corp.)
-