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Outline

1. Autonomous Ship – NYK’s Motivation

2. Feasibility Study of Autonomous Ship (Deep Sea Vessel)

3. A Framework of Action Planning System (APS)

4. Summary
1. Autonomous Ship – NYK’s Motivation
Obviously human factor is the key to reduce accident
2. Feasibility Study of Autonomous Ship
(Deep Sea Vessel)
2. Feasibility Study of Autonomous Ship (Deep Sea Vessel)

Level of Autonomous Navigation for Economic Evaluation

Level of Autonomous Navigation

1. Current
   - Seafarer
   - Onboard Equipment

2. Manned Autonomous
   - Onboard Equipment
   - Seafarer
   - Seafarer
   - Seafarer

3. Remote
   - Onboard Equipment
   - Onboard Equipment
   - Onboard Equipment
   - Remote Operator

4. Unmanned Autonomous
   - Onboard Equipment
   - Onboard Equipment
   - Onboard Equipment
   - Onboard Equipment

Information Acquisition → Analysis → Planning → Approval

Quote:
2. Feasibility Study of Autonomous Ship (Deep Sea Vessel)

Assumption for Economical Evaluation

(1) Equipment (CAPEX and OPEX)

➢ The onboard equipment and the onshore facility cost, which are required additionally to the autonomous ship are estimated.
➢ The reliability and redundancy of the system are taken into account.
➢ Assumed life of equipment as 10 years

<table>
<thead>
<tr>
<th>Type</th>
<th>Additional On-board Equipment</th>
<th>Additional On-shore Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Current</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.Manned Autonomous</td>
<td>Action Planning System 1 $300,000</td>
<td>Remote Control Center $500,000</td>
</tr>
<tr>
<td>3.Remote</td>
<td>Action Planning System 2 $500,000</td>
<td>Remote Monitor $50,000</td>
</tr>
<tr>
<td>4.Unmanned Autonomous</td>
<td>Action Planning System 3 $700,000</td>
<td></td>
</tr>
</tbody>
</table>

* The annual maintenance cost of additional equipment is estimated as five percent of the equipment cost.
## Assumption for Economical Evaluation

### (2) Personnel Expenses (OPEX)

- The manning of bridge team and additional costs are estimated as below.
- For the remote navigation, five remote operators are set to comply with the ILO regulations.
- The Master and other crew members involved in other operations are excluded from this consideration, assumed being onboard as they are.

<table>
<thead>
<tr>
<th>Type</th>
<th>Officer $5,000/month</th>
<th>Rating $2,000/month</th>
<th>Remote Operator $5,000/month</th>
<th>Additional Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Current</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2.Manned Autonomous</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3.Remote</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>Mooring &amp; Cargo Operation $1,000 per operation per person</td>
</tr>
<tr>
<td>4.Unmanned Autonomous</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
2. Feasibility Study of Autonomous Ship (Deep Sea Vessel)

Assumption for Economical Evaluation

(3) OPEX (communication and cyber security)

- In case of remote navigation, high speed satellite communication to transmit visual images from the ship to shore is assumed.
- As for unmanned autonomous navigation, the communication cost for monitoring from shore is assumed.
- In addition, countermeasure cost for cyber security is assumed.

<table>
<thead>
<tr>
<th>Type</th>
<th>Additional Communication Cost</th>
<th>Cyber Security Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Current</td>
<td>None</td>
<td>$1,000/month</td>
</tr>
<tr>
<td>2.Manned Autonomous</td>
<td>None</td>
<td>$2,000/month</td>
</tr>
<tr>
<td>3.Remote</td>
<td>$40,000/month</td>
<td>$10,000/month</td>
</tr>
<tr>
<td>4.Unmanned Autonomous</td>
<td>$10,000/month</td>
<td>$10,000/month</td>
</tr>
</tbody>
</table>
(4) Accident Loss

- Assumptions are based on the P&I and H&M insurance payments
- Occurrence frequency and average loss amount of navigational accidents, as 0.02 times per year per vessel, and $300K per case.
- 90 percent of the losses can be reduced by manned autonomous and remote navigation, and 95 percent of the losses can be reduced by unmanned autonomous navigation

<table>
<thead>
<tr>
<th>Type</th>
<th>Occurrence Frequency</th>
<th>Average Loss Amount per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Current</td>
<td>0.02 times/year · vessel</td>
<td>$60,000</td>
</tr>
<tr>
<td>2.Manned Autonomous</td>
<td>0.002 times/year · vessel</td>
<td>$8,700</td>
</tr>
<tr>
<td>3.Remote</td>
<td>0.002 times/year · vessel</td>
<td>$8,700</td>
</tr>
<tr>
<td>4.Unmanned Autonomous</td>
<td>0.001 times/year · vessel</td>
<td>$3,000</td>
</tr>
</tbody>
</table>
2. Feasibility Study of Autonomous Ship (Deep Sea Vessel)

Result of Economic/Practicability Evaluation

At the current stage, manned autonomous navigation has the highest economic performance with practicability.

- Combining autonomous mooring/cargo operation
- Improvement of fuel efficiency due to drastic changes in hull form can increase the economics of remote and unmanned autonomous.

Cost efficiency
<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Manned Auto</th>
<th>Remote</th>
<th>Unmanned Auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidents</td>
<td>Base</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workload</td>
<td>Base</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cyber risk</td>
<td>Base</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total reliability</td>
<td>Base</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. A Framework of Action Planning System (APS)
NYK group currently aims to conceptualize Action Planning System as the first stage of autonomous navigation in 2019.

- Control unit/Actuators
- Human’s verification
- Action Planning Unit
- ECDIS/ARPA
- Sensors
- Human in the loop
- Action Planning Analysis
- Information integration (by Integrated Navigation System)
- Remote Concierge
- Value added Information
4. Summary
Manned Autonomous Navigation as a Waypoint

Manned autonomous navigation can be positioned as a “technological waypoint” towards fully autonomous and remotely controlled navigation.

4. Summary

Human Flexibility

Risk Monitoring

Risk Evaluation

Man-Machine I/F

R&D

Technology Retrofit

Fully Autonomous ship

Manned Autonomous Navigation (APS)

Remote Control
NYK Group’s R&D Projects around Autonomous Ship

4. Summary

Study on Navigation Support
- Algorithm Development with Deep Learning
  w/Kobe Univ. and MLIT
- AI Platform Development
  w/Univ. of Southern California
- Geometrical Navigation Model Development
- Navigation Evaluation Scheme Development

Onboard System Development
SIMS, J-Marine NeCST

Demonstration
(2018-2020) w/ MLIT etc.
Concept Development, Demonstration and Standardization utilizing Ship Maneuvering Support Functions and Remote Control

Study on collision risk judgement and autonomous operation
(2016-2020) w/ MLIT etc.
Technological Development on Collision Risk Analysis, Remote Control and Computer Vision

Survey of Regulatory Barriers on Autonomous Ship w/ JSTRA
Input for IMO MSC from Shipping Company’s perspective
Thank you very much for your attention