DIWA Report

Sub-Activity 3.5: Guidelines on capturing Remotely Operated Vessels (ROV) and Autonomous Vessels (AV) for Inland Waterway Transport future planning

Version: V1 (Final Version), Oktober 2023
(Editorial Deadline: March 2023)

Main author: Project team Masterplan DIWA

Contributing: Generaldirektion Wasserstraßen und Schifffahrt
via donau – Österreichische Wasserstraßen-Gesellschaft mbH
Rijkswaterstaat
De Vlaamse Waterweg
Voies navigables de France

Co-financed by the European Union
Connecting Europe Facility

Main author: **Oltmann, Jan-Hendrik** - Federal Waterways and Shipping Administration (GDWS)

Contributing: **Van der Burgt, Therry**. Rijkswaterstaat

Co-funded by
the European Union

Table of content

Note: A dedicated *Executive Summary* has been omitted due to the brevity of the main part of these guidelines (four pages, including two figures) as well as to their orientation towards the general reader.

Co-funded by
the European Union

1 The advent of Remotely Operated and Autonomous Vehicles in relevant modes of transport

In all modes of transport under consideration the respective autonomous vehicles have arrived: there are under consideration or even (broadly) operational autonomous cars, autonomous trains, autonomous aircrafts, autonomous sea-going ships – labelled Maritime Autonomous Surface Ships (MASS) for precision sake by the International Maritime Organization (IMO) [IMO-MSC1-Circ1638] -, and autonomous inland waterway vessels. In principle, the same holds true for remotely operated vehicles.

Also, in all modes of transport, there have been (tentatively) defined various degree scales of vehicle automation leading up via the degree of remote operation to vehicle autonomy as the ultimate degree. Hence, when considering the potential impact of technologies in other modes of transport, which is the task of Sub-Activity 3.5, likewise the potential technological consequences of the advent of Remotely Operated Vessels (ROV) and Autonomous Vessels (AV) for the IWT fairway & navigation domain should be considered.

However, it can generally be observed that there are a large number of projects and developments ongoing in the domain of remotely operated and/or autonomous vehicles: To take those into consideration even only superficially, would certainly far exceed the scope. This would hold true even if only the relevant projects and developments related to sea-going vessels' autonomy were considered.[1]

Also, looking into the maritime domain alone, the major concerns regarding the sea-going ships' autonomy do not seem to lie with technology issues but rather with operational and regulatory issues: IMO has therefore prioritised their *IMO Regulatory Scoping Exercise (RSE)* [IMO-MSC.1/Circ.1638][2] and the *recent roadmapping of IMO's own work* on creating the identified operational and regulatory pre-requisites to allow for the (future) general introduction of autonomous sea-going ships [IMO-MSC105/20-Add.2,Annex28]. By the same token, IMO has issued 'Interim Guidelines for MASS trials' [IMO-MSC.1/Circ.1604].

Further, it can be observed generally, that technologies required for higher degree of automation via remote operation up to supporting vehicle autonomy are required to have *a (much) higher degree of certain quality parameters* (such as more stringent time behaviour, accuracy, integrity, and resilience) as opposed to when the *same* technologies are employed for traditionally operated vehicles/vessels. Hence, the difference can generally be expressed in different requirements sets for the *same* technology. But that does *not* constitute a new technology as such.

2 Generic vessels and generic functional centres

On the other hand, the advent of remotely operated vehicles/vessels as well as autonomous vehicle/vessels *requires to capture them conceptually from the outset* in order to be able to apply technologies to use for those applications in addition to their usefulness for traditionally operated vessels. Additionally, certain *new generic types of shore-based centres* need to be recognised from the outset. These enter the IWT fairway & navigation domain as shore-based stakeholder entities besides the established fleet management centres of shipping companies and besides the fairway infrastructure and are also operated by or on behalf of shipping companies.

Therefore, a *conceptual framework in generic terms* was created for seamlessly capturing all generic types of vessels as well as all relevant types of generic centres conceptually operative in the IWT fairway & navigation domain – well-known existing and new ones. These relevant generic operational entities in the IWT fairway & navigation domain are shown in the following figure.

---

[1] A recent study identified a number of over 90 internationally relevant projects or developments going on in that domain [Hey 2022].

[2] Which has even created resonance with the International Telecommunication Union (ITU) when setting up their preliminary agenda for the World Radiocommunication Conference 2027 (WRC-27), namely recognising 'that the International Maritime Organization (IMO) has initiated a regulatory scoping exercise for the use of maritime autonomous surface ships (MASS)' ([ITU-WRC2019-Res-812], considering g).

Co-funded by the European Union

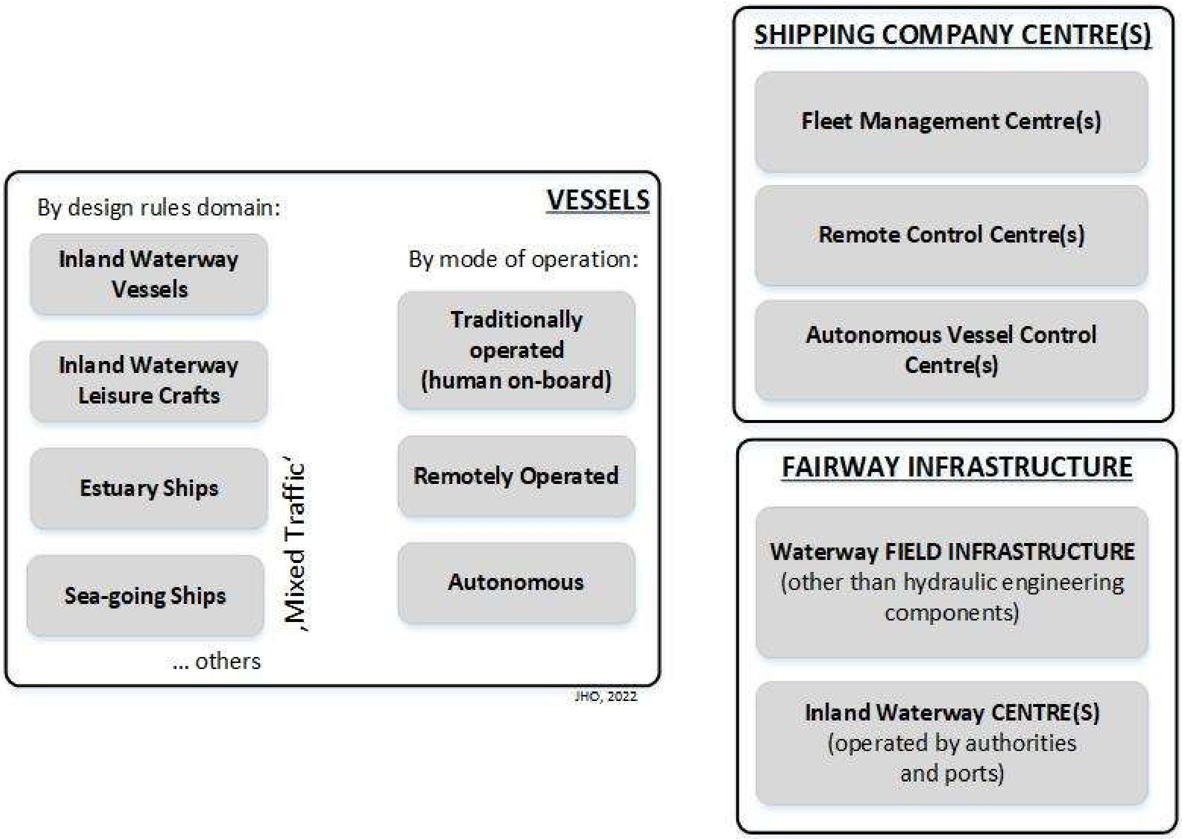

Figure 1: Relevant operational entities in the IWT Fairway & Navigation domain

The terms in Figure 1 are defined solely for the purposes of the present DIWA project; there may be different names used outside that scope to designate the same functionality. For the vessels it was roughly possible to find the two discerning criteria ('discriminators') by a) the design rule domain these vessels are subject to when operating in the inland waterway domain and b) mode of operation.

- Generic vessels by design rules domain mainly are *inland waterway vessels, inland waterway leisure crafts, estuary ships*, and *sea-going ships*. Design rule domain means to say, that there are specific legal/regulatory bodies defining what a vessel of this rule domain should consist of and carry as a carriage requirement. Here, the present and/or future legal/regulatory situation regarding digital electronic equipment is of particular relevance, and that may differ in different rule domains. In certain areas of the IWT Fairway & Navigation domain, there are mixed traffic situations between those different types.
- Generic vessels by mode of operation:
  - A *Traditionally operated vessel* is a vessel the navigating functions of which are performed by a human on-board by using appropriate Human-Machine-Interfaces (HMI) designed for that task. The degree of automation supportive of that task is encapsulated within the 'traditional operation' and is therefore irrelevant here as long as the human on-board is in charge of the vessel's navigation.
  - A *Remotely Operated Vessel (ROV)* is a vessel the navigating functions of which are performed remotely as the regular case from a *Remote Control Centre* (RCC) by a human at that centre. Whether an ROV is actually manned or unmanned is irrelevant in regards to its navigating functions as long as they are performed remotely as the intended regular case. ROV appears to be an established term beyond DIWA's scope, too.
  - An *Autonomous Vessel (AV)* is a vessel the navigating functions of which are performed autonomously as the regular case by an appropriate machinery of the vessel itself without on-board human interaction. Whether the AV actually is manned or unmanned is irrelevant in regards to its navigating functions as long as they are performed by the ship-board machinery as the intended regular case. It is assumed that it will be required that AVs are subject to a constant *Autonomous Vessel Monitoring & Contingency*

Response functionality performed at an *Autonomous Vessel Control Centre (AVCC)* while navigating autonomously. As part of the contingency response, an AV may fall back to become an ROV (or even a traditionally operated vessel, for that matter).

- Generic shipping company centres:
  - *A Remote Control Centre (RCC)* is a shore-based centre that performs the remote operation of an ROV and is operated by or on behalf of the shipping company that also operates the ROV(s). RCC appears to be an established term beyond DIWA's scope and is used here for that reason, although remote control, strictly speaking, may be limited in scope compared to remote operation.
  - An *Autonomous Vessel Control Centre (AVCC)* is a shore-based centre that monitors and controls an AV and is operated by or on behalf of the shipping company that also operates the AV(s). Since an AV, by its very definition, does not need a human operation or control in regular cases, there is still a requirement that the AV is constantly monitored and contingency response is active in non-regular modes of operation or even malfunction of the AV. Hence, Autonomous Vessel Monitoring & Contingency Response is the main functionality to be performed by the AVCC. Since an AV may fall-back to an ROV as part of the contingency response, the AVCC may also fall-back to an RCC.

3 Resulting operational relationships and the consequentially required functional and physical links

Amongst all technology families considered, the above generic definitions and the distinctions implied by them will be recognisable most prominently at the *radio communication technologies*, because they establish *functional and physical link(s)* between the participating entities, which in turn satisfy all communication needs of the *operational relationships* existing in the IWT fairway & navigation domain. With the advent of the ROVs and AVs, a number of new operational relationships appear, the most relevant of which are shown in the following figure generically.

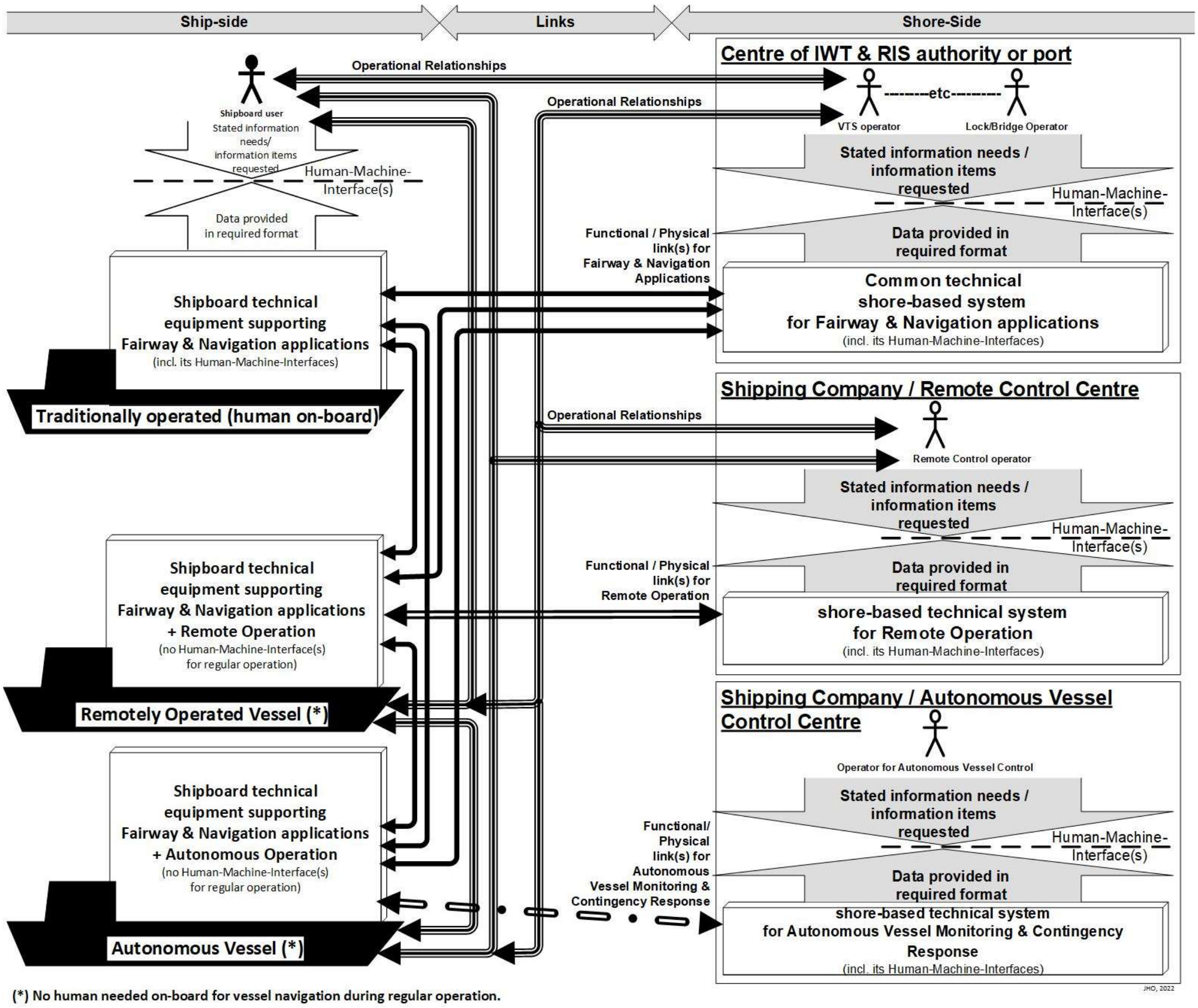

Figure 2: Operational relationships and required functional/physical links due to the advent of remotely operated and autonomous vessels

The news to the IWT Fairway & Navigation domain is in particular: *There are now and will be increasingly in the future Human-to-Human, Human-to-Machine, and Machine-to-Machine operational relationships **on the entity level** of the IWT Fairway & Navigation domain.*[3]

From this certain recommendations follow that are given in the Annex.

[3] So far human-to-machine operational relationships and machine-to-machine operational relationships have existed almost exclusively *on the component level*, such as expressed by the well-known concepts of an HMI or a Machine-to-Machine (M2M)-Interface. Note as an example, that even co-operative technologies like the Automatic Identification System (AIS) so far provided a M2M-interface via the 'AIS VHF data link' as a physical link *on component level, only*, although between different vessels both of which were traditionally operated.

Co-funded by the European Union

4 Glossary of terms

This Glossary lists definitions of and explanations to important terms used in these guidelines,

Accuracy 'Degree of conformance between estimated parameter at a given time and its true parameter at that time.' ([IMO-MSC.1/Circ.1575], Annex, page 29).

Centre A part of a shore-based organisation dedicated to and set apart for the provision of certain functionalities – here: relevant for shipping - and which is staffed to that purpose with adequately trained personnel and equipped with technical entities required to adequately support the functionalities provided at the centre.

Co-operative technology is a technology where both the vessels and the field infrastructure of fairway or waterway need to be equipped appropriately with corresponding components in order to allow for the desired functionalities. Any kind of radio communication technology is co-operative by definition, for example. With the increase of the operational relationships to be supported by functional and physical links provided by co-operative technologies and with the increase of the digitalisation level, co-operative technologies will be proliferated, which in turn has specific consequences and results in requirements to be met.

Estuary ship is a vessel that has been designed and equipped in accordance with the rules in force at estuaries, if introduced by the competent authority to cater for the specific situations in estuaries.

Field Infrastructure (of fairway or waterway) is a summary term used in the context of DIWA to generically describe all kind of (digital) electronic technical entities and components deploy along or for a fairway or waterway for (digital) electronic interaction with vessels. If vessels need to be equipped specifically for that (digital) electronic interaction with field infrastructure, the technology used for that interaction is called co-operative.

Functional link uses certain technical protocols and encodings in addition to (a) Physical Link(s) to establish data exchange channels with certain relevant characteristics. Relevant characteristics of the data transmission determined by Functional Links are regularly in particular identification of participants, session-orientation, security, and resilience. A Functional link may still be agnostic of the contents and purposes of the data transmitted, depending on the operational purpose it is designed for or tailored too.

Human-Machine-Interface (HMI) 'The part of a system an operator interacts with. The interface is the aggregate of means by which the users interact with a machine, device, and system. The interface provides means for input, allowing the users to control the system and output, allowing the system to inform the users.' ([IMO-SN.1/Circ.288], App. 1)

Inland waterway vessel is 'a vessel intended solely or mainly for navigation on inland waterways' ([UNECE-Res61], 1-2.3).

Inland waterway leisure craft is used here as a synonym to the UNECE term 'recreational craft', which is defined as 'a vessel other than a passenger vessel, intended for sport or pleasure' ([UNECE-Res61], 1-2.25),

Integrity 'The ability to provide users with information within a specified time when the system should not be used for navigation including measures and/or indicating of trust' ([IMO-MSC.1/Circ.1575], Annex, page 30).

IWT fairway & navigation domain comprises all aspects related to the navigation of vessels from berth to berth by using the fairways and their infrastructure provided. The complementary term for fairway & navigation domain is the IWT logistics domain. Both terms have been coined within the framework of the DIWA Maturity Model (compare [DIWA 2021b], 4), to allow to conceptually express requirements of the DIWA desired synchromodality precisely.

Co-funded by the European Union

Mixed Traffic	designates fairway a traffic situation where sea-going vessels and/or estuary ships are operating concurrently with inland waterway ships and/or inland waterway leisure crafts.
Operational Relationship	is any relationship between a vessel and another vessel or between a vessel and a centre that is relevant for the navigation of the vessel or vessels. A specific instance of an operational relationship is an Operational Service provided from ashore.
Operational Service	in the context here is a consistent and concurrent set of functionalities for one specified part or facet of the overall navigation process. An Operational Service always, by very definition, instantiates an Operational Relationship.
Physical Link	is a data transmission performed by a (radio) communication technology while regularly being agnostic of the contents and purposes of the data transmitted, i.e. the Physical Link employs the communication technology as a 'carrier' for the data transmitted. Relevant characteristics of the data transmission determined by Physical Links are regularly e.g. range/coverage, bandwidth/transmission speed, and thus time behaviour.
Resilience	'Resilience is the ability of a system to detect and compensate external and internal disturbances, malfunction and breakdowns in parts of the system. This should be achieved without loss of functionalities and preferably without degradation of their performance' ([IMO-MSC.1/Circ.1575], Annex, page 30).
Sea-going ship	is 'a vessel intended mainly for navigation at sea' ([UNECE-Res61], 1-2.4). A sea-going ship has been designed and equipped in accordance with rules relevant to (international) sea voyages; the rules for international sea voyages have been mainly defined by the International Maritime Organization.
Vessel	is an umbrella term for 'an inland waterway vessel or a sea-going ship' ([UNECE-Res61], 1-2.2) (and as opposed to a 'craft' that is defined as an even broader umbrella term as 'a vessel or item of floating equipment' (([UNECE-Res61], 1-2.1).

5 Abbreviations

AIS	Automatic Identification System
AV	Autonomous Vehicle or Autonomous Vessel (depending on context)
AVCC	Autonomous Vessel Control Centre
DIWA	Masterplan Digitalisation of Inland Waterways project
HMI	Human-Machine-Interface
IMO	International Maritime Organization
ITU	International Telecommunication Union
IWT	Inland Waterway Transport
M2M	Machine-to-Machine-Interface
MASS	Maritime Autonomous Surface Ships
MSC	Maritime Safety Committee (of IMO)
ROV	Remotely Operated Vehicle or Remotely Operated Vessel (depending on context)
RCC	Remote Control Centre
UNECE	United Nations Economic Commission for Europe
WRC	World Radiocommunication Conference (of ITU)

Co-financed by the European Union
Connecting Europe Facility

6 References

[DIWA 2021a] DIWA Masterplan Digitalisation of Inland Waterways Project. 2021. *Work Programme V2.0 (March 2021).*

[DIWA 2021b] DIWA Masterplan Digitalisation of Inland Waterways Project. 2021. *Masterplan's content and framework V2.0. Final Version. (March 2021).*

[Hey 2022] Hey, Alexander. 2022. *International Analysis of the Environment of Use Cases of Autonomous Maritime Systems (AMS). Management Summary.* Hamburg: German Maritime Centre. 17 March 2022. https://dmz-maritim.de/en/study-ams-environment_analysis-management_summary-2/ and https://dmz-maritim.de/en/international-field-analysis-on-use-cases-for-autonomous-maritime-systems/ Accessed 25 July 2022.

[IMO-MSC.1/Circ.1575] IMO. 2017. *MSC.1/Circ.1575. Guidelines for Shipborne Position, Navigation and Timing (PNT) Data Processing.* London: IMO. 16 June 2017.

[IMO-MSC.1/Circ.1604] IMO. 2019. *MSC.1/Circ.1604. Interim Guidelines for MASS trials.* London: IMO. 14 June 2019.

[IMO-MSC.1/Circ.1638] IMO. 2021. *MSC.1/Circ.1638. Outcome of the Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS).* London: IMO. 3 Jun 2021.

[IMO-MSC105/20-Add.2, Annex 28] IMO. 2022. *Report of the Maritime Safety Committee on its 105th Session. Annex 28. "Road Map for Developing a Goal-Based Code for Maritime Autonomous Surface Ships (MASS)".* London: IMO. 24 May 2022.

[IMO-SN.1/Circ.288] IMO. 2010. *SN.1/Circ.288. Guidelines for Bridge Equipment and Systems, their Arrangement and Integration (BES).* London: IMO. 02 June 2010.

[ITU-WRC2019-Res-812] ITU-R World Radiocommunication Conference 2019. *Resolution 812 (WRC-19). Preliminary agenda for the 2027 World Radiocommunication Conference.* Geneva: ITU

[UNECE-Res61] United Nations Economic Commission for Europe. 2020. *Resolution No. 61, Revision 2. Recommendations on Harmonized Europe-wide Technical Requirements for Inland Navigation Vessels. (ECE/TRANS/SC.3/172/Rev2).* Geneva. https://unece.org/sites/default/files/2021-07/ECE-TRANS-SC.3-172-Rev.2e_for_web.pdf. Accessed 04 August 2022.

7 Figure copyright references

Both figures are own creations by the present author.

8 Annex – Recommendations

Recommendations *all* carry their *respective context* in order to reduce ambiguity for the reader. The recommendations are therefore, for ease of reference, labelled with a *meaningful name* – as opposed to a running number.

Recommendations are grouped into *Study*- and *Action-Recommendations*. While the planning for further study also is an action in itself and is thus also incorporated in the Action-Recommendation, a Study-Recommendation implies that for the topic at hand additional studies are *required to arrive at the capability for final decision making*.

For each Recommendation, an estimation is given to the *size of work incurred* by following this Recommendation: 'C' meaning, what a committee can possibly accomplish in the course of several meetings, over e.g. two years; 'SubAc' meaning a sub-activity workload of a project; 'Ac' meaning an activity workload of a project with the view to integrate several facets of the topic at hand; 'P' meaning a dedicated project solely for the topic indicated.

- Study-REC-AV/ROV-Regulatory-Scoping-Exercise: Conduct an IWT fairway & navigation regulatory scoping exercise for autonomous inland waterway vessels, by following – as a suggestion - the example of IMO when developing their Regulatory Scoping Exercise for autonomous sea-going ships.

  Estimation of size of work incurred: 'Ac'

- Study-REC-AV's/ROV's-Impact-On-Technical-Standards: Study the expected impact of Autonomous Vessels and/or Remotely Operated Vessels on technical standards relevant for the technical service provision of IWT fairway & navigation authorities and ports, when entering into operational relationships with these vessels.

  Estimation of size of work incurred: 'Ac'

- Study-REC-AV's/ROV's-Demand-Of-High-Data-Quality: Study the expected higher demand of AVs/ROVs on quality of data to be provided by waterway field infrastructure and inland waterway centres operated by IWT fairway & navigation authorities and ports, when entering into operational relationships with these vessels.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-AV's/ROV's-Impact-On-Cyber-Security: Study the resulting cyber security requirements regarding the interactions of AVs/ROVs with waterway field infrastructure and inland waterway centres operated by IWT fairway & navigation authorities and ports, when entering into operational relationships with these vessels.

  Estimation of size of work incurred: 'SuAc'

- Action-REC-AV/ROV-Regulatory-Framework-Roadmap: Develop a roadmap for facilitating the legal framework and regulations for AVs/ROVs and their consequential technological requirements by following – as a suggestion - the IMO example for sea-going ships.

  Estimation of size of work incurred: 'C'
  (based on the IMO MSC's example [IMO-MSC105/20-Add.2, Annex 28])

- Action-REC-AV's-Technology-Impacts: Include in the roadmap further studies, as needed, as well as appropriate actions to generically assess and potentially mitigate the technological impacts of the new operational relationships with AVs/ROVs as well as their respective AVCCs/RCCs responses, taking into account relevant developments in the maritime domain, too.

  Estimation of size of work incurred: 'C'

In total the estimation of size of work incurred by these Recommendations would sum up to a project size ('P') of a project tentatively topically described as 'AVs/ROVs advent's operational and technical impact assessments' and mitigation measures' development from administrations' point of view'.

Co-funded by the European Union