DIWA Report

Sub-Activity 3.5: Manual on Inland Waterway Transport Digitalisation and Assessment Methodology

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1 Executive Summary

The DIWA stated goal is to compile a 'masterplan' for the Digitalisation of Inland Waterways in Europe. That is essentially a roadmap, on how to move the IWT fairway & navigation domain in Europe from its present state regarding digitalisation to higher digitalisation levels – called *IWT Digitalisation Level (IDL)* throughout – and what would be required in terms studies and activities along that roadmap to accomplish that goal until 2032 or likely beyond.

Since one of DIWA's goal is to facilitate synchromodality, the IDLs are defined concurrently for the IWT logistics domain, and it is assumed that the IWT fairway & navigation and the IWT logistics domains may converge seamlessly if and when they both have reached the same IDL simultaneously. This is at least the assumption for an ideal situation: Convergence may also already happen to some degree and with certain caveats when only similar IDLs are reached by the two domains.

From that it follows, that the IDLs are foundational regarding the assessments of the individual contributions or items studied in the various sub-activities of DIWA. The cornerstone question can be thus phrased as follows: *'What increase in terms of IDLs would be incurred when incorporating a certain item - as studied in an DIWA (Sub-)Activity - in the roadmap - specifically?'*

In order to avoid that important question ending up as a hindsight consideration in the chapter of a report on 'critical evaluation of results achieved' with almost inevitably unspecific conclusions as a result, it was considered how the potential increase of the IDL of the IWT fairway & navigation domain by an item could be assessed from the outset of its consideration. Even more specific, *can an 'IDL impact metric' be defined that would render a somewhat quantitative assessment* of an item in this regards even, thus *ultimately allowing the roadmapping of DIWA to focus on those items with the potential high(est) IDL increases.* And what are the costs or efforts associated with that high(est) increase of IDL? These questions culminate in the question of *what can be recommended from the study of item(s) to the roadmapping process – honestly.*

Obviously, this need for assessment metrics is there for any and all items under consideration by any (Sub-)Activity contributing to the roadmapping, but in particular when there are *many* different items. The latter is the case when looking into technology developments in other modes of transport (road/ITS, rail, maritime – and to a limited degree – aviation): There is so much on the move, that the above questions for assessment metrics came up naturally within the Sub-Activity 3.5 dealing with these items; and in particular how to arrive at justifiable recommendations for roadmapping in the light of their findings. The substance of the present manual was thus part of a first draft of Sub-Activity's 3.5 report, but the DIWA project management felt it should be lifted off into a stand-alone document, i.e. this manual – for use by others and for ease of reference.

Hence, this manual contains *firstly* a study on the *consequences of the DIWA desired increase of IDL* for the IWT fairway & navigation domain, together with consequential recommendations for further study and roadmapping. *Secondly,* the above assessment methodology is introduced, that is capable of arriving at even *quantitative assessments of items* under consideration and even recommendations directly following from those assessments, again *together with consequential recommendations*.

The five different IDLs are pre-given in DIWA's foundational documentation and are already embedded in the pre-given DIWA Maturity Model, together with a brief characterisation as given in the right column of the following table overleaf. Supporting explanations and illustrative examples are added in this manual for each and every IDL.

One assessment metric can be derived from that IDL definition directly, namely the *'IDL Impact' metric* which states to which IDL an *item* under consideration contributes significantly. The different IDLs are abbreviated as follows: The IDLs 'Reactive' (0-) and 'Organised' (0+) can be frequently found presently, i.e. at 'situation zero', when a limited number of digitalisation processes have partly become effective and thus frequently constitute the starting point for any (future) increase of digitalisation maturity proper. The latter IDLs are therefore abbreviated with Roman numerals 'above zero'.

DIWA IDL Impact (= 'item has the potential to contribute to …')		Features at this Level (SUMMARY)
III	Intelligent IWT fairway & navigation domain	Digital transformation established; AI assisted process information; Predictive digital capability; Automated response to standard situations.
II	Connected IWT fairway & navigation domain	Advanced digital features aligned with partners; Digital information exchange by default; Full real-time situational picture digitally available.
I	Digitised IWT fairway & navigation domain	Advanced digital features in silos; Overarching vision established; Digital information exchange possible; Limited real-time situational picture digitally available.
0+	Organised IWT fairway & navigation domain	Specialists deliver changes using established process; Traditional digital features; Building digital capabilities.
0-	Reactive IWT fairway & navigation domain	No overarching vision; Requires heroics to change; Management sceptical about digitalisation; Unfocused digital initiatives.

In the above table, the *entity* to which the IDL was applied to as a qualifier was the IWT fairway & navigation domain as a whole. Certain other generic entities are part of that overarching domain, namely vessels, waterway field infrastructure, centres, and data objects. All of these entities have a specific IDL each, specifying the digital maturity of these entities in appropriate derivations of the general above definitions. Also, the IDL Impact metric can be applied for each entity: 'What would be the impact of an item (e. g. a technological development) on a specific entity regarding increase of the latter's IDL'.

For example, when adapting a certain technological development (= item) to a (generic) inland waterway vessel (= entity) what impact for the IDL of the (generic) inland waterway vessel would be incurred. Another example might be: *What IDL impact would be incurred* when adapting a certain data feature treatment (=item) to a data object of the IWT fairway & navigation domain (=entity)?

The other way round also renders meaningful results: If a (generic) inland waterway vessel (= one kind of entity) would incur an IDL impact towards a higher IDL, *what consequences would this have in terms of necessary consequential IDL impact on another kind of entity* the inland waterway vessel is dependent on that IDL, for example of a certain data object and its necessary IDL.

In other words: The desired benefits of IDL increase are improved functionalities available for the IWT fairway & navigation applications and/or human users using them. However, *IDL increase also brings with it the increased variety and/or proliferation of co-operative technologies.* These benefits of the IDL increase are thus correlated by necessity with the disadvantage of increased interdependency. To mitigate this disadvantage, *certain non-cooperative technologies are still needed on a regular basis and/or for fall-back arrangements even with the advent of the highest possible IDL throughout.*

Further, the combination of the above implications of the increase of the IDL in the IWT fairway & navigation domain results in the necessity for the IDLs of above entities, which have one or several operational relationships between them, to match. I.e. it is necessary *that the entities involved in the same operational relationship demonstrate the same IDL.* This principle is called *IDL-Match-Principle* here. An *IDL mismatch* is a situation where different entities engaged in the *same* operational relationship(s) would not only be unable to use the benefits offered by the entity with the higher IDL - which could be considered a less important disadvantage -, but may result in a more severe situation where the necessary operational relationship may not even be established, whatever this may mean in practical detail. It is important to note, that in the digital domain, there *does not exist a 'graceful degradation' by default* – as opposed to the analogue domain, which may lead to dropping from IDL to (very) low IDL if no graceful degradation is in place: The *assumption* that the occurrence of an IDL mismatch will still 'always' allow for 'some sort of' operational relationship being available 'somehow' is *flawed from the outset in the digital domain.* Any 'graceful degradation' needs to be designed into the desired IDL of the IWT fairway & navigation domain embracing all relevant entities and operational relationships.

Finally, as opposed to the analogue domain, *data exchange by digital technologies generally disallows ambiguities* in data object definitions and in data models governing these data objects. Since data objects and data models are just representations of the real world they intend to represent, up to the ultimate degree of creating a digital twin of an entity, the *necessary disambiguation* needs to *start with the terminology r*elated to the data objects and interaction concepts that govern the data object definitions and data models. This in turn prompts the need to *remove ambiguity from operational procedures* governing the interaction concepts as well as *from regulations* governing the operational procedures in turn. This needs to be done to that extent induced by the desired IDL: For arriving at 'digital information exchange *as a default*', which is a key feature of 'even only' the IDL 'Connected' (II), basically *all* relevant regulations, operational procedures, terminology and data models need to be free of ambiguities, as far as possible.

Admittedly, these are highly abstract considerations, but a high degree of abstraction is an essential feature of *digital transformation* and can thus not be avoided when embarking on it. Also, admittedly, the consequences and requirements stemming from in particular higher IDLs when introduced throughout, becoming visible by these considerations, may be scary. But again, when roadmapping towards a higher IDL for the IWT fairway & navigation domain at large, it is necessary to face those consequences upfront and potentially also find mitigation measures. It is the intent of this manual, to bring these aspects to the fore.

While the above IDL Impact metric of an item was the starting point, all assessment metrics developed in this manual are given in the following summary table (overleaf), which is intended to be used as a template to facilitate the individual item's assessment. The other assessment metrics besides the IDL Impact metric are resting on the three different additional rationales as follows:

- What is the *inherent maturity* of an item? I. e. what is – for example – the maturity of a technological development 'in itself'? Resulting from this are the metrics *Hype Cycle Phase* and the *Technology Readiness Level*.
- What is the degree of *adaptability* of an item to the IWT fairway & navigation domain, and what resources would this require (if possible at all)? Resulting from this are the metrics Adaptability and *Adaptation Demands*. (NB: Adaptation in principle should not be confused with deployment.)
- Looking into the future, when will be a certain item potentially fully deployable in the IWT fairway & navigation domain? (Assuming 'due diligence' to that end and taking in the necessary efforts). Resulting from this is the *(item) Radar metric*, e.g. a Technology Radar metric for technologies as items.

DIWA Assessment metric (short names)	Assessment results
DIWA- Hype Cycle Phase	5 - Plateau of Productivity 4 - Slope of Enlightenment, 3 - Trough of Disillusionment, 2 - Peak of Inflated Expectations, 1 - Technology Trigger
DIWA-Technology Readiness Level	9 (Market expansion) 8 (Initial market introduction) 7 (Pilot production demonstrated) 6 (Pilot production – pre-production product) 5 (Prototyping & Incubation – testing prototype in user environment) 4 (Concept Validation – lab prototype) 3 (Concept Validation – first assessment feasibility) 2 (Invention – Technology concept formulated) 1 (Invention – Basic principles observed)
DIWA-Adaptability	++ (Seamless Adaptability) + (Adaptability with minor modifications) 0 (Adaptable with substantial modifications) - (Adaptable by redesign in analogy) -- (Not adaptable)
DIWA-Adaptation Demands	++ (Little adaptation resource/time demands) + (Intermediate adaptation resource/time demands) 0 (Substantial adaptation resource/time demands) - (High adaptation resource/time demands) -- (Not feasible)
DIWA-Radar	2022-2026 2027-2032 'Future Box'
DIWA-IDL Impact	Supportive for transformation into III (Intelligent IWT fairway & navigation domain) II (Connected IWT fairway & navigation domain) I (Digitised IWT fairway & navigation domain) 0+ (Organised IWT fairway & navigation domain) 0- (Reactive IWT fairway & navigation domain)

Last but not least, the assessments results of the different (potentially many) items can be directly put into a *decision making context* by using the *4-Quadrant-Matrix model*. How recommendations can be derived from it directly, is finally introduced in this manual.

2 The IWT Digitalisation Levels and their implications

2.1 Introduction to IWT Digitalisation Levels

A DIWA framework document ([DIWA 2021b], 5) describes the vision of the future situation of IWT in terms of *'IWT Digitalisation Levels' (IDL)* and with the target to eventually reach the highest achievable IDL, namely an 'Intelligent IWT'. Intermediate IDLs would be 'reactive', 'organised', 'digitised', and 'connected'. In order to achieve the DIWA envisaged 'seamless conversion into multi-modality' ([DIWA 2021a, 26) in IWT, the two dimensions 'Digitalisation of fairway & navigation' on one hand and 'Digitalisation of Logistics' on the other hand need to *converge* in their respective ramp up towards 'intelligent'. The following figure illustrates this overarching vision of the Masterplan DIWA project.[1]

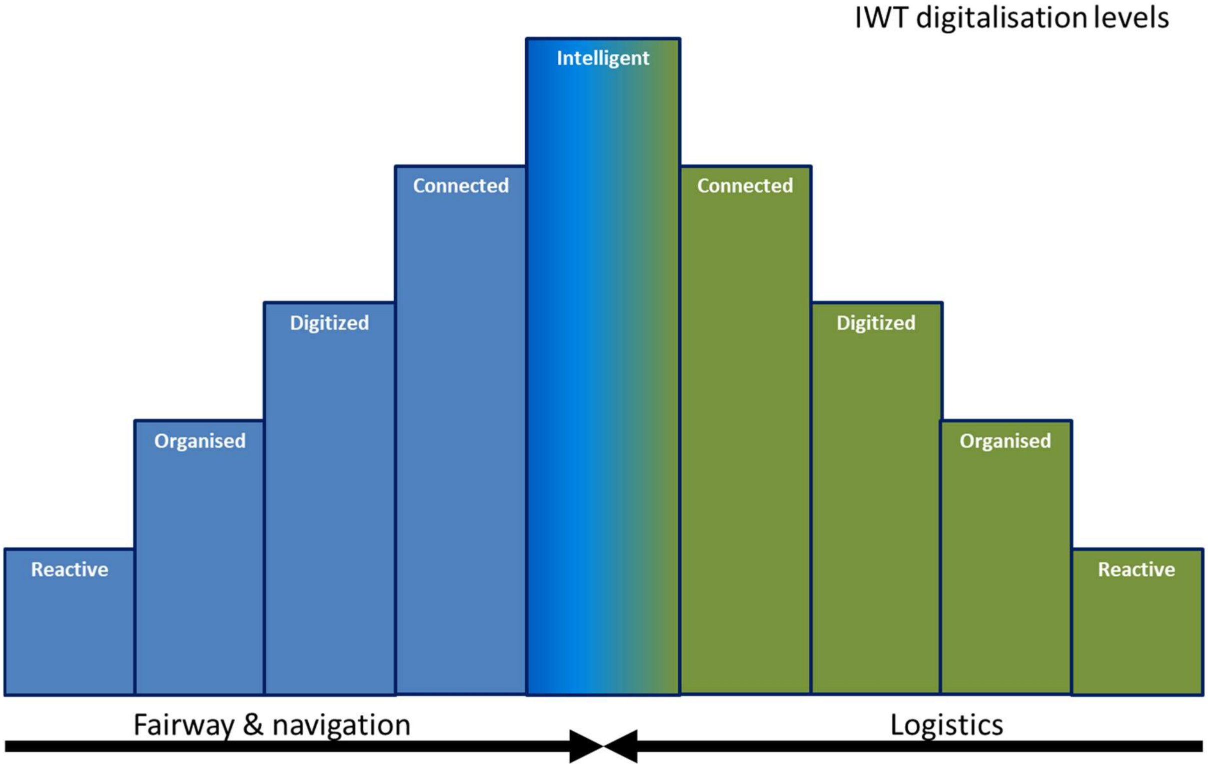

Figure 1: IWT Digitalisation Levels (Source: [DIWA 2021b], 5).

The *IWT fairway & Navigation domain* is contributing significantly to the above vision; *it is this domain that is the focal point of this manual.*

2.2 DIWA Maturity Model – Introduction and explanation

Within the DIWA framework document ([DIWA 2021b], 5) the different IDLs were defined as given in the following figure which is called 'DIWA Maturity Model'. The DIWA Maturity Model was informed by the much more elaborate *Capability Maturity Model (CMM)* but simplified and adapted to the needs and specifics of IWT .[2]

[1] It should be noted, however, that the Figure does not exclude convergence between the two domains on (same) lower IDLs, although the benefits of that convergence will be lower.

[2] That backdrop to the DIWA Maturity Model has developed over several decades now into a science of its own. For an introduction to the Capability Maturity Model compare [Wikipedia2022c].

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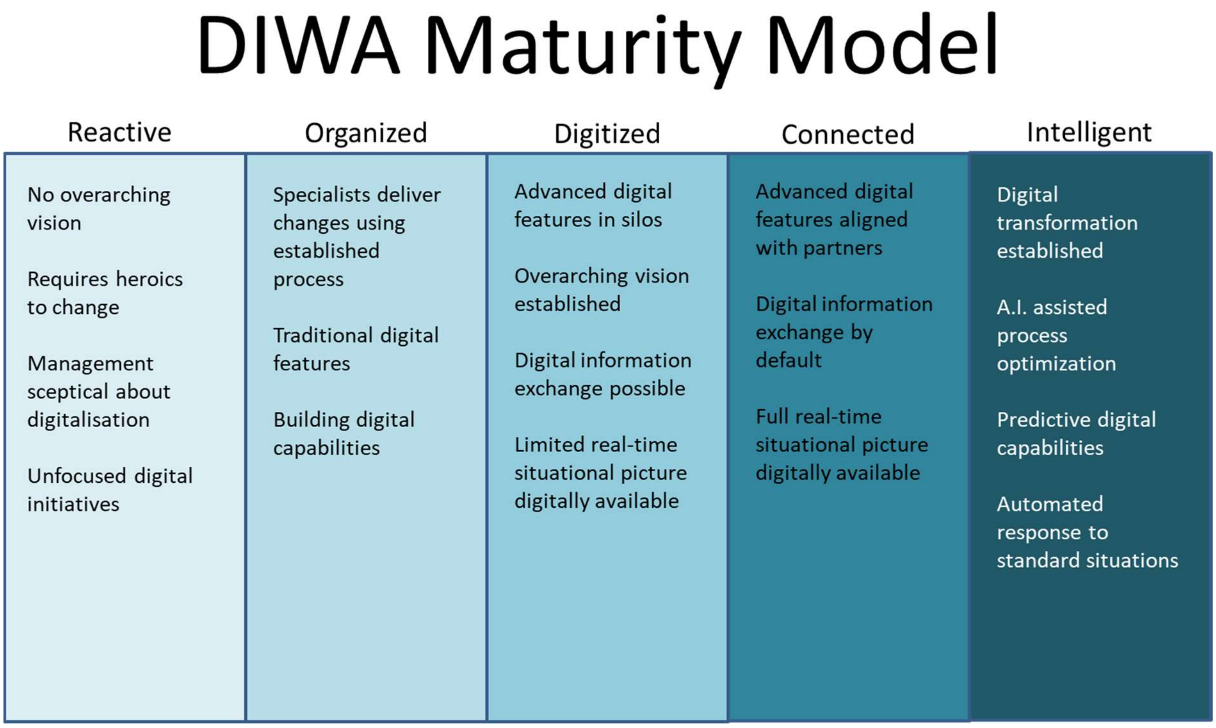

Figure 2: IWT Digitalisation Levels as defined for DIWA (Source: [DIWA 2021b], 5).

During the work of DIWA Sub-Activity 3.5, the following explanations and examples to complement above figure were developed.

2.2.1 General explanations

The whole DIWA Maturity Model is set against the backdrop of a purely analogue environment, where – for example – communication by word of mouth via analogue (radio) communications means and data storage on paper prevail. This analogue backdrop is not shown in the DIWA Maturity Model figure itself.

IDLs can be assigned to any relevant entity under consideration, such as an organisation and/or a development. The kind of entities will be introduced further below. Here the IDLs as such will be introduced.

The assignment of an IDL intends to indicate the maturity of an entity regarding digitalisation, to be specific regarding certain characteristics relevant for digitalisation. *An entity can only achieve a higher IDL when all prerequisites or requirements from a lower IDL have been accomplished or fulfilled respectively.*

That does not imply that the entity under consideration in its entirety is fulfilling the features of that IDL. That may be difficult when considering larger organisations as the entity under consideration, for example. All parts of the entity relevant for digitalisation and therefore for the assignment of the IDL need to conform to the features of that IDL, however. Those relevant parts should be indicated.

2.2.2 Additional explanation and examples for IDLs

To illustrate the meanings of the above IDLs, the following examples are given per each IDL.

Example for IDL 'Reactive': A logistics company that has a website but only with static reference information, no interaction possibilities. Customer contact is primarily conducted via phone (voice) and traditional (paper) mail. Every logistic service offering has its own (customer) database. Management considers IT/digitalisation a purely supportive tool instead of a business enabler. Generally speaking, it is strongly advised to leave this IDL and progress to higher IDLs.

Explanations and examples for IDL 'Organised':

- 'Traditional digital features' are interpreted here as those exhibited by well-established digital systems in the IWT fairway & navigation domain such as ATIS, Inland-AIS and S57-based Inland-ECDIS.

- 'Building digital capabilities' is construed as the (systematic) building of digital capabilities is introduced to/by stakeholders in/of the IWT fairway & navigation domain starting with this level.

Explanations and examples for IDL 'Digitised':

- 'Digital information exchange' is construed here to mean, that data and/or information exchange is using pre-defined structures, such as machine-readable templates, as a pre-requisite and as opposed to e.g. bitmap-based documents. This in turn results in exchange of structured data/information as a rule, thus again prompting appropriate encoding, protocols, and interfaces supporting this exchange.

  Examples: S-57-format of Inland-ECDIS (at present) and potentially S-100-format (in the future); Notices to Skippers (RIS NtS standard).

- 'Limited real-time situational picture' is construed here to mean that the positions and intents of all vessels in a given area are available but limited in terms of geography and/or technology.

  Example: Radar coverage only on certain parts of the fairway, AIS coverage only on certain parts of the fairway, Radar-AIS-fusion only available for some areas covered by both radar and AIS simultaneously.

- 'Advanced digital features in silos' is construed here to mean that digital data/information is available and combined in an automated fashion to provide new services.

  Example: berth occupation calculation based on AIS and berth polygon data.

Explanations and examples for 'Connected':

- 'Advanced digital features aligned with partners' is construed to mean here, that available digital data/information is combined automatically to provide new services across organisational boundaries.

  Example: Fairway route calculation taking en-route limitations (as contained in NtS) into account across areas of multiple organisations.

- 'By default' is construed here to mean that all communication data exchange (ship-ship, ship-shore) is done digitally machine to machine in a (semi) structured format. Spoken word via VHF or other means and/or unstructured data exchange (email, texting) are considered exceptional.

- 'Full real-time situational picture' is construed here to mean that positions and intents of all vessels in the entire area of competency of multiple organisations are available.

  Example: Full AIS coverage, full Radar-AIS-fusion available in radar covered areas, every vessel intent is known or predicted.

Explanations and examples for 'Intelligent':

- 'Digital transformation' is construed here to mean that an entity has adopted digital technology throughout all its parts relevant for the IDL assessment. 'Common goals for its implementation are to improve efficiency, value or innovation' [Wikipedia-EN 2022d].
- Examples for 'Artificial Intelligence (AI) assisted process optimisation': Authority patrol vessels are positioned at locations where the likelihood of their required use is the greatest (following from risk level prediction based on statistical and real-time data). Bridge operators are assisted by image recognition algorithms to detect potentially dangerous situations.
- Example for 'predictive digital capabilities': Future traffic situation, berth occupation, lock cycle and bridge openings are automatically predicted within a small probability bandwidth on a large scale.
- Example for 'Automated response to standard situations': Vessels entering designated (even temporary) danger or no-go zones are automatically detected and contacted with increasing forcefulness to contain and mitigate potential unwanted events.

2.3 Implications of the DIWA Maturity Model for the work of DIWA

From DIWA point of view, the most desirable IDL would be 'Intelligent', rendering *'Intelligent IWT fairway & navigation'* the highest achievable target. According to the definition and explanations above, this would mean,

- that the digital transformation of the IWT fairway & navigation domain would have been completed (for all of its parts relevant for digitalisation);
- that AI assists in the optimisation of processes related to fairway provision, operation and maintenance as well as in the optimisation of inland waterway vessels' navigation processes proper;
- that prediction algorithms are in place to support IWT fairway & navigation processes; and
- that there are implemented standard responses in fairway provision, operation and maintenance processes as well as inland waterway vessels' navigation processes.

This goal might not be achievable within DIWA's time frame 2022-2032 and/or with the technologies available within that time, however. Hence, it is necessary, to also use the other different IDLs, thus rendering the following intermediate states of the digital transformation of the IWT fairway & navigation domain:

- 'Reactive IWT fairway & navigation';
- 'Organised WT fairway & navigation';
- 'Digitised IWT fairway & navigation'; and
- 'Connected IWT fairway & navigation'.

As a consequence and in order to securely meet DIWA's objective to assess the effects on digital transitions in the period 2022-2032 (as a minimum time frame for consideration), ***all proposals for digitalisation of entities discussed by DIWA need be assessed regarding their minimum and potential maximum achievable IDL***. This would also support roadmapping and migration path design by building on the results of these assessments.

For simplicity of reference, the following abbreviations to the different IDLs have been assigned:

- III - Intelligent
- II - Connected
- I - Digitised
- 0+ - Organised
- 0- - Reactive

The IDLs 'Reactive' (0-) and 'Organised' (0+) can be frequently found presently, i.e. at 'situation zero', when a limited number of digitalisation processes have partly become effective and thus frequently constitute the starting point for any (future) increase of digitalisation maturity proper. The latter IDLs are therefore abbreviated with Roman numerals 'above zero'.

2.4 Implications of the DIWA Maturity Model for the IWT fairway & navigation domain

Certain important implications associated with increased digitalisation of the IWT fairway & navigation domain are brought to the fore by employing the DIWA Maturity Model as follows. They are not 'invented' by the DIWA Maturity Model.

2.4.1 Disambiguation of regulations, operational procedures, terminology, and data models

As opposed to the analogue domain, ***data exchange by digital technologies generally disallows ambiguities*** in data object definitions and in data models governing these data objects. Since data objects and data models are just representations of the real world they intend to represent, up to the ultimate degree of creating a digital twin of an entity, the *necessary disambiguation* needs to *start with the terminology r*elated to the data objects and interaction concepts that govern the data object definitions and data models. This in turn prompts the need to *remove ambiguity from operational procedures* governing the interaction concepts as well as *from regulations* governing the operational procedures in turn.[3,4]

This needs to be done to that extent induced by the desired IDL: For arriving at 'digital information exchange *as a default'*, which is a key feature of *'even only' the IDL 'Connected' (II),* basically ***all*** relevant regulations, operational procedures, terminology and data models need to be free of ambiguities, as far as possible.

Obviously, this is a major task, in particular when starting from IDLs **0-** or **0+**. To achieve this within DIWA's time scope of up to 2032 would require to start soon. Associated Recommendations are given in the Annex.

2.4.2 Increased variety and/or proliferation of co-operative technologies with IDL increase

Another consequence of the increase of IDL is the *increased variety and/or proliferation of co-operative digital technologies employed,* necessitated by the very definition of the IDL.

A technology is called co-operative when requiring a terminal (such as an transceiver) on *each* side of the (communication) link to accomplish its (communication) task: Both terminals need to work *together, i.e. co-operate,* in accordance with a pre-defined set of rules (such as data object encoding, link protocols governing the digital data exchange processes, and – in the case of radio communication - radio frequency usage stipulations).[5] The opposite is a non-cooperative technology that does not rely on the co-operation of any other entity to perform its task (for example radar).

The desired benefits of IDL increase are improved functionalities available for the IWT fairway & navigation applications and/or human users using them. However, IDL increase also brings with it the increased variety and/or proliferation of co-operative technologies. These benefits of the IDL increase are thus correlated by necessity with the disadvantage of ***increased interdependency***. To mitigate this disadvantage, *certain non-cooperative technologies are still needed on a regular basis and/or for fall-back arrangements even with the advent of the highest possible IDL throughout.* Therefore, even when arriving at higher or even the highest possible IDL, it will be necessary to also provide certain non-cooperative technologies 'with a digital edge' and to provide certain ***fall-back arrangements***.

Some initial suggestions are given as recommendations in the Annex.

2.4.3 All entities of the IWT fairway & navigation domain affected

The term 'IWT fairway & navigation domain' - as well as any possible alternative terms for that matter – is an umbrella term, namely a composite term, to be precise. It designates a meaning- and purposeful composition of several entities that interact in order to achieve their intended purpose and meaning. *Applying the above IDL concept to the 'IWT fairway & navigation domain' actually applies it to all the entities it is composed of: vessels, waterway field infrastructure, organisations providing services, and data objects for exchange*, to name the most important ones. ***This means, that each and every entity can and will have an IDL*** – in general as a generic object and when considering individual instances of these entities. Compare following figure.

[3] This holds true even with the advent of *digital* technologies such as Fuzzy Logic or AI algorithms that deliberately create the *impression* of permissible ambiguity to the human user or to applications using them.

[4] Learning from maritime: To that end, the International Maritime Organization (IMO) has set up a *Harmonisation Group on Data Modelling (HGDM)* as a consequence of their e-navigation strategy.

[5] The notion of a co-operative digital technology is not new at all: There are well known examples of co-operative digital radio communication technologies in the IWT fairway & navigation domain, such as the Digital Selective Calling (DSC; used in ATIS-equipped radio telephony) and Inland-AIS. Also, in principle, visual aids flashing a light-on-off sequence as a code for identification form a co-operative digital (visual light) communication link with the human eye as the other 'terminal'. But also Inland-ECDIS is an example of digital technology because there is not only the digital co-operative technology needed to exchange chart data but also the close and unambiguous co-operation of several organisations involved in creating the chart data on one hand (i.e. for example chart providing authorities) and displaying it on the shipboard side on the other hand (i.e. for example equipment manufacturers).

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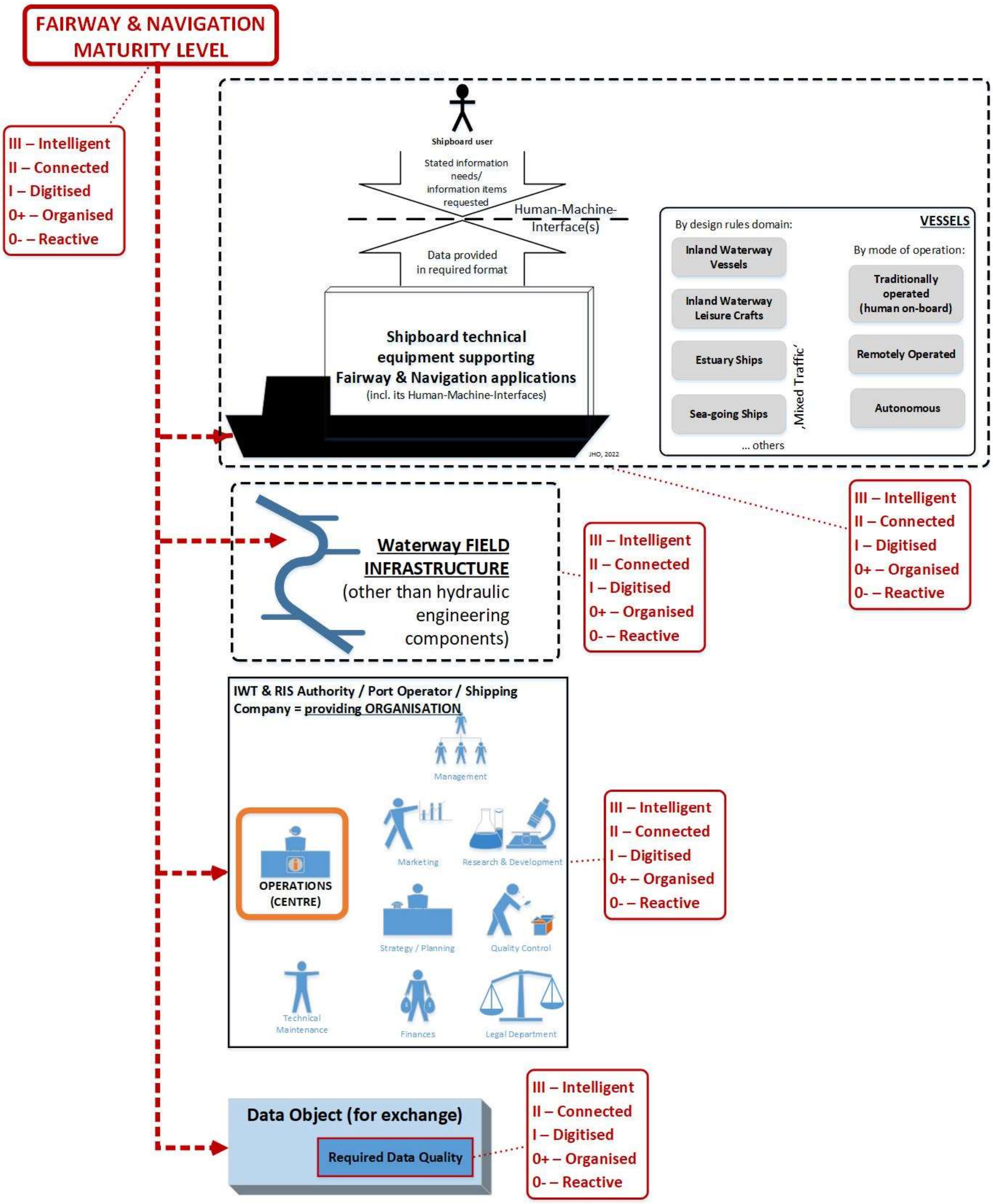

Figure 3: IDLs applied to generic entities of the IWT fairway & navigation domain

So it would be possible or even required to use the notions for example

- of a 'connected vessel', designating vessels, the IDL of their relevant digital equipment would have reached 'Connected',
- of an 'intelligent waterway field infrastructure', the IDL of their digital representation and installations would have reached 'Intelligent',
- of 'digitised organisation', the digital processes of which would have reached the IDL 'Digitised',[6] and
- of an 'intelligent data object' supporting those digital data exchange processes and interactions of the above entities on the IDL 'Intelligent'. In the example depicted, the feature 'Required Data Quality' is labelled with the IDL, because this feature often is critical to the achievable IDL.

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[6] The entities that an organisation may be composed of are depicted as examples; a very important entity within any organisation providing service to the IWT fairway & navigation domain is the operations centre which therefore features prominently.

2.4.4 Implications of the IDL-Match-Principle during implementation and deployment

The combination of the above implications of the increase of the IDL in the IWT fairway & navigation domain results in the necessity for the IDLs of above entities, which have one or several operational relationships between them, to match. I.e. it is necessary *that the entities involved in the same operational relationship demonstrate the same IDL.* This principle is called *IDL-Match-Principle* here.

An *IDL mismatch* is a situation where different entities engaged in the *same* operational relationship(s) would not only be unable to use the benefits offered by the entity with the higher IDL - which could be considered a less important disadvantage -, but may result in a more severe situation where the necessary operational relationship may not even be established, whatever this may mean in practical detail.

To adhere to the IDL-Match-Principle and thus to avoid IDL mismatches is relevant in particular during implementation and deployment, which are the goals of the DIWA roadmap and activity beyond. The following examples illustrate the above:

- A 'connected vessel' would expect a 'connected waterway field infrastructure' and relevant operational centres with IDL 'Connected' – due to the 'digital information exchange by default' feature of IDL 'Connected' (II).
- A 'connected vessel' (IDL=II) – due to the feature 'digital information exchange by default' – expects a certain digital information exchange when entering a waterway field infrastructure by crossing its boundary, but an IDL mismatch occurs if this field infrastructure does not support this IDL-II digital information exchange being 'only' a 'digitised waterway field infrastructure' (IDL=I) which has – by very definition of the IDL – 'advanced digital features in silos', only.

It is important to note, that *in the digital domain, there* ***does not exist a 'graceful degradation' by default*** – as opposed to the analogue domain, which may lead to dropping from IDL to (very) low IDL if no graceful degradation is in place: *The* ***assumption*** *that the occurrence of an IDL mismatch will still 'always' allow for 'some sort of' operational relationship being available 'somehow' is* ***flawed from the outset in the digital domain****. Any 'graceful degradation' needs to be designed into the desired IDL of the IWT fairway & navigation domain embracing all relevant entities and operational relationships.*

On the other hand, the IDL-Match-Principle states the ideal of the DIWA Maturity Model: As with any ideal, there may be circumstances which disallow for reaching the ideal state. Hence the resulting question for further study would be:

- What 'IDL match margin' would be permissible between which (specific) entities engaged in which (specific) operational relationship(s)?
- What would be permissible degradations IDL in regular case operations, and
- what would be permissible or anticipated IDL fall-back arrangements for exceptional conditions?

Finally, it needs to be re-iterated that any IDL mismatch will demonstrate its impact only during implementation and deployment, not necessarily when discussing regulatory, operational, and technical in general during planning phase *unless specifically taken into consideration*. It is therefore advised to carefully study the implications of the IDL-Match-Principle early on and act upon findings accordingly. Some initial suggestions are given as recommendations in the Annex.

3 Assessment methodology and assessment metrics

This chapter introduces a methodology for assessing items for potential adaptation to the IWT fairway & navigation domain and thus facilitates the learning from general trends in management, regulations, and technology and/or from other modes of transport. The purpose of this methodology is to make sure, that meaningful assessments can be provided, in particular regarding the masterplan composition and/or - by means of recommendations for further study - beyond, eventually, To achieve meaningful assessments, it is necessary to find or develop assessment metrics.

3.1 Maturity and readiness in itself

The first assessment metric to be defined and used allows to assess the maturity of an item in itself. Of particular interest would then be the 'readiness' of an entity for adaptation *in general*. That means, that a specific target domain, such as the IWT fairway & navigation domain, is not yet considered here.

3.1.1 Employing Trend Research

A whole branch of research has established itself that tries to forecast the technology trends of the foreseeable future and their potential assessment. This trend research provides necessary background information and methods for practical use.

3.1.1.1 Trend Research Literature

In professional newspapers, journals and book publications, there regularly appear articles on technological trends and their assessed impact(s) to be expected in some relevant future, for example during the forthcoming year or years. There are even professional journals dedicated to technological trends and their potential future impacts, such as the MIT Technology Review. When turning towards the logistics domain specifically, the logistics company DHL, for example, has established a routine in publishing their own trend research, namely social & business trends alongside with technology trends. This has appeared in the 5th edition recently and is publically available [DHL 2021]. As a summary of their assessments, a 'trend radar' picture is created, which appears to speak for itself, at least in general terms.

While the above reflection on current topics of trend research provides some helpful background information, its topics are too general for the scope of the IWT fairway & navigation domain and are thus not further considered in this Manual.

However, a practically useful result from this trend research is the synoptical representation that assists in arriving at conclusions. This practical method to synoptically represent the assessments of several or many individual items into one picture will be adapted to DIWA needs in a section below.

3.1.1.2 The Hype Cycle assessment

When looking at trends and in particular at their public discussion the Hype Cycle assessment curve – also known as the Gartner curve –[7] has proven to be helpful to develop sober views on (technology) hypes while preventing to miss the potential of those items, in particular technologies, being hyped at some point of their life cycle. The Hype Cycle assessment curve is based on the observation, that items follow the same expectation-over-time pattern as indicated in the following figure.

[7] For a more elaborate introduction compare for example [Wikipedia-EN 2022a].

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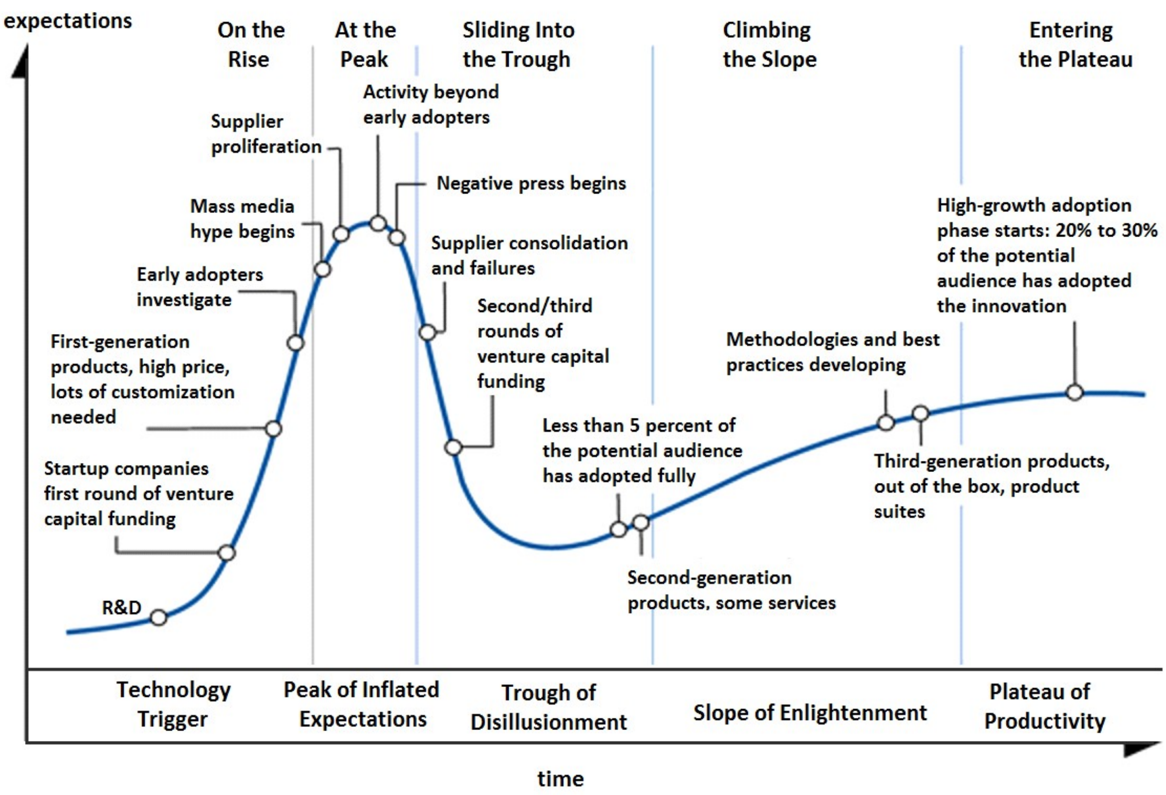

Figure 4: Hype-Cycle (source: [Wikipedia-Commons 2021])

In the Hype Cycle, the early part of a life cycle is subdivided into five different phases:

- *'Technology trigger'* – Some research & development has produced a technology that attracts start-up companies to create first generation products that are attractive to early adopters.
- Thus expectations rise to the *'Peak of Inflated Expectations'*, i.e. the hype,
- Since hypes regularly are short-lived, the expectations collapse, and the technology perception falls into a *'Trough of Disillusionment'*, sometimes also called 'Winter' or 'Valley of Tears'. During this phase the true value and applicability of the technology under consideration is recognised.
- If the technology survives this phase because it has demonstrated persistent true value and applicability, it enters the *'Slope of Enlightenment'* where methodologies and best practices are developing and mature off-the-shelve products are being developed and brought into the respective markets.
- In the *'Plateau of Productivity'* the technology establishes itself in its applications.

It should be added that the full life-cycle comprises also the end of the 'Plateau of Productivity', namely when the termination of usage is imminent or even announced leading to being *'Retired'*.

The Hype Cycle provides essential qualitative insights into a life cycle development, but is not directly applicable to quantitative assessments. That end will be served by the following metric.

3.1.2 Technology maturity and readiness to practical application

In order to assess the maturity of an item quantitatively – or more precisely: its readiness for being adapted or deployed widely – a readiness metric is required. In the past, there have been developed several such elaborate metrics for specific domains (such as – most prominently – astronautics) and thus cannot be applied to the IWT fairway & navigation domain – or any other specific domain - directly.

Recognising the need to have an elaborate readiness metric with a more general applicability in terms of subjects, the European Association of Research and Technology Organisations (EARTO) has develop the EARTO Technology Readiness Level (TRL) to satisfy those needs ([EARTO 2014], Section 1.4 incl. Figure 5). According to EARTO, this TRL can and needs to be interpreted and potentially adapted in accordance with the needs of the target domain. This has been done for the IWT fairway & navigation domain as given in the following figure. The left three columns are EARTO definitions; the right column shows the DIWA interpretation.

TRL #	Stage (EARTO)	Description (EARTO)	IWT fairway & navigation domain related remarks
9	Market expansion	Production & product fully operational	Inventory item is ready for the IWT fairway & navigation domain within the DIWA scope 2032.
8	Initial market introduction	Manufacturing fully tested, validated and qualified	
7	Pilot production & demonstration	Low scale pilot production demonstrated	
6		Pre-production product	
5	Prototyping & incubation	Testing prototype *in user environment*	Evaluate by an individual assessment whether the inventory item is ready for the IWT fairway & navigation domain within DIWA Scope. No general rule can be applied here.
4	Concept validation	Validation integrated prototype in lab environment	Despite being beyond the DIWA scope most likely, keep an eye on the developments by means of a 'study further recommendation' (by e.g. Follow-Up Study, technology studies etc.).
3		First assessment feasibility concept & technologies	
2	Invention	Technology concept formulated	
1		Basic principles observed	

Table 5: DIWA Technology Readiness Level (source: adapted from [EARTO 2014])

Note regarding the *difference between TRL grades 7 and 8:* The telecommunication industry's example is adopted here to determine the TRL grade here: Should at least three successful projects have investigated the pilot productions/demonstrations, then it would be justified to assign a TRL grade of 8.

3.2 Adaptability to the IWT fairway & navigation domain

The previous section introduced an assessment metric for an item 'in itself'. It is now necessary to turn towards the assessment question, whether it is possible to adapt an item from the general domain or from a different mode of transport to the IWT fairway & navigation domain, and if so, how. That means, an adaptability metric would be required that indicates the ease of a potential adaptation to the IWT fairway & navigation domain. Further, it would be interesting to know, what amount of resources would be required to adapt and what time would be needed. These metrics are developed as follows.

3.2.1 The Adaptability Grade

The Adaptability Grade provides a metric on the ease (or difficulty) to adapt an item to the IWT fairway & navigation domain. The Adaptability Grade ranges from 'Seamless Adaptability' to 'Not Adaptable'. The following figure defines the grades and provides examples.

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<table>
<tr><th>Adaptability Grade</th><th>Name</th><th>Description</th><th colspan="3">IWT fairway & navigation domain related remarks</th></tr>
<tr><td>++</td><td>Seamless Adaptability</td><td>Exactly the same product as used in a different mode of transport can be used for IWT purposes without any (intrinsic) modification needed.</td><td rowspan="3">Wet (Maritime)-to-wet (IWT fairway & navigation domain): Would allow for Adaptability Grade of (0) to (++).</td><td rowspan="2">Employ 'always-under-land' ('in-land' waterway) criterion at inland waterways to use – in particular - land mobile radio communication technologies.</td><td>Example: Usage of maritime shipboard X-band radar for inland vessels and for inland-VTS, bridges, locks</td></tr>
<tr><td>+</td><td>Adaptable with minor modifications</td><td>Off-The-Shelf products used in a different mode of transport can be used for IWT purposes with 'minor modifications' (intrinsic to the product) (Modified Off-The-Shelf (MOTS) product)</td><td>Example: (Analogue) VHF radio (Amendment for IWT: ATIS (DSC) code at the end of voice message.)</td></tr>
<tr><td>0</td><td>Adaptable with substantial modifications</td><td>Technology used in a different mode of transport can be used for IWT purposes with substantial modifications</td><td colspan="2">Examples:
Inland-AIS, Inland-ECDIS</td></tr>
<tr><td>-</td><td>Adaptable by redesign in analogy</td><td>The idea or certain technology modules of a different mode of transport's technology can be applied to IWT, but only by redesign taking into account the specifics of the physical IWT environment</td><td rowspan="2">Dry-to-wet (ITW fairway & navigation domain): Resulting Adaptability Grade cannot be better than (-) as a rule.</td><td colspan="2">Example:
concept of balises in trackside infrastructure at rail to be adapted to inland waterway balises ('IWT Infrastructure Site')</td></tr>
<tr><td>--</td><td>Not adaptable</td><td>Engineering efforts needed to adapt to IWT purposes beyond reasonable limits.</td><td colspan="2"></td></tr>
</table>

Table 6: DIWA Adaptability Grade, here applied to a technology as the item under consideration

3.2.2 Assessment of resources needed for adaptation to IWT fairway & navigation

In order to arrive at a solid recommendation for the feasibility of adaptation of an item in the IWT fairway & navigation domain, it might be helpful to have a metric available that reflects the amount of resources needed. This metric will be called *Adaptation Resource Demand* metric.

Ideally, such a resource metric would be readily available by already existing definitions of a recognised body. However, this appears not to be the case. Also, a variety of generic resource metrics are available in the domain of resource management,[8] but they regularly were developed to satisfy the project management and / or controlling demands, thus requiring quite specific and concrete input data such as project related human resources and finances. It is not possible to provide this kind of data within the scope and limitations of this study and report, and therefore this kind of resource metric is not available for an Adaptation Resource Demand metric.

However, the above Adaptability Grade may provide a working solution due to the following rationale: The easier adaptable a certain item is, the less resources would be required to adapt and even-

[8] Compare for example [Wikipedia-EN 2022b].

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tually implement it to the IWT fairway & navigation domain. This means, that the desired Adaptation Resource Demand metric could be derived by transforming *the interpretation* of the Adaptability Grade.

Adaptation Resource Demand Grade	Adaptability Grade for an item	Remarks
++	++	Little adaptation resource demand
+	+	Intermediate adaptation resource demand
0	0	Substantial adaptation resource demand
-	-	High adaptation resource demand
Not feasible	--	The resource demand for adaption exceeds reasonable limits.

Table 7: DIWA Adaptation Resource Demand metric

3.2.3 Assessment of time needed for adaptation to IWT fairway & navigation domain

Following the above rationale, it holds true in principle for the time needed to adapt an item to the IWT fairway & navigation domain: The lesser the adaptability, the more time would be required. In fact, the above Adaptation Resource Demand grade reflects also and even identically the time demands for an adaptation. Hence, *no* additional metric is defined, but the above grade can be broadened in scope by relabelling it to *Adaptation Resource & Time Demands* metric, or *Adaptation Demands* metric for short.

3.3 Assessing the impact on the DIWA Maturity level and on roadmapping

It is now finally necessary to develop assessment metrics that assess the impact of an item under consideration

- on the digital transformation of the IWT fairway & navigation domain and
- on the migration path(s) from the present situation towards the DIWA desired maturity level of the IWT fairway & navigation domain within the allotted time frame.

3.3.1 The (Technology) Radar assessment metric and the notion of the 'Future Box'

The method and imagery of the trend radar was already mentioned. The method to represent the impact of item assessments over a time frame looking ahead into the future may be called radar assessment, thus showing its origin in navigation. There, navigation radar is a well-established means for collision avoidance. Like in a navigation radar image, the position of the observer (i.e. own position) is in the centre at the lower margin of the figure, while the relative distance and bearing of the item assessments introduced into the radar image as 'radar targets' show the *relative unavoidability*. If an assessment of a certain item is close to own position, it will most likely have a (major) impact on own operation. Usually, the radar image is subdivided into zones, that stand for a specific time expectation when a certain item will potentially 'hit' own operation. Hence, the radar image allows for drawing relevant conclusions. Thus this method and imagery is useful to synoptically represent several assessments in one picture which in turn allows for conclusions to be drawn.

When the items under consideration are technologies or technology-oriented, the resulting figure or table can be called Technology Radar assessments. Also, the diagram version can be simplified to a table when there is just one kind of items under considerations as in the case of technology or technology-oriented items. The following figure shows the adaptation of the trend radar to become the DIWA Technology Radar.

Time of intended/expected deployment to the IWT fairway & navigation domain	(technology or technology-oriented) items' assessments results	Remarks
'Future Box': from 2033 onwards	x (per assessment result)	Beyond DIWA time scope; Compare (1), (4), (5) and (6)
>5 years and <10 years from now = 2027-2032	y (per assessment result)	Compare (3)
<5 years from now = 2022-2026	z (per assessment result)	Compare (2)
Here we are today: present DIWA project (2022)		

Table 8: DIWA Technology Radar assessment grades

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- **Note (1):** Already from the hype-cycle analysis it can be concluded, that certain items would not be available for deployment in the IWT fairway & navigation domain during the period 2022-2032, but would need to be put into the 'Future Box'. To be more specific, it may be safely assumed that an item still assessed as being in any of the hype-cycle phases *before Trough of Disillusionment*, meaning, that everything which has not achieved a thorough evaluation by walking through the Trough and entering the 'Slope of Enlightenment', would require more time than until 2032 to reach the 'Plateau of Productivity' which is the level required for broad(er) deployment.

The (Technology) Radar assessment considers (broader) *deployment* of the items at hand, i.e. their 'unavoidability' to the domain, not just implementation of pilot projects. Hence, there can be inferred the following criteria from the above Technology Readiness Level as follows:

- **Note (2):** For an item to be implemented in this (very near) time period of **2022-2026**, the TRL *must be rated 8 or 9* as *one* pre-condition; see Future Box for another critical condition.
- **Note (3):** For an item to be implemented in the time period **2027-2032**, pilot implementation(s) and/or test bed(s) must have been done successfully in the time frame 2022-2026, which means in turn, that the TRL *must have been rated at least 5 as one pre-condition*; see Future Box for another critical condition.
- **Note (4):** All items with a TRL *of below 5* would fall into the 'Future Box'.
- **Note (5):** Items need to be put into the 'Future Box' *even if rated with a TRL of 8* ('initial market introduction'), if *any* single of the organisational or operational or legal or regulatory pre-requisites is *not* operative prior to or shortly after the beginning of the respective intended implementation time period (2022-2026, 2027-2032).[9]
- **Note (6):** If an item is supposed to be deployed to *publicly administered infrastructure*, experience shows that this would need a long ramp up time due to the organisational needs to adapt to the new and emerging technology and its impacts. Hence, those items regularly need to be put into the 'Future Box', i.e. their deployment to publicly administered infrastructure would start with the beginning of the 'Future Box'.

Promising items not be ready within the DIWA scope should be addressed in one or more Study-Recommendations to track their developments and study them in more detail even beyond DIWA

It is assumed that the exercise performed at DIWA regarding the adaptation to the IWT fairway & navigation domain will be re-iterated in several years' time in the future – hence this would provide an opportunity to re-visit in particular the 'Future Box'.

[9] Conversely, a TRL of 9 ('market expansion') could take place only, if and when the essential pre-requisites of the above have been met. Example: Open frequencies for IoT (incompatible) products would have been made available for any market expansion of these IoT products.

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3.3.2 The DIWA Maturity Level Impact assessment metric

The assessment of the potential contribution to the digital transformation of the IWT fairway & navigation domain was introduced above. This is applied to an item under consideration, i.e. the item's DIWA maturity level impact assessment metric, or DIWA IDL Impact for short, is defined as follows.

DIWA IDL Impact (= 'item has the potential to contribute to …')		Features at this Level
III	Intelligent IWT fairway & navigation domain	Digital transformation established; AI assisted process information; Predictive digital capability; Automated response to standard situations.
II	Connected IWT fairway & navigation domain	Advanced digital features aligned with partners; Digital information exchange by default; Full real-time situational picture digitally available.
I	Digitised IWT fairway & navigation domain	Advanced digital features in silos; Overarching vision established; Digital information exchange possible; Limited real-time situational picture digitally available.
0+	Organised IWT fairway & navigation domain	Specialists deliver changes using established process; Traditional digital features; Building digital capabilities.
0-	Reactive IWT fairway & navigation domain	No overarching vision; Requires heroics to change; Management sceptical about digitalisation; Unfocused digital initiatives.

Table 9: DIWA Maturity Level impact assessment (DIWA IDL Impact) (adapted from [DIWA 2021b], 5)

Note, that the assessment of an item may render a statement like: 'Inventory item X has the potential to contribute to the digital transformation of at least the level A up to the level B'. This can and should be reflected, and the pre-requisites of or resulting effects for the different levels should be given as remarks; this may include specifically dependencies on the introduction of certain other items previously or concurrently – compare the IDL-Mismatch-Principle specifically.

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3.4 Resulting assessment table for an item

Now that the assessment metrics of for an item have all been developed, this section provides a summary table that will be used as a template to facilitate the individual item's assessment.

DIWA Assessment metric (short names)	Assessment results
DIWA- Hype Cycle Phase	5 - Plateau of Productivity 4 - Slope of Enlightenment, 3 - Trough of Disillusionment, 2 - Peak of Inflated Expectations, 1 - Technology Trigger
DIWA-Technology Readiness Level	9 (Market expansion) 8 (Initial market introduction) 7 (Pilot production demonstrated) 6 (Pilot production – pre-production product) 5 (Prototyping & Incubation – testing prototype in user environment) 4 (Concept Validation – lab prototype) 3 (Concept Validation – first assessment feasibility) 2 (Invention – Technology concept formulated) 1 (Invention – Basic principles observed)
DIWA-Adaptability	++ (Seamless Adaptability) + (Adaptability with minor modifications) 0 (Adaptable with substantial modifications) - (Adaptable by redesign in analogy) -- (Not adaptable)
DIWA-Adaptation Demands	++ (Little adaptation resource/time demands) + (Intermediate adaptation resource/time demands) 0 (Substantial adaptation resource/time demands) - (High adaptation resource/time demands) -- (Not feasible)
DIWA-(Technology) Radar	2022-2026 2027-2032 'Future Box'
DIWA-IDL Impact	Supportive for transformation into III (Intelligent IWT fairway & navigation domain) II (Connected IWT fairway & navigation domain) I (Digitised IWT fairway & navigation domain) 0+ (Organised IWT fairway & navigation domain) 0- (Reactive IWT fairway & navigation domain)

Table 10: Summary table for DIWA assessment metrics

Notes on the table's application:

- In the column 'assessment results', the values of the expert discussions should be entered.
- The assessment of the DIWA-Hype Cycle Phase is omitted for this study and report, because the DIWA-Technology Readiness Level renders more precise results.

3.5 Arriving at recommendations for the masterplan of DIWA and beyond

After all assessment tools have been developed, it is finally necessary to use their results to arrive at conclusions and recommendations for the crafting of the DIWA masterplan including its migration path(s). The quantitative assessment metrics were developed may be used for conclusions and recommendations requiring quantifiable assessment metrics. In addition, qualitative conclusions and recommendations need to be drawn and collected. These methodology for this is the subject of this section.

3.5.1 The 4-Quadrants-Matrix

It is desirable to condense the individual findings and assessments into one figure that directly allows to arrive at conclusions and – based on those conclusions – at recommendations. Such a figure is generally known as the 4-Quadrants-Matrix, and it is capable of transforming assessments into recommendations for roadmapping and migration paths. The generic 4-Quadrants-Matrix is shown in the following figure.

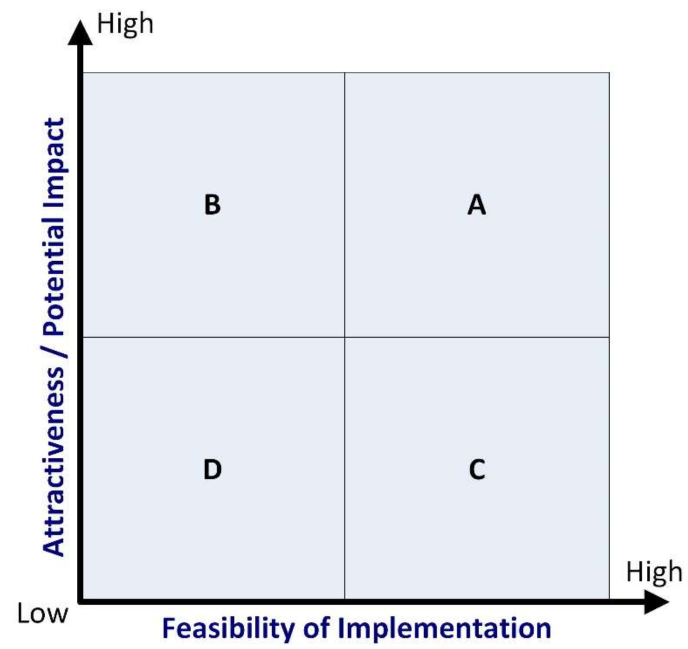

Figure 11: Generic 4-Quadrants-Matrix

The four quadrants are determined by two dimensions, namely the attractiveness of implementing of the items under consideration (y-axis) versus the feasibility of their implementation (x-axis). For a meaningful 4-Quadrant-Matrix it is important, that meaningful metrics are found for 'attractiveness' and 'feasibility'. All items are thus entered into the 4-Quadrant-Matrix at their place resulting from their assessments.

In a next step the square is subdivided into the four quadrants (A, B, C, D) as shown in above figure. The generic meanings for entries into the four quadrants would be:

- A – Items are (relatively) easy to implement and also have a (relatively) high attractiveness of implementation – they should be implemented as a priority.
- B – Items have a (relatively) high attractiveness, but require (relatively) more effort for implementation – they should be made implementation goals for the medium to long run, and preparations for reaching them should be started as a priority.
- C – Items are (relatively) easy to implement but only have a (relatively) limited attractiveness; they should be implemented when there are compelling needs.
- D – Items are neither attractive nor easy to implement; they should be discarded.

This general method needs to be adapted to the specific meanings of the axis and of the quadrants for the purpose under consideration. The adaptation can be directly achieved by use of the previously developed assessment metrics as follows:

- The axis *'Feasibility of Implementation'* becomes the *DIWA Application Resource and Time Demands*: A low feasibility of implementation corresponds with the grade 'Not feasible', while the highest feasibility corresponds with the grade '++'.
- The axis *'Attractiveness / potential impact'* becomes the *DIWA IDL Impact*: From DIWA's point of view, it is 'attractive' to achieve a high DIWA Maturity Level, so that 'Reactive Fairway & Navigation' (0-) corresponds with low attractiveness and 'Intelligent Fairway & Navigation' (III) with the highest degree of attractiveness.
- The *assessments of items* are introduced in that grid of 25 discrete fields. Since the DIWA IDL Impact can range from values y_1 to y_2, this is then indicated by a vertical line spanning from y_1 to y_2. Should the assessment of the DIWA Application Resource and Time Demands of an item have

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rendered a range from values x_1 to x_2, this is then indicated by a horizontal line spanning from x_1 to x_2.

- The *four quadrants* would acquire the following meanings, which can be ***directly interpreted as recommendations for roadmapping*** as follows:
    - A – *Items entered here reach desired high DIWA IDL Impact at low effort.*

      Resulting recommendation: Apply that relevant selection of these items that covers all of the required functionality as soon as possible.
    - B – *Items entered here reach desired high DIWA IDL Impact at a higher effort.*

      Resulting recommendation: Start all preparations for applying that relevant selection of the items that covers the required functionality fully as soon as possible, with the goal to introduce these items in the long term, i.e. likely beyond the time scope of DIWA.
    - C – *Items entered here can be applied to IWT fairway & navigation domain with relatively little effort, but also limited DIWA IDL Impact and should thus at best only be construed as intermediate or 'bridge' items for the IWT fairway & navigation domain.*

      Resulting recommendation: Apply these items only when compelling needs mandate the introduction of an intermediate 'bridge' in certain migration path(s).
    - D – *Items entered here wouldn't progress the DIWA Maturity Level much while their adaptation would require much effort.*

      Resulting recommendation: Prefer other quadrants' items if at all possible.
- Note: The value 'not feasible' of the *DIWA Application Resource and Time Demands* metric renders the whole left column irrelevant and is therefore not part of any matrix A, B, C, and D of the DIWA-tailored matrix. Since there are 20 remaining fields of the DIWA-tailored matrix, there is a certain margin to move the boundaries of the four quadrants to.

The DIWA-tailored matrix with an example allocation of the four quadrants is given in following figure.

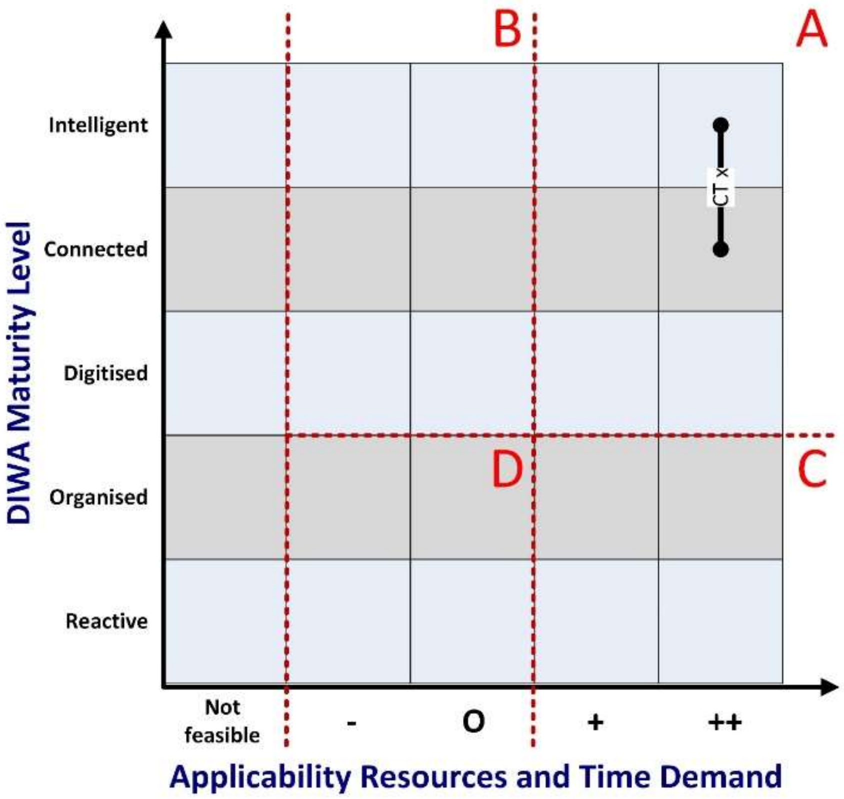

Figure 12: DIWA-tailored 4-Quadrants-Matrix with example 'Dream Item x' and example quadrant allocations

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4 Glossary of terms

(DIWA-)Adaptability — is a metric that reflects the ease (or difficulty) to adapt an item to the IWT fairway & navigation domain.

(DIWA-)Adaptation Resource Demand — is a metric that reflects the amount of resources needed for the adaptation of an item to the IWT fairway & navigation domain.

Centre — is 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.

Connected Fairway & Navigation — means by definition of ([DIWA2021b], 5) that advanced digital features have been aligned with partners; that the exchange of information is done by default; and that full real-time situational pictures are digitally available for the fairway(s) and the inland waterway vessels' navigation. It may be assumed that 'digital situational pictures' is a paraphrase of what is commonly known as 'digital twin' of the entity under consideration. This IDL is abbreviated with the Roman numeral II.

Co-operative technology — is a technology where participating entities, e.g. 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.

Digital Transformation — 'is the adoption of digital technology by an organization. Common goals for its implementation are to improve efficiency, value or innovation'. [Wikipedia-EN 2022d]

Digitised Fairway & Navigation — means by definition of ([DIWA2021b], 5) that an overarching vision (for the digital transformation of fairway & navigation) has been established; that advanced digital features are implemented within confined topical domains ('silos') of the fairway and/or inland waterway vessels' navigation; and that a limited real-time time situational pictures are digitally available for the fairway(s) and the inland waterway vessels' navigation. This IDL is abbreviated with the Roman numeral I .

DIWA Maturity Model — is a maturity model pre-given by the DIWA project framework that is based on the much more elaborate Capability Maturity Model (CMM) but simplified and adapted to the needs and specifics of IWT.

Entity — is a generic designation for any generic object class being an essential functional part of the IWT fairway & navigation domain, such as 'vessel' (and subclasses), 'centres', 'waterway field infrastructure', and 'data objects'. (NB: 'Entity' should not be confused with 'item (under consideration)'.)

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.

'Future Box' — is the part of the roadmap developed to describe and determine the migration towards the DIWA desired IDLs of the IWT fairway & navigation domain that is outside of the DIWA time frame, i.e. beyond 2032. As such, the 'Future Box' is the part of any DIWA (Item) Radar that is most remote from present.

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(DIWA-)IDL Impact of an item under consideration is a metric stating that the item has the potential to contribute to achieving the IDL stated – or, if a range of IDLs is given, to achieve at least the minimum IDL stated and at best the maximum IDL stated.

IDL-Match-Principle states that that the entities involved in the same operational relationship demonstrate the same IDL.

IDL-Mismatch occurs if and when the IDL-Match-Principle cannot be met e.g. due to a border situation of whatever kind.

Intelligent IWT is achieved when *both* the IWT fairway & navigation and the IWT logistics domains have reached the highest IWT Digitalisation Level 'Intelligent' during the IWT digital transformation process.

Intelligent Fairway & Navigation means by definition of ([DIWA2021b], 5) that the digital transformation of fairway and navigation would have been completed; that Artificial Intelligence assists in the optimisation of processes related to fairway provision, operation and maintenance as well as in the optimisation of inland waterway vessels' navigation processes proper; that prediction algorithms are in place to support fairway & navigation processes; and that there are implemented standard responses in fairway provision, operation and maintenance processes as well as inland waterway vessels' navigation processes. This IDL is abbreviated with the Roman numeral **III**.

Item under consideration is the subject of introduction and assessment for potential adaptation to the IWT fairway & navigation domain. Different (Sub-)Activities of DIWA cover different classes or families of items, such as business use cases, operational procedures, regulations, technologies, or technological trends. In several (Sub-)Activities there is the task to establish an inventory of items under consideration, thus rendering 'inventory items'. (NB: An item should not be confused with an entity (of the IWT fairway & navigation domain)).

(DIWA-) (Item) Radar is a generalisation of the Technology or Trend Radar, where item may not be a technology or a trend.

IWT Digitalisation Level (IDL) is a metric that defines the degree of digital transformation an entity has acquired. This metric is defined in ([DIWA 2021b], 5) with the two domains 'Fairway & Navigation' and 'Logistics' as examples. The different levels are – from least to highest – 'reactive', 'organised', 'digitised', 'connected', and 'intelligent'. For simplicity of reference, the following abbreviations were assigned to the different IDL as follows:

- III - Intelligent
- II - Connected
- I - Digitised
- 0+ - Organised
- 0- - Reactive

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.

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.

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Organised Fairway & Navigation means by definition of ([DIWA2021b], 5) that specialists deliver changes using established process(es); that traditional digital features prevail; and that digital capabilities are being built. This IDL has been abbreviated '**0+**'.

Reactive Fairway & Navigation means by definition of ([DIWA2021b], 5) that there is no over-arching vision for the digital transformation of fairway & navigation; that changes require 'heroics' to accomplish them; that management is sceptical about digitalisation; and that unfocused digital initiatives are common. This IDL has been abbreviated '**0-**' .

Technology or Trend Radar shows the 'qualitative proximity' or 'relative unavoidability' of many technologies and/or trends compared to the present state of the art of the domain under consideration at a glance. The present state of the domain under consideration is located at the centre spot of the diagram: The closer an item, such as technology or trend, is located to that centre, the higher the 'degree of imminence' to the domain under consideration; the further distant an item is, the more less likely it is that the item will be introduced in the domain under consideration soon or at all (if also far away towards the margins). If an item is located on a straight 'collision course', the more likely it is unavoidable for introduction to the domain under consideration.

(DIWA-) Technology Readiness Level(s) is a metric for a technology under consideration stating its inherent technological readiness to be deployed to an application domain, which is regularly the one for which the technology was developed for. The readiness metric ranges from 'invention' to 'market expansion'. Hence, 'market expansion' would also imply that a technology has acquired the maturity to also transcend its original application domain.

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

0-	IWT Digitalisation Level 'Reactive'
0+	IWT Digitalisation Level 'Organised'
AI	Artificial Intelligence
AIS	Automatic Identification System
ATIS	Automatic Transmitter Identification System
CMM	Capability Maturity Model
DIWA	Masterplan Digitalisation of Inland Waterways project
DIWA-TRL	DIWA –Technology Readiness Level
DSC	Digital Selective Calling
EARTO	European Association of Research and Technology Organisations
ECDIS	Electronic Chart Display and Information System
HGDM	Harmonisation Group on Data Modelling (at IMO)
I	IWT Digitalisation Level 'Digitised'
II	IWT Digitalisation Level 'Connected'
III	IWT Digitalisation Level 'Intelligent'
IDL	IWT Digitalisation Level.
IMO	International Maritime Organization
Inland-AIS	AIS derivative adapted specifically for the needs of IWT navigation
Inland-ECDIS	ECDIS developed specifically for the needs of IWT navigation
IWT	Inland Waterway Transport
MOTS	Modified Off-the-Shelve (product)
NtS	Notices to Skippers
RIS	River Information Services
TRL	Technology Readiness Level(s)

6 References

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[Wikipedia-Commons 2021] Wikipedia Commons. 2021. *Figure Hype-Cycle-General.* https://upload.wikimedia.org/wikipedia/commons/b/bf/Hype-Cycle-General.png. Accessed 08 August 2022. Compare Chapter "Sources of Figures".

7 Sources of Figures

The sources of the Figures and Tables used in this report are own creations of the present author unless stated as follows:

- Figures 1 ('IWT Digitalisation Levels') and 2 ('DIW Maturity Model)' are from the DIWA framework documentation ([DIWA 2021b], 5f) and are thus to be used for any purpose of the DIWA project, including this manual.
- Figure 4 ('Hype Cycle'): Hype-Cycle is from Wikipedia-Commons with the following attribution text given there: "By Olga Tarkovskiy - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27546041"

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-Overcoming-Ambiguities-1: Study and report all relevant existing regulations, operational procedures and related terminology with the goal to identify definition ambiguities that may impede progression to higher IDLs.

  Estimation of size of work incurred: 'Ac' (but potentially even 'P')

- Study-REC-Overcoming-Ambiguities-2: Study and report all relevant existing technical standards, recommendations, and related terminology with the goal to identify definition ambiguities that may impede progression to higher IDLs.

  Estimation of size of work incurred: 'Ac' (but potentially even 'P')

- Action-REC-Overcoming-Ambiguities-1: Determine a migration path towards removing definition ambiguities from *all* relevant regulations, operational procedures, terminology and data models need as far as possible, in order to arrive at 'digital information exchange as a default' (IDL Connected key feature).

  Estimation of size of work incurred: 'Ac'

- Action-REC-Overcoming-Ambiguities-2: When setting up the migration path towards removing definition ambiguities, plan for further study in this regard beyond what will have been achieved during DIWA Activities.

  Estimation of size of work incurred: 'Ac'

- Action-REC-Overcoming-Ambiguities-3: Plan for initiating and eventually initiate a 'round table' of *all* relevant IWT bodies, learning from the example of IMO regarding their e-navigation inspired Harmonisation Group on Data Modelling (HGDM), with the goal to remove definition ambiguities from all regulations, operational procedures from *all* relevant regulations, operational procedures, terminology and data models need as far as possible, in order to arrive at 'digital information exchange as a default' (IDL Connected key feature).

  Estimation of size of work incurred: 'Ac' (but potentially even 'P')

Note: All Recommendations on Overcoming Ambiguities together would incur not only a project-size effort, but also interactions of the relevant committees involved in order to agree on goals and on the roadmap towards those goals. That in turn would likely require several committee sessions each.

- Study-REC-Cooperative-Technology-Proliferation: Study to which degree non-cooperative technologies will be still needed on a regular basis and/or for fall-back arrangements even when arriving at the highest possible IDL throughout.

  Estimation of size of work incurred: 'Ac'

- Action-REC-Cooperative-Technology-Proliferation: Determine a migration path towards implementing relevant non-cooperative technologies needed on a regular basis and/or for fall-back arrangements even arriving at the highest possible IDL throughout, including planning for further study in this regard.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-Required-Legal+Regulatory-Framework-When-Employing-IDLs: Study the potential shape and structure of the future IWT fairway & navigation domain's legal and regulatory framework for application of the IDL as a new guiding principle for IWT development when applied to the different entities of the IWT fairway & navigation domain.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-Avoiding-IDL-Mismatches-At-Borders: Study from a legal/regulatory framework perspective, how IDL-Mismatches can be avoided at borders between adjacent IWT fairway & navigation domain stakeholder's areas of competency, in particular at country and/or regional and/or operational domain borders.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-Required-Technical-Standards-Framework-When-Employing-IDLs-1: Study the potential shape and structure of the future IWT fairway & navigation domain's technical standards framework for application of the IDL concept as a new guiding principle for IWT development when applied to the different entities of the IWT fairway & navigation domain, in particular for arriving at IDLs I, II, and III.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-Required-Technical-Standards-Framework-When-Employing-IDLs-2: As a follow-up to Study-REC-Required-Technical-Standards-Framework-When-Employing-IDLs-1 identify the necessary amendments to the existing technical standards framework and to all relevant individual technical standards.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-Required-Data-Quality-Requirements-When-Employing-Higher-IDLs: Study the impact of desired IDLs I, II, and III on data quality requirements for authorities when providing data.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-Required-Cyber-Security-When-Employing-Higher-IDLs: Study the impact of desired IDLs I, II, and III on requirements on cyber security for the IWT fairway & navigation domain at large, the different entities of the IWT fairway & navigation domain individually, and the functional links between them.

  Estimation of size of work incurred: 'SuAc'

- Study-REC-Administration-As-Trusted-Third-Party: Study the necessary steps for rendering administrations Trusted Third Parties when approaching IDLs I, II, and III in order to remove any potential distrust amongst IWT stakeholders regarding sharing of data.

  Estimation of size of work incurred: 'SuAc'

- Action-REC-Required-Legal+Regulatory-Framework-When-Employing-IDLs: Determine a migration path for future implementation of the envisaged future IWT fairway & navigation domain's legal and regulatory framework for application of the IDL as a new guiding principle for IWT development when applied to the different entities of the IWT fairway & navigation domain.

  Estimation of size of work incurred: 'C'

- Action-REC-Avoiding-IDL-Mismatches-At-Borders: Include in the migration path towards IDLs I, II, and III further studies. as needed, as well as appropriate actions from a legal/regulatory framework perspective, how IDL-Mismatches can be avoided at borders between adjacent IWT fairway & navigation domain stakeholder's areas of competency, in particular at country and/or regional and/or operational domain borders.

  Estimation of size of work incurred: 'C'

- Action-REC-Required-Technical-Standards-Framework-When-Employing-IDLs: Determine a migration path for future implementation of the envisaged future IWT fairway & navigation domain's technical standard framework for application of the IDL as a new guiding principle for IWT development when applied to the different entities of the IWT fairway & navigation domain.

Estimation of size of work incurred: 'C'

- Action-REC-Required-Data-Quality-Requirements-When-Employing-Higher-IDLs: Include in both the operational/regulatory as well as technical standardisation migration paths towards IDLs I, II, and III further studies. as needed, as well as appropriate actions to cater for the potential impacts of higher IDLs on data quality requirements for authorities when providing data.

  Estimation of size of work incurred: 'C'

- Action-REC-Required-Cyber-Security-When-Employing-Higher-IDLs: Include in both the operational/regulatory as well as technical standardisation migration paths towards IDLs I, II, and III further studies. as needed, as well as appropriate actions to cater for the potential impacts of higher IDLs on cyber security requirements.

  Estimation of size of work incurred: 'C'

- Action-REC-IDL-Graceful-Degradation+Fallback-Arrangements: Include in both the operational/regulatory as well as technical standardisation migration paths in the migration path towards IDLs I, II, and III further studies. as needed, as well as appropriate actions to design the graceful degradation and fall-back arrangements needed into the technical, regulatory, operational, business continuity planning domains from the outset.

  Estimation of size of work incurred: 'C'

- Action-REC-Administration-As-Trusted-Third-Party: Include in the migration path towards IDLs I, II, and III further studies. as needed, as well as appropriate actions for rendering administrations Trusted Third Parties when approaching higher IDLs (I and above) in order to remove any potential distrust amongst IWT stakeholders regarding sharing of data.

  Estimation of size of work incurred: 'C'

Note:

- All action recommendations on **planning the migration path towards mitigating the consequences of approaching higher IDLs together** could be done within the framework of an project's Activity workload.
- The **necessary studies** themselves (refer to study recommendations) **together** would incur a major portion of a project's workload.