FOREMAST

Vessel Autonomy in Inland Waterways: Definitions and Building Blocks

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CCNR Degrees of Automation in Inland Navigation

Central Commission for Navigation on the Rhine: six-level classification framework (adopted 2018)

°	Degree Name	Definition - boatmaster role & system scope
0	**No Automation**	Human helmsman performs all dynamic navigation tasks, at all times. Automation limited to warning or assistance systems (e.g. radar installation).
1	**Steering Assistance**	Automation handles **context-specific steering tasks** (e.g. track-keeping along pre-defined lines, rate-of-turn control). *Human performs all remaining tasks*.
2	**Partial Automation**	Automation handles both **steering** and **propulsion** in specific contexts. Human helmsman manages all remaining navigation tasks and monitors continuously.
3	**Conditional Automation**	Automation performs **all dynamic tasks** including collision avoidance. Human helmsman must remain available and respond to requests to intervene or to system failures.
4	**High Automation**	Automation handles all tasks and fallback operations. **No expectation of human intervention**, shore-based Remote Operations Centre provides oversight.
5	**Full Automation**	Sustained, unconditional full automation under all conditions. No human helmsman expected to intervene under any circumstances. **Fully uncrewed operation**.

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The Seven Dimensions of Vessel Autonomy

Achieving autonomous inland navigation requires progress across seven interdependent dimensions

Technology

- Sensor fusion & situational awareness
- AI navigation
- Remote Operations Centre (ROC)
- 5G vessel-shore link
- Automatic berthing

Cybersecurity

- New attack surfaces from remote ops & 5G links
- EU AI Act high-risk classification
- No agreed conformity pathway yet
- Resilience-by-design

Infrastructure

- 5G maritime corridors
- Smart locks & bridges Shore-side ROC facilities
- AIS/digital waterway integration
- Significant CAPEX required for network scale rollout

Regulation

- CCNR automation degrees
- IMO MASS Code (mandatory 2032)
- EU AI Act (high-risk)

Business Case

- Significant crew cost savings
- Fuel efficiency through AI routing
- Incident reduction via collision avoidance
- New service models
- Modal shift incentives from road to IWT

Environment

- Enables zero-emission propulsion
- Optimised routing cuts fuel & CO_2
- Reduced noise footprint
- Greener port turnarounds

Social Acceptance

- Public & passenger trust
- Crew role transition
- Industry culture change
- Transparent safety Communication

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