ENAV17-10.4.3

ACCSEAS North Sea Region Route Topology Model (NSR-RTM)

Description and contribution to an international generic Route Topology Model definition

Issue: 1

Issue Status: Approved

Issue Date: 05/05/2015

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Executive Summary

Starting point for the work described in this 'ACCSEAS North Sea Region Route Topology Model (NSR-RTM) Description' was the vessel traffic analysis reported in the 'ACCSEAS Baseline & Priorities Report' in conjunction with *lack* of available information about the actual routes of the EU Motorways of the Seas (MoS) in the North Sea Region (NSR). At the beginning of the ACCSEAS project only sketchy data and illustrations were available as illustrated by below figure.

(for source information,
compare main body of this description)

Obviously, nobody prior to ACCSEAS (to the knowledge of the present authors) has ventured to identify the true locations and the connectivity of the MoS grid in the NSR as a whole. This was recognised as a task to match, in particular, the impact on shipping by the advent of Marine Spatial Planning (MSP) which seems to render even more confined shipping lanes in even more quarters of the region.

So, the fundamental idea was to take up the undisputable existence of those already defined shipping lanes in combination with the ACCSEAS vessel traffic analysis for the present and future NSR situation (compare above 'ACCEAS B&P Report') and transform these facts and findings into *an abstract, seamless model of all practically possible vessel routes in the region based on a generic mathematical (or, more precisely topological) model as a basis, called Route Topology Model (RTM) in generic and NSR-RTM in its regional instance.* Once this would have been done, i.e. after this walk through the abstract domain, the idea was to arrive at a number of relevant findings, including the answer to above introductory question, but also at some spin-offs for future work.

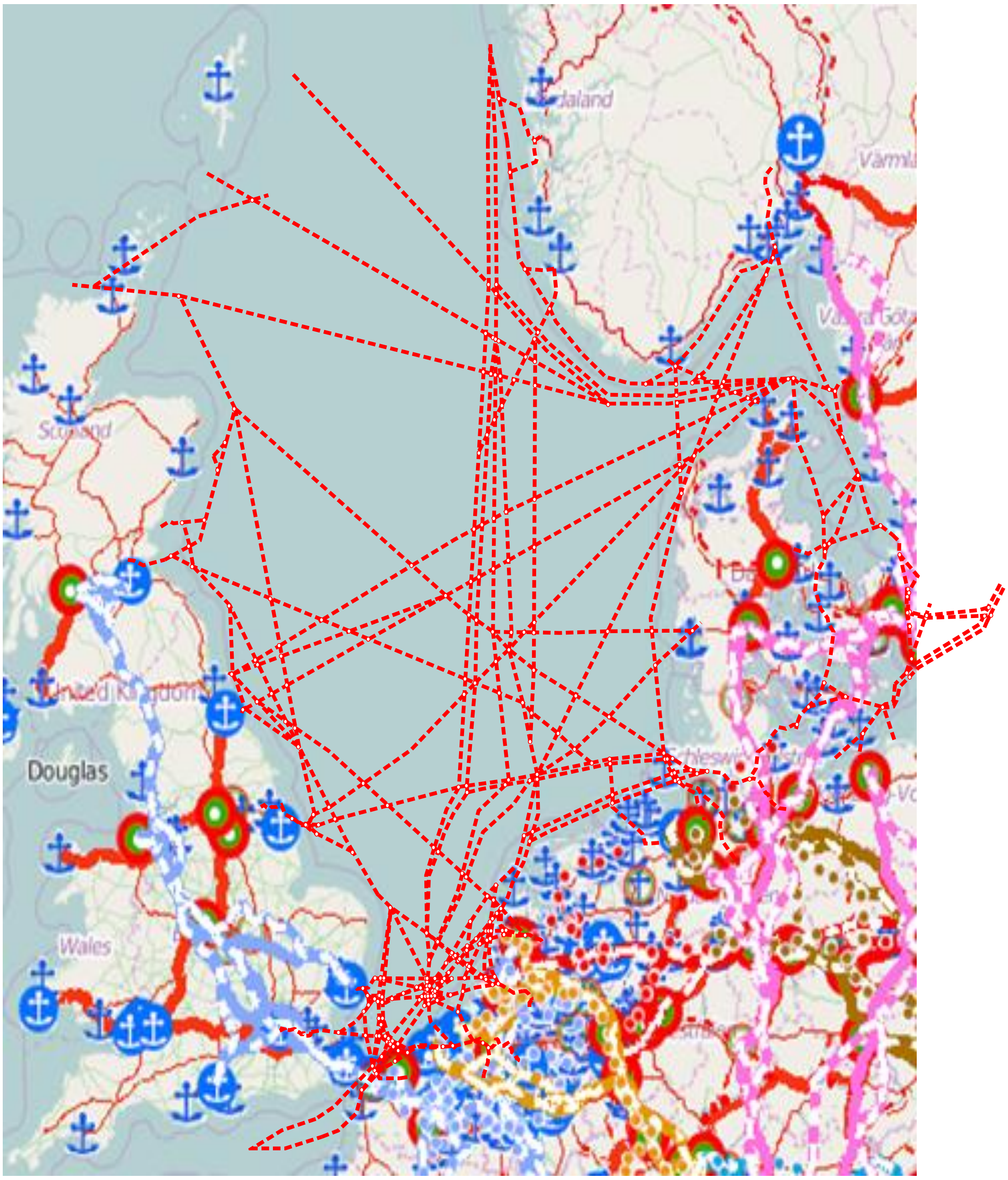
The first step was to create the generic RTM using only a minimum of abstract elements, namely 'nodes' and 'legs.' The nodes were subdivided into several classes to reflect the different features of nodes in reality, such as waypoints, junctions, cross-border connections, and destinations (e.g. ports). Having in mind the manifold shipboard and shore-based users and stakeholders as defined by IMO's e-Navigation strategy, three fundamentally different but co-existent user display modes for different user applications were developed and portrayed. These are the ENC display mode (based on readily available Electronic Navigational Charts) which displays any RTM in its true topo*graph*ical location, the London Tube Map (LTM) display mode which shows the vessel traffic routes in their essential connectivity relationships (but still retaining a true topo*log*ical representation), and the Head-Up-Display (HUD) / Augmented Reality (AR) display mode for the mariners. Drawing also upon definition work in the European and international domains, this rendered a consistent and – by applying it to the NSR specifics – tested and evaluated generic model to further build on reliably.

After the generic definitions work was finalised as described above, the methodology was tested and thereby evaluated using data of the present situation and planning forecasts into

2020+ for the whole of the NSR, thus rendering instances of the RTM for the NSR (NSR-RTM) accordingly. This work not only provided the answer to the above initial question of where the MoS in the region are exactly, but also provided a means to identify *two other classes of shipping lanes which complement the MoS level to arrive at a seamless, meaningful and versatile RTM for all classes of vessel*, down to small craft size, as follows:

- ***Motorways of the Sea (MoS)*** shipping lanes;
- ***Roads of the Sea (RoS)*** shipping lanes, i.e. shipping lanes, other than MoS, relevant for *professional/commercial shipping* (including ferry routes, offshore construction and supply traffic etc.);
- ***Trails of the Sea (ToS)*** shipping lanes, i.e. all other shipping lanes, which are in most cases only available, due to physical dimensions, for small crafts such as fishing vessels and leisure crafts.

Having in mind also the logistics chain and the connection of maritime transport to other modes of transportation, the original question how the MoS truly connect in the region was answered for the first time ever (to the knowledge of the present authors) as shown in the following figure in graphical superimposition.



But this was not the only application recognised: In conjunction with several user and stake-holder consultations a list of meaningful applications was identified and a more elaborate description of each is given in the present Description. Among the applications identified were the following:

- Harmonisation of route definitions of different stakeholders to arrive at a common under-standing – the most fundamental benefit;
- Enable (NSR) transport and traffic pattern analysis for policy making;
- Assist in the Marine Spatial Planning of a given sea area;
- Transport management by employing an improved route and voyage planning, both regard-ing initial (pre-trip) and en-route (re-)planning;
- Traffic planning and management in strategic and tactical terms: a number of application notes are given in the present Description in this regard, including shipboard applications as well as VTS applications, regarding in particular Traffic Organisation Service (TOS);
- Just-in-time arrival processes with 'Precision-Estimated Time of Arrival (ETA)-applications';
- Implementation of IMO defined 'shore-based Navigational Guidance and Information Schemes;'
- Support of the IMO defined Maritime Service Portfolios (MSPs) within e-Navigation;
- Maritime information dissemination tailored to the specific needs of different user groups;
- Improved risk assessment by basing the risk assessment on defined routes;
- Establishment of improved Routing Measures, in particular an improved Traffic Separation Scheme (TSS)-grids;
- Extensive or more precise cost / benefit analysis.

Obviously, taking into account the limited duration and resources available in a project like ACCSEAS, the present work opened a field of ACCSEAS 'legacy' work and applications to be further investigated after the project. These have been captured throughout the present Description, including the Appendices to it.

It should finally be noted that future such work would result in providing specific contributions to European and international initiatives, strategies and ongoing implementation work, such as TEN-T, INSPIRE, Intelligent Transport Systems (ITS) directives, e-Maritime initiative, an emerging NSR basin strategy, MSP at large, IMO TSS definitions, the IHO Universal Hydro-graphic Data Model (S-100; GI Registry), IMO 'Navigational Guidance and Information Schemes' and e-Navigation strategy implementations, including in particular the MSPs, and – last but not least, considering the logistics chain – the IMO Secretary General's proposed Sustainable Maritime Transportation System (SMTS).

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Contents

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Document Information

Project Title	ACCSEAS
Work Package No.	4
Document Title	ACCSEAS North Sea Region Route Topology Model
Description	Description and contribution to an international generic RTM definition
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iManage Location	29850
Circulation	1. Client 2. Project Files (i-manage) 3. Transnational Project Co-ordination Group 4. Project Steering Committee
NSRP Secretariat Approval	Not required

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1 Introduction

1.1 Purpose and context of this document

This document is called *'ACCSEAS North Sea Region Route Topology Model (NSR-RTM) – Description and contribution to an international generic RTM definition.'* This 'description' aims at capturing the essence of the findings of the ACCSEAS project in regard to the *ACCSEAS candidate solution* 'North Sea Region (NSR) Route Topology Model (RTM)' (ACCSEAS 2015a). Thus, this description forms part of the required legacy of the ACCSEAS project beyond the duration of the ACCSEAS project itself (ACCSEAS 2015b).

Figure 1 illustrates the highlights the present document in the context of the ACCSEAS deliverable framework.

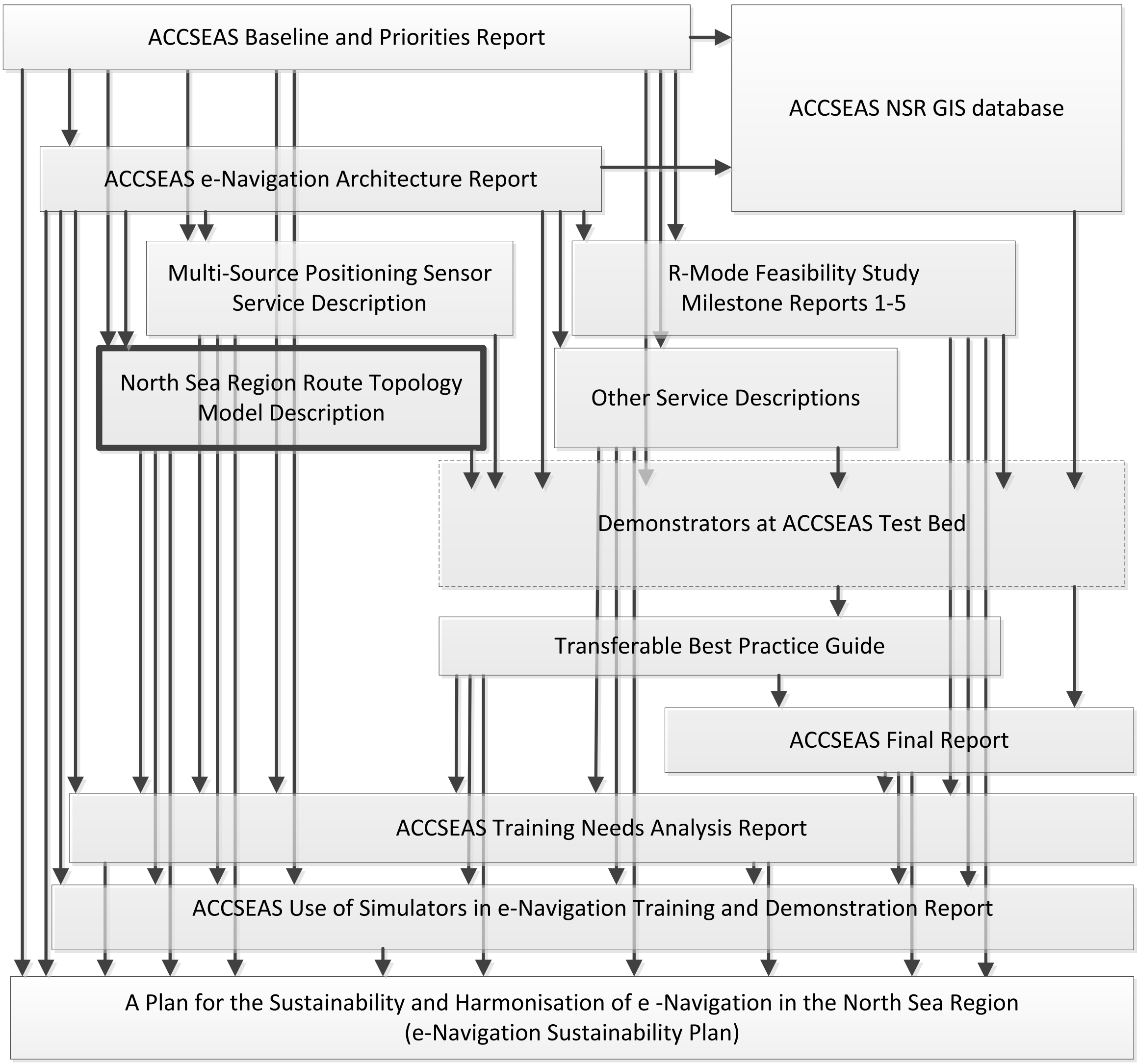

Figure 1: Context of the NSR-RTM Description within ACCSEAS Reports.

For further details on the context of this description compare 'ACCSEAS Baseline & Priorities Report,' Ed. 3, Chapter 6 (ACCSEAS 2015a) and the 'ACCEAS e-Navigation Architecture Report' (ACCSEAS 2015c). In the latter, there is given an architectural analysis of where and how the (NSR-)RTM fits into and would be supportive to the proposed Sustainable Maritime Transportation System (SMTS) and the IMO defined concept of e-Navigation.

The present Description also serves as a potential source for contributions to relevant international and European standards and regulations. Thereby, this description contributes to the 'set of standards' ACCSEAS is supposed to produce (ACCSEAS 2011, para 14.2i). This Description is designed as a stand-alone document and intends to be self-explanatory.

1.2 The Motivation of the NSR-RTM in the context of the EU's Motorways of the Seas (MoS) concept

From the figures analysing the shipping traffic density in the NSR it is obvious, that (commercial) shipping does *not* take place 'everywhere' in the NSR but is *rather confined to recognizable 'shipping lanes*' (ACCSEAS 2015a, ch.1).[1] The following *major factors* determine the location of those shipping lanes:

- In general, (commercial) shipping seeks to use the fastest way between the ports of call of a vessel's voyage for economic reasons (operation costs of a vessel including fuel costs, time constraints etc.). Often, the fastest way happens to be the shortest way, too. Obviously, this depends on natural conditions such as natural topology, including draught limitations, as well as on man-made topological conditions such as artificial waterways like the Kiel-Canal.
- IMO has introduced several mandatory Traffic Separation Schemes (TSSs) in the NSR. Each TSS constitutes one (bi-directional) shipping lane.
- There are certain areas where shipping is not permitted for various reasons, i.e. 'No-Go-Areas.' Hence, shipping must avoid those areas, and shipping lanes must circumvent them.
- The same holds true for physically existing off-shore structures and installations, for which IMO has determined a minimum passage distance of 500 m. Again, a shipping lane may not pass through that protective circle and must circumvent any off-shore structure. This determining factor will become particularly increasingly important in the future.

The notion of a shipping lane also carries the implication of a certain degree of vessel traffic density and also the notion of a certain degree of ease of vessel traffic. This has led the EU, in their Trans-European Network-Transport (TEN-T) program, to recognize a specific subset of the shipping lanes as so-called *'Motorways of the Sea (MoS)*,' namely the *most important shipping lanes* in terms of cargo carried or in terms of economic importance for the Union.

Figure 2: Overview depiction of the Motorways of the Sea in the North Sea Region (blue lines, TEN-T project No. 21) (Amt für Veröffentlichungen 2005, 12)

Figure 2 shows the recognized MoS in the NSR, namely the ones through the English Channel/Dover Straits, the Kiel Canal cutting short Jutland Peninsula, and the one around

[1] The term 'shipping lane' is used here in much the same connotation as in colloquial parlour.

Skagen into the Baltic Sea. This overview depiction must be construed as an 'artistic impression' in regard to the MoS, however, as they end somewhere in the middle of the North Sea without any obvious connection to each other, to the Kiel Canal, or to any port at all. Therefore, a more elaborate depiction of the MoS was created (Figure 3), which correlates those MoS shipping lanes with figures of cargo carried.

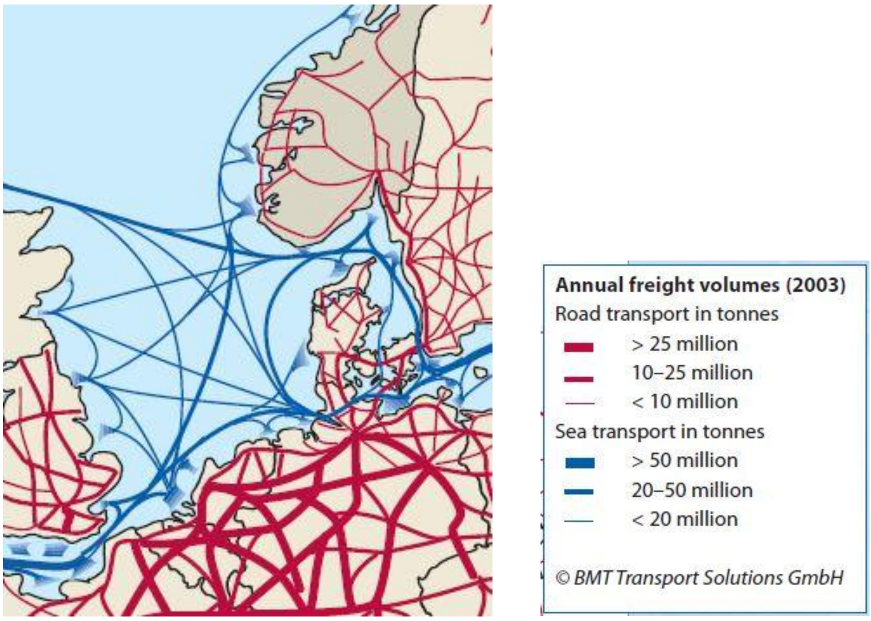

Figure 3: More elaborate overview depiction of the MoS in the NSR (blue lines)
(Office for Official Publications of the European Communities 2006, 2).

While Figure 3 now avoids the deficiencies of the Figure 2, this depiction does not show the very important MoS shipping lanes connecting the English Channel and Skagen at all, and also the assumption is made that vessel traffic around the UK will take a deep North Sea detour. Also, in Figure 3 there still is a certain degree of fuzziness at large. This is in stark contrasts with the generally available depictions of the shore-based TEN (motorways and other roads, railroads). From this observation it follows, that *it would be a major contribution to the regional-European as well as to the pan-European strategy developments should the shipping lanes of the NSR including their connectivity to the shore-side via the ports be known with appropriate precision.*

Such a knowledge base could also recognize the *different degrees of importance of shipping lanes,* which is implied by the 'motorways' notion. ACCSEAS has tentatively recognized the following three classes of shipping lanes:

- ***Motorways of the Sea (MoS)*** shipping lanes;
- ***Roads of the Sea (RoS)*** shipping lanes, i.e. shipping lanes, other than MoS, relevant for *professional/commercial shipping* (including ferry routes, offshore construction and supply traffic etc.);
- ***Trails of the Sea (ToS)*** shipping lanes, i.e. all other shipping lanes, which are in most cases only available, due to physical dimensions, for small crafts such as fishing vessels and leisure crafts.[2]

[2] The nomenclature needs to be finalized eventually. The name *'Trails of the Sea (ToS)' follows* the land road analogy as implied by 'Motorways of the Sea' and 'Road of the Sea'; a possible alternative designation, namely ***'Small Craft shipping lane,'*** would make a statement regarding the size of the vessels which the shipping lane is assumed to be using. To be in keeping with the overall analogy of land road traffic and to avoid the assumption of the vessel size, the name 'Trails of the Sea' is used throughout this Description.

Based on the well-known natural and artificial topologies, on the well-known IMO stipulated existing TSS as well as on the AIS vessel traffic density footprint it is now possible to create both *a list and a graphical, user-friendly depiction of all shipping lanes existing in the NSR today*, *together with their true locations as well as their true connectivity amongst each other and with land via ports.* This could be done by using *one consistent description methodology (or 'tool') which could be called 'Route Topology Modelling (RTM),'* thus creating a *North Sea Region Route Topology Model (NSR-RTM)* for the ***present*** situation.

Any RTM would be constructed using only *legs* and *nodes*. With legs and nodes *a vessel traffic network can be formed which would reflect the situation of possible routes for vessel traffic in a given area for a given point in time.*

It would further be possible and necessary to distinguish in this NSR-RTM the *different classes of shipping lanes* as introduced above, both in terms of their features and attributes as well as in terms of their display to the user via a Human Machine Interface (HMI).

It would thus be possible

- *to assist – with appropriate precision – in any strategic planning effort regarding the NSR* and therefore *match the precision of land traffic and airborne traffic strategic planning;*
- to also reap *significant direct benefits for the navigation of the vessels through the NSR when using NSR-RTM based application,* i.e. applications and benefits *directly for mariners*;
- to model also intermodal transport needed for logistics decision making, when considering the connection of the port nodes modelled in the RTM with the landside transport networks which have the same port nodes included in their grid models.

Since this NSR-RTM would use the presently available data, any application implementation would be possible, in principle, *within a relatively short-term implementation period.*

Looking into the ***future,*** the main challenges from a shipping perspective in the NSR arises

- from decreased 'open waters,'
- from increased shipping traffic, and
- from a combination of both factors (ACCSEAS 2015a, chapter 2).

The decrease of 'open waters' in the NSR will be most likely due to the erection of many off-shore installations, the most prominent of which will be off-shore renewable energy plants, and to the protection of large sea areas as nature reserves. Even assuming ideal and fair negotiation of interests between all stakeholders affected in the process of Marine Spatial Planning (MSP),[3] as demonstrated by the German example (Figure 4), extrapolating into the future, there will be only shipping lanes left throughout the NSR (ACCSEAS 2015a, Ch. 2).[4] Also, these remaining shipping lanes will be less in number and may be less in space than the present shipping lanes.

[3] At present, there is incoherence in usage of the terms '*Marine* Spatial Planning' vs. '*Maritime* Spatial Planning' throughout. UNESCO as the competent United Nations body who has defined MSP internationally uses 'Marine' while the EU Directive on MSP uses 'Maritime.' 'Marine' appears to be somewhat broader in meaning from an English usage point of view as opposed to 'maritime.' This broader meaning is appropriate to the concept of MSP; hence, within this Description 'marine' is used throughout unless within a direct quote.

[4] It is stressed, that the German example is considered a good example, in principle, as a fair negotiation of interests of different stakeholders was sought. The consequences of a poor negotiation of interests between shipping and other stakeholders in the process of MSP may result in even less 'open space' for shipping, i.e. in even more constricted shipping lanes.

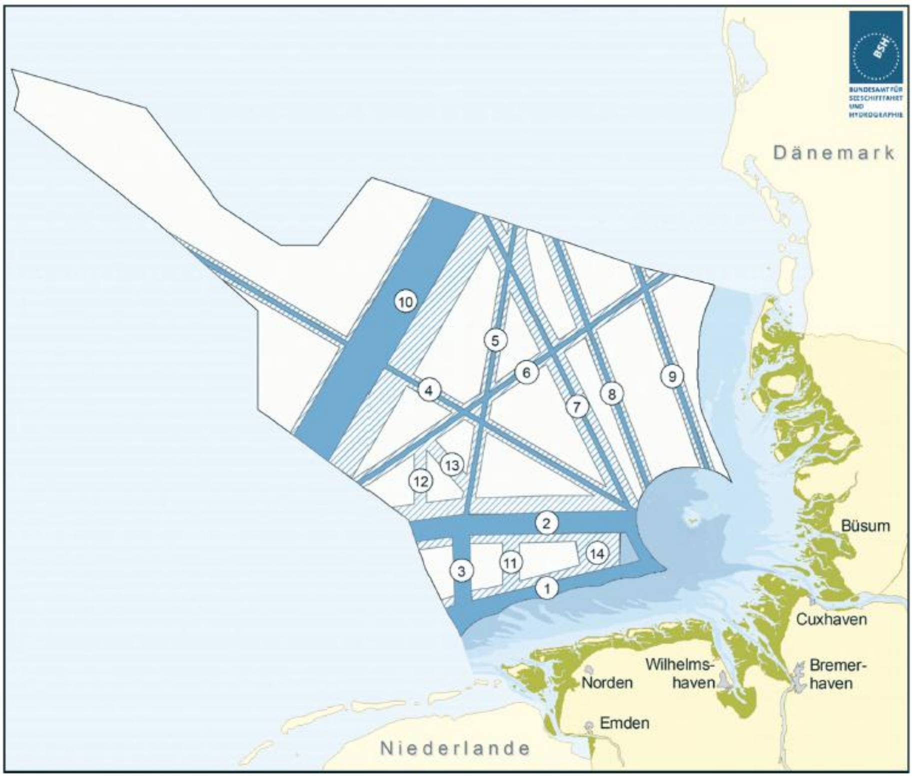

Figure 4: Example of future perspective of shipping lanes left, indicated by number, after national negotiation of interests has been achieved in MSP over a period of several years (Example: German EEZ) (BMVBS 2009, para 3.1)

Hence, this constitutes a motivation to use the NSR-RTM, once developed, for the description of the future situation. Namely, there may be a *NSR-RTM for the year 2020+,* tentatively dubbed ***'NSR-RTM-2020+,'*** which may assist in *describing* in a harmonized manner the perceived future situation throughout the NSR.

Since the methodology used to create the present NSR-RTM and the future NSR-RTM-2020+ would be the same, the findings may be comparable.

Thus, the NSR-RTM will render a *two-fold set of descriptions*, namely one for the present situation and one for the perceived future situation, using the same harmonised methodologies and thus preserving methodological continuity which in turn is essential for any valid strategic planning in the NSR.

1.3 Related international examples and potential international application

Recently there were introduced related international application examples for usage of the route or shipping lane notion regarding the context of MSP and regarding the 'general usage' of those routes and shipping lanes by vessels. This demonstrates that 1) there is a similar motivation to model routes of vessel traffic internationally, and 2) therefore it may be expected that relevant findings from ACCSEAS may be applicable internationally as well.

The first example stems also from the MSP context. The Australian Maritime Safety Authority (AMSA) presented how the very publication of shipping lane demarcations 'for information' has led to a convergence of shipping activities towards and within the published shipping lanes (compare Figure 5). It should be specifically noted, that the publication was not done by any mandatory instrument.

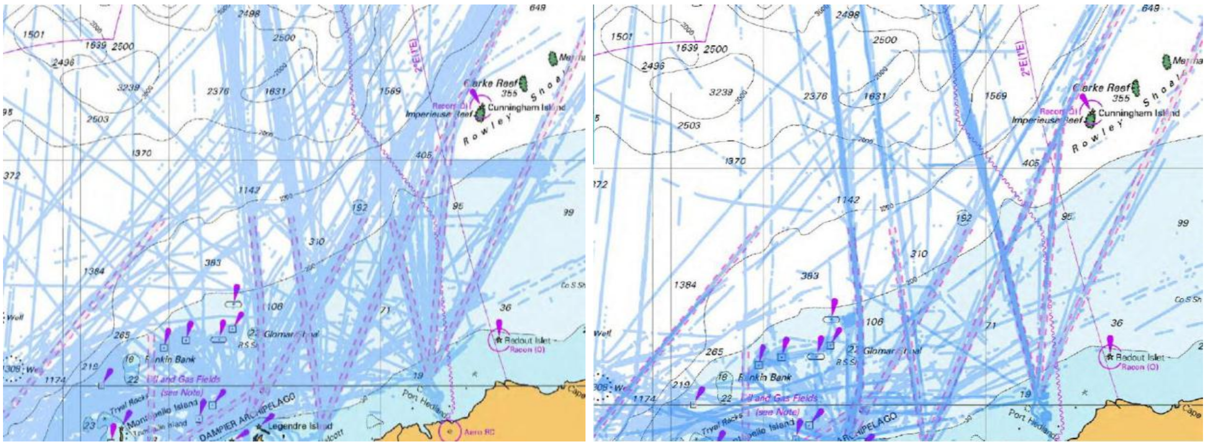

Figure 5: Example of convergence effect of non-prescriptive publication of shipping lanes or routes by competent authority on shipping (red dashed lines). Left: before; right: after (AMSA 2013, slides 11+12)

The second example stems from a Japanese R&D project called 'Development of Next Generation Navigation Display (NGND) for e-Navigation' and is intended to 'reduce marine accident in congested water to half' (Fukuto & Urano 2014, 10). Here, on the shipboard side, the route used by 'own vessel' presently is compared with a *'commonly used route'* within the same ENC display of the vessel (Figure 6). The point here is, that obviously the vessel has been provided data/information by some electronic means from ashore on the 'commonly used route' and that the usefulness of the comparison of the vessel's own route compared to the 'route commonly used' for the navigation of the vessel in the context of improving safety is investigated. This example implies that there is *(shore-based) knowledge on the 'commonly used routes,' which was established over time and which is now made available for navigation purposes to vessels,* even under trial conditions as in the NGND project.

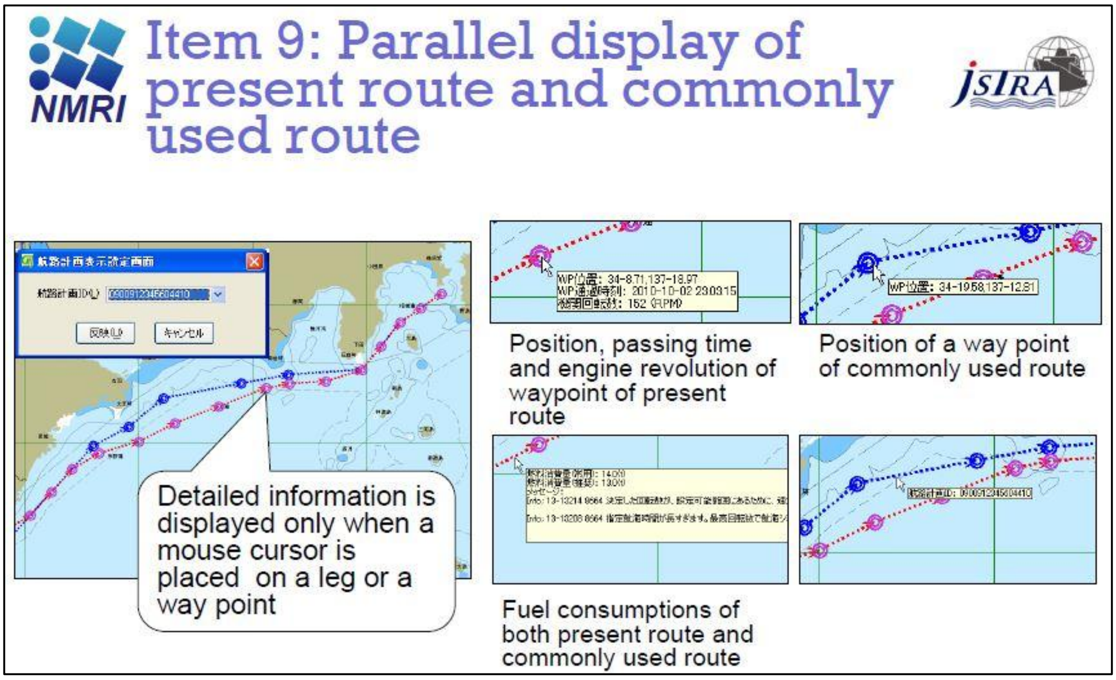

Figure 6: Example of creating shipboard awareness of the potential deviation of the vessel's own route from a 'commonly used route' (Fukuto & Urano 2014, 10)

2 The generic 'Route Topology Model (RTM)'

This chapter elaborates on the concepts and notions introduced above.

2.1 The composition of the generic RTM

Any RTM would be constructed using only *legs* and *nodes* in an abstract sense (Figure 7).

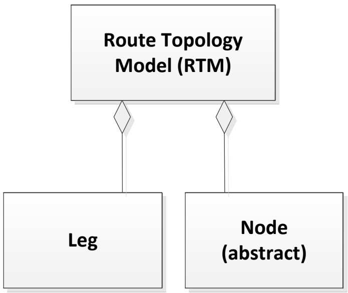

Figure 7: Composition of a RTM by two fundamental 'atomic' elements

Nodes are defined as points where some decision and/or action is to be taken such as the navigational decision to alter course (i.e. a waypoint in its traditional meaning, called *Node.Waypoint*) or the start or termination of a voyage (called *Node.Destination*). The destinations are further subdivided to designate the kind of destinations such as ports, off-shore-sites, and anchorages. *Junctions* would be defined as nodes in the shipping lanes where there is a useful option for diversion into either more than one new leg (called *Node.Junction*). Figure 8 provides the inheritance tree for those node classes.

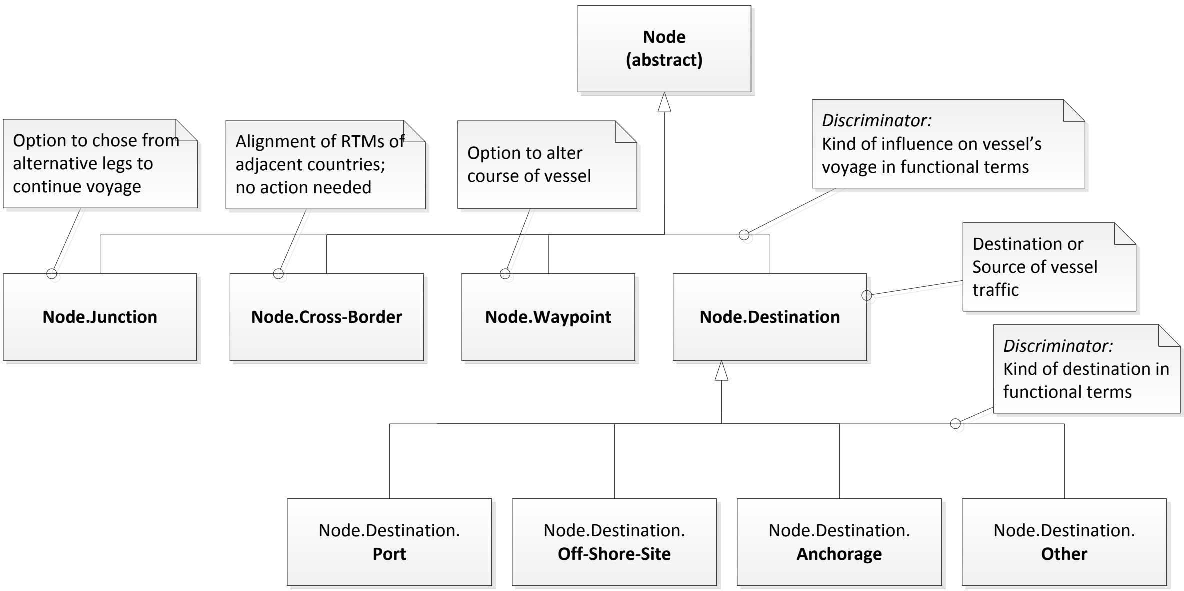

Figure 8: Inheritance derivation of different classes from 'abstract Node' class, together with the appropriate discriminators

The *legs* would be defined as sections of the voyage of a vessel where there are no or no useful *possibilities* to divert between junctions, i.e. where there could not be identified a meaningful junction.

In order to allow for a situation where *adjacent countries would need to align their RTMs* at the same points, a leg that crosses the mutual border of two countries' terrestrial waters or of their Exclusive Economic Zones (EEZ) would be broken down in two separate legs each on one side of the border with a cross-border node (*Node.Cross-Border*) on the border itself.

Legs and nodes each would be associated with an accumulated list of *attributes* which would describe the relevant features of these entities, such as their topological qualities (see details below). These features would be capable of being represented using IHO's S-100 framework.

2.2 The nature and philosophy of a RTM

In mathematical terms, the RTM is a *graph model* tailored to the vessel traffic situation. As such, a graph model differs from the spatial or topographical point of view a chart takes. However, the graph model will always complement the geospatial and/or topographical information contained in charts.

The RTM is to model *traffic options*, i.e. it is essentially oriented towards vessel traffic (as opposed to the tactical navigation of an individual vessel) while taking into account natural or man-made constrictions or limitations to traffic.

Hence, the RTM does not intend to represent another chart, but *an abstraction from that chart domain, which is useful for traffic oriented applications.* The chart domain serves as a valuable input to the RTM, however, where it has an impact on the traffic.

It is important to note, that the RTM depicts in an abstract mode the *possibilities* for a vessel (whatever kind) to make a route: The RTM, once fully completed, contains all possibilities for all kind of vessels, even if the possibilities thus emerging are only rarely used (i.e. only under certain circumstances).

- Example: The RTM should show ***all*** available options for any and all vessels to go, but the establishment of a set of choices at run-time for a specific vessel depends on the specific's vessel's needs/limitations.

The above goals essentially determine the definition of the *attributes* of the *elements* of which the RTM is composed. It should be noted that these attributes may differ due to that different orientation from similar attributes in charting or – if identical – they may assume a different meaning due to the different context.

The RTM operates within the *Object-Oriented Paradigm (OOP),* i.e. it recognizes, amongst other things, the distinction between a *'class'* and an *'instance.'* A description of a class is a generic description, while an instance is a specific application of the class to the very specific reality to be modeled by that instance. The class description aims at allowing a maximum of many different instances which 'inherit' and use the features of the class description. This document contains a generic description of the RTM, as well as an application of that RTM class to the specifics of the NSR, thus rendering the instance of the NSR-RTM.

Different instances of RTMs need to be defined for present and future situation (to be specified regarding point in time) if there are factors operative which will (likely) change the routes vessel take (such as construction of off-shore structures). When adding the point in time, where for which the NSR-RTM is constructed (e.g. present and 2020+), this renders several instances of the RTM.

Standard description tools compatible with the OOP, like the *Unified Modeling Language (UML)*, should be used.

2.3 Defining 'Nodes' and 'Legs'

This section now turns towards the proper definition of 'nodes' and 'legs' as introduced in Figure 7 and Figure 8.

2.3.1 Fundamental rules for nodes and legs of the RTM

There are some fundamental rules for the modelling of an RTM regarding legs and nodes:

- ***'Be-atomic' rule:*** Legs and nodes are atomic in characteristic; if a 'compound' or 'complex' is detected, it should be checked whether it could be broken down into these atomic features.

  Example 1: Potentially another sub-class for a node may be required which would be again 'atomic'. E.g. the node class 'Port' (Node.Destination.Port) could be sub-divided into legs and 'berths' (Node.Destination.Port.Berth) should this be required to model the interior of a port by a specific port-related application of the generic RTM.

  Example 2: A leg crossing the EEZ border would be subdivided in separate legs for the different EEZs with a cross-border node on the border.

- ***'Minimum number' rule:*** Strive for the minimum number of nodes to simplify analysis or to reduce complexity for management (even when there is a need to break down compound structures).

- ***'Uniformity-vs-metering/percentage' rule:*** *By default, it is assumed that in a leg the attributes are uniform.* When modeling, different attribute values may lead to the need to model different legs with different attributes, connected by waypoints (Node.Waypoint). Alternatively, changes in attributes should be encapsulated by the 'metering' or 'percentage' feature of an attribute, when then needs to be made an *explicit* attribute.
  - Example: The attribute 'width of navigable space' attributed to a leg will be assumed to be valid throughout the length of the leg, unless indicated by an expressive metering or percentage feature attributed to the 'width of navigable space.'
  - *Percentage feature:* 'Only x% of the leg's length are subject to 'width of navigable space of y miles' (does not tell you where on the leg);
  - *Metering feature:* 'From offset x to offset y on the leg the feature applies' (tells where on the leg the feature applies).

2.3.2 Attributes of a 'node'

Nodes are defined as geospatial points where some decision and/or action is to be taken. For of a generic RTM, any node can be defined by the following attributes, *as a minimum:*

- ***Unique Identifier of the node***, in accordance with kind of node***:*** If there is no possibility for ambiguity a simple running number for the different kind of nodes may suffice for simple RTM constructions; more sophisticated RTMs would require a more complex unique identifier.

- ***Geospatial location of the node (reference point):*** i.e. coordinates. They can be given in one or several, if required, of the recognized coordinate systems like UTM or WGS-84.

- ***Kind of node:*** as given in Figure 8, i.e. the *enumeration type*
  - ***Node.Junction***
  - ***Node.Waypoint***
  - ***Node.Cross-Border***
  - ***Node.Destination;*** potentially immediately replaced by the sub-classes
    - ***Node.Destination.Port***
    - ***Node.Destination.Offshore-Site***
    - ***Node.Destination.Anchorage***
    - ***Node.Destination.Other***

- ***Class of shipping lane:*** This is an attribute which is essential for the visibility of the node when zooming in or out of the RTM upon display. I.e. a certain node is *always* visible if it belongs to the Motorways of the Sea (MoS) shipping lane class; it becomes visible only, however, when zooming in to the level of Trails of the Sea (ToS) shipping lanes, when a certain node belongs to the ToS class, only. Hence, this attribute is of *enumeration type,* containing the defined classes of shipping lanes:
    - ***Motorways of the Sea (MoS)***
    - ***Roads of the Sea (RoS)***
    - ***Trail of the Sea (ToS)***

It is important to note, *that for construction of a RTM the above limited number of attributes suffice.* The limited number of those essential attributes renders the RTM versatile for a number of diverse applications.

Certain applications may also associate or correlate attributes relevant at their domain to the above RTM node attributes.

> Example: Should in an application for Aids-to-Navigation (AtoN) the geospatial location of a Node.Junction be identical with a charted buoy position, this charted buoy position may be associated with the geospatial location of the node; similarly, the name of that charted buoy may be associated by the application on its application level to the unique identifier of the RMT node. Thus, the generic RTM may be linked to the conventions of the IALA Marine Buoyage System (MBS) – on the application level.

Should certain applications of the RTM require to add application-specific attributes, they need to do so *on their application level* to the nodes as defined above.

> Example: The services available at a certain node, for example in the context of the IMO defined concept of Maritime Service Portfolios (MSPs) may be attributed by an MSPs-oriented application of the generic RTM on its application level.

Specific examples for those additional attributions on the application level are given in a chapter below.

2.3.3 Definition of a 'Leg'

A leg is the possible connection between two nodes without any node required in-between: If there is reasonable margin for another node in a leg, this situation renders two legs and an additional node.

Again, the number of required attributes of a leg for the construction of a generic RTM is minimum and is confined to the essentials, as follows:

- ***Unique Identifier of the leg***: This could be ranging from a simple running number in a small RTM when there is no risk of ambiguity, over a conventional name to an identifier (ID) uniquely assigned in a global naming space convention. When constructing the generic RTM, there needs to be made a selection of *one* kind of unique ID for all legs of that RTM throughout. Applications of the RTM may then associate additional IDs on their application level, thus rendering their leg IDs a complex type (but that is beyond what is required as a minimum).

- **Associated end points of a leg, i.e. unique node IDs of the nodes at both ends of the leg:** The IDs of the nodes at the two ends of the leg are given; i.e. this attribute is an association with the definition of the above unique node IDs. The nodes definition referenced by their unique node ID would include the reference of these nodes to the geospatial orientation (in particular the co-ordinates).This avoids introducing redundancy in regard to the geospatial orientation of the leg, which would be subject to error.

- ***Length***, i.e. the *real minimum distance* between the associated nodes, including necessary bends, but not included is ‘detours’ or condition-dependent lengths such as ‘sailing length.’
- ***Class of shipping lane:*** Similarly to the definition at the node, this is an attribute which is essential for the visibility of the leg when zooming in or out of the RTM upon display. I.e. a certain leg is *always* visible if it belongs to the Motorways of the Sea (MoS) shipping lane class; it becomes visible only, however, when zooming in to the level of Trails of the Sea (ToS) shipping lanes, when a certain leg belongs to the ToS class, only. Hence, this attribute is of *enumeration type,* containing the defined classes of shipping lanes:
    - ***Motorways of the Sea (MoS)***
    - ***Roads of the Sea (RoS)***
    - ***Trail of the Sea (ToS)***

With these four attributes as a minimum, a meaningful generic RTM may be constructed. Similarly as with the node definitions, additional attributes may be defined and associated with the above minimum set attributes on the application level by a specific application. Examples are given in the chapter on applications below.

The following additional attribute, while not required for all applications of the RTM, may become important in some applications and is needed to be associated with the above minimum set of attributes required to define a leg in those cases.

- ***Width* of free navigable space:** As a leg is an abstraction of the true topographical navigable space between the two nodes which define the leg under consideration, this attribute would contain data regarding the dimension (and potentially shape) of that true topographical space available for navigation as abstracted by the leg, and potentially of its shape. Depending on the target RTM there are the following options to define the attribute:
    - Plain width of navigable space relative to the centre line defined by the leg [meters];
    - polygon area associated with the leg if the navigable space associated with the leg cannot be defined or approximated satisfactorily by the plain width concept;

  Note, that both concepts are capable to include the (larger) sailing length and that both concepts may result in overlay of width contours of different legs, for example a ‘Y-shape’ at Node.Junctions.

Figure 9 shows the above attributes operative in an example.

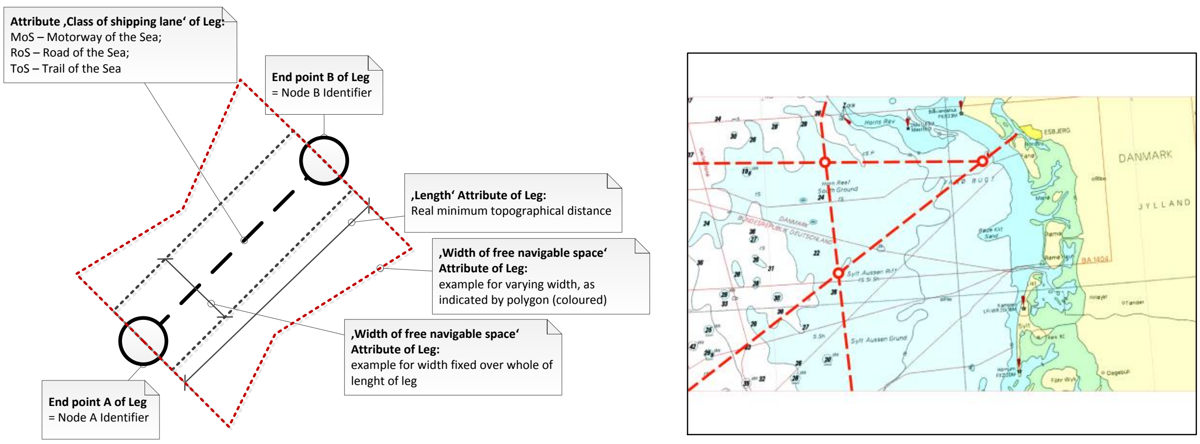

Figure 9: Example of abstract leg definition including sample attributes (left) and example of leg definitions on sea chart (right)

2.4 International and European standards relevant for the RTM

The graph model philosophy of the RTM, as introduced above, is not a new invention. Rather, graph modeling has been used for creating applications in *several modes of transportation,* like the London tube map (mode of transport: railway), car navigation tools (mode of transport: individual vehicles), aviation when en-route or taxiing (mode of transport: air transport). The *application to the vessel traffic domain,* as done with the example of the NSR as a whole sea basin made explicit herein, *may be considered novel and thus an innovation, however, both in terms of systematic application and in terms of size of area to which applied.*

When defining the attributes for the legs and nodes, it is necessary *to import existing international and/or European definitions, if at all applicable,* in order to avoid redundancy and ambiguity. If defined elsewhere, that definition is incorporated *by reference*, possibly adding configuration range and other comments.

For the same reason, the above definitions of the attributes for legs and nodes do not go into any further detail in this Description. ACCSEAS is aware of existing and ongoing work in the international and European domains which have provided or are in the process of providing elaborate solutions for the more detailed definitions (compare Figure 10).

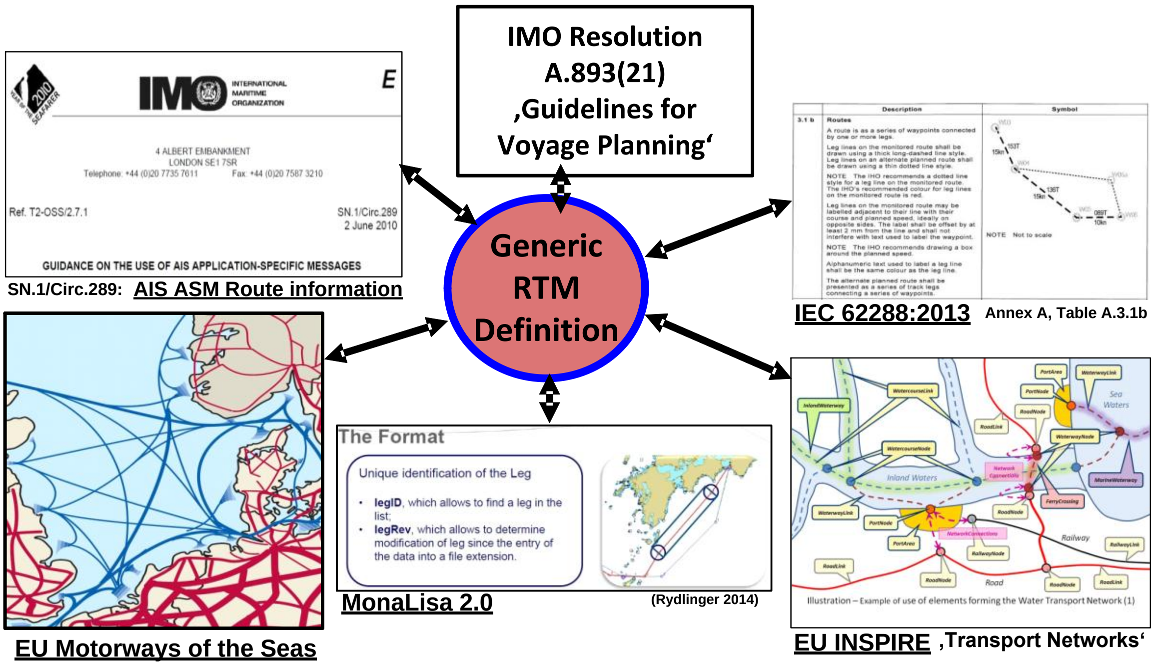

Figure 10: International and European contributions to and interactions of the generic RTM definition

The following list provides some significant examples but has no aspiration to be exhaustive:

- There are several *IMO publications* with relevance for the definition of the generic RTM, namely in particular *IMO Resolution A.893(21) 'Guidelines for Voyage Planning'* (IMO 1999) which contains fundamental definitions and stipulations for constructing routes when planning a vessel's voyage, the *IMO SN.1/Circ. 289 'Guidance on the Use of AIS Application-Specific Message' (ASM)* which contains the definition of an ASM to exchange route data amongst participants of the Automatic Identification System (AIS) and contains route construction data definitions to that end which are encoded in the ASM-specific format. The various *definitions of IMO for TSS* and other

IMO 'routeing measures' would contribute to the instances of RTM specific to the relevant regions.

- It is assumed that the above minimum number of generic RTM attributes would eventually be reflected as entries into the *'Feature Concept Dictionary' Register* of the *IHO GI Registry (based on S-100),* if not already defined therein to some extent, while additional attributing necessary for applications would be done on application level by the *'product specifications'* appropriate for those applications, thus drawing and binding together attributes ('features') from various domains.
- Specifically, this present Description is aware of definition work carried out by the European *'MonaLisa 2.0' project* (Rydlinger 2014) regarding routes (nodes, legs) with the expressive intention to introduce the results of this work into the next edition of the *IEC 61174* on ECDIS (Ed. 4) via the appropriate IEC Maintenance Group. Thus, specific relevant definitions will be available as internationally agreed IHO S-100 based data definitions in due course by this work.
- Regarding display of routes to users, appropriate portrayal definitions contained in *IEC 62288:2013* (IEC 2013) on the presentation of navigation-related information on shipborne navigational displays can be employed (compare chapter below).
- The data object definitions of the EU Directive *INSPIRE module 'TN – Transport Networks'* (Inspire Thematic Working Group Transport Networks 2010; EU 2007) may be appropriate for constructing the RTM as well, although they may need to be amended from a maritime point of view (to which this Description may serve as a contribution).
- Potential application of a RTM, there may be relevant work on the modelling of waterways and ports at the *UN IEHG (Inland ECDIS Harmonization Group)* and at *PIANC 'Design guidelines for harbor approach channels'* (PIANC 2012).

The bi-directional arrows in Figure 10 imply that there may be a, at least in principle and in the course of the usual revisions, a feedback from an internationally agreed generic RTM back to the above international and European documents. This potential feedback will be further investigated in a dedicated chapter below.

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3 User Display Modes of the (NSR-)RTM

3.1 Introduction to different display modes

This chapter addresses the question how the (NSR-)RTM may be made visible to a human user at a HMI and how this can be portrayed.

Three fundamentally different display modes have been identified by ACCSEAS as follows:

- ***ENC display mode,***
- ***London tube map display mode,*** and
- ***Head-up display (HUD) / Augmented Reality (AR) display mode.***

These three different display modes will be portrayed in the following sections.

3.2 Portrayal of the ENC display mode for (NSR-)RTM

Due to its geospatial orientation, a (NSR-)RTM may be displayed as an additional overlay layer in an ENC in a shipborne navigational display. Target users for this display mode are mariners and shore-based operators engaged with ENC displays, such as operators of Vessel Traffic Services (VTS) using a vessel traffic image overlaid on an ENC.

Relevant stipulations for this display mode can be found in IEC 62288:2013 (IEC 2013) as follows:

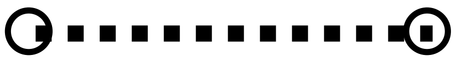
- 'Leg lines on the monitored route shall be drawn using a thick long-dashed line style. Leg lines on an alternate planned route shall be drawn using a thin dotted line style. (…) Leg lines on the monitoring route may be labelled to their line' (IEC 2013, Annex A, Table A.3.1b on 'routes').
- 'Waypoints shall be presented as circles centred at the position of the waypoint. The circles shall be at least 4 mm but not more than 6 mm in diameter. Waypoints on the monitored route shall be drawn using a thick solid line style with the same basic colour used for the route. (…) Circles representing waypoints on the alternate planned route shall be drawn using a thin solid line style. Optionally, waypoints may be labelled adjacent to their symbol.' (IEC 2013, Annex A, Table A.3, 3.1a on 'waypoint').

These stipulations are accepted and further developed for the purpose of the display of (NSR-)RTM in the ENC display mode.

- ***General:*** in principle in accordance with IEC 62288:2013; the width of the long-dashed or of the dotted lines would reflect the level of the road. Nodes (waypoints, junctions etc.) would be presented as given by the IEC 62288:2013. The colour would be dependent on the ENC context, but it would be the same for the nodes and the legs.

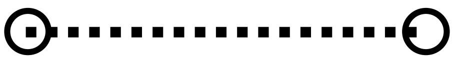
- **Class of shipping lane: MoS level**

  The MoS class would be indicated by a ***very thick*** line.

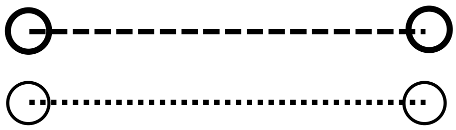
  - planned 
  - alternate 

- **Class of shipping lane: RoS level**

  The RoS class would be indicated by a ***thick*** line.

  - planned 
  - alternate 

- **Class of shipping lane: ToS level**
  The ToS class would be indicated by a ***thin*** line.
  - planned
  - alternate



The nodes would be plotted at their true geographical position within the ENC, and the legs with their true geographical length. I.e. the topographical relationship of nodes and legs would be fully conveyed in this RTM display mode.

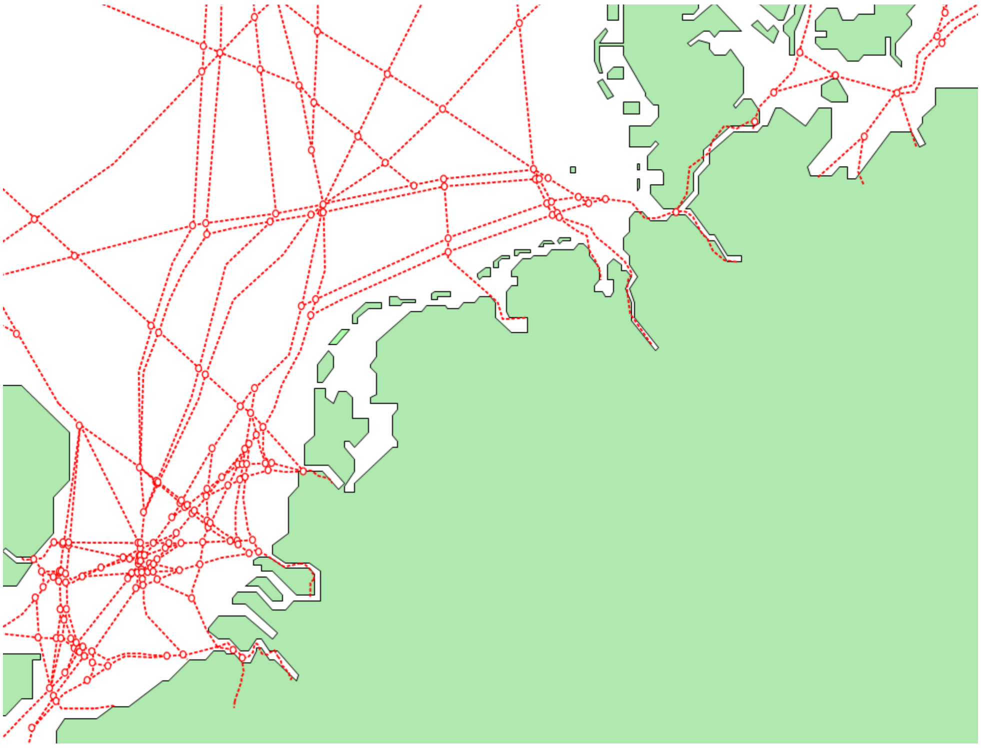


Figure 11: Example of a RTM using the ENC display style at large scale: Motorways of the Seas, including IMO defined TSS, off the coasts of the Netherlands and Germany

3.3 Portrayal of the London Tube Map display mode for RTM

The London Tube Map (LTM) is a user friendly, graphical representation of the London transportation system, the most important part of which is the London underground railway system. Originally invented by Harry Beck (1902-1974) for the London transportation system, the depiction of the transportation system as an infographic reduced the amount of details shown to the most essential topological features, only, and introduced certain rigid rules for the graphical representation of the railway lines. The purpose was to allow passengers (‘users’) to easily make optimum usage of the transportation system available. Due to its success, the LTM consequentially served as a model for virtually all topological network depictions of public transportation networks globally. It also serves as a model for portrayal of shipping route networks in the context of this Description.

Target applications for the LTM display mode are ***strategic vessel traffic planning and voyage planning.***

Here, the 'original' LTM is only used as a fundamental guidance because it contains several features such as the colour coding of 'tube' lines which are not directly applicable to the maritime RTM. Instead, the different levels of the shipping lanes need to be incorporated.

The LTM display mode *deliberately accepts topo**graph**ical distortions* in favor of a user friendly, disentangled presentation of the network as a whole. In data modelling terms, this means, that waypoints (*Node.Waypoints*) are disregarded. However, wherever possible i.e. not contradictory to the purpose, the LTM display mode tries to adjust to a very rudimentary topographical representation.

On the other hand, the LTM display mode is true to the connectivity contained in the route topology, i.e. that is the point of the LTM display mode, i.e. it is correct *topo**log**ically*. Hence, all junction and destination nodes (*Node.Junction*, *Node.Destination*) are truly preserved.

Hence, there is a direct correlation preserved with the ENC display mode. Also, while the legs and nodes of the LTM display mode may be represented un-proportional to scale, the underlying attribute set for legs and nodes is still accurate and may be retrieved by e.g. a 'pick report.'

When this Description was researched, there was no apparent international standard for the info graphs of the London tube map style found.[5] Hence, a generic rule base was compiled.

- ***General:***
    - The LTM display mode constructs the network with solid lines only, which are oriented in multitudes of angles of 45°, only.
    - Legs are depicted as solid red lines. Junctions (*Node.Junction*) are (dark-)red solid circles. The size of the junction should be that used to the highest class of shipping lane connected to the junction. Cross-Border Junctions (*Node.Cross-Border*) may be depicted like Junctions, possibly with a different colour and/or with an additional outer circle.
    - Destinations (*Node.Destination*) are either rounded black squares with solid lines or black circles with solid lines. (Waypoints (*Node.Waypoint*) are deliberately omitted.)
    - The class of shipping lane is indicated by a combination of shape, width and outline contrast colour for the legs. The colour is always black, by default. *The size of the port symbol corresponds with the highest class of shipping lane the port is directly a destination of:* i.e. a 'core port' would thus be a direct destination in the MoS grid, a port for professional traffic but not a destination of MoS (compare criteria for RoS) would be a direct destination in the RoS grid, and any other port or marina would be a destination of the ToS grid, only).

[5] Only company specific guidelines, such as the Transport for London style guide for their tubes, could be retrieved.

- **<u>Class of Shipping lane = Motorway of the Sea (MoS):</u>**
  - Broad width, outline contrast colour (dark red)
  - Portrayal with junction to the left and a port at MoS grid added to the right

- **<u>Class of Shipping lane = Road of the Sea (RoS):</u>**
  - Medium Width, outline contrast coulour (dark red)
  - Portrayal with junction to the left and with port at RoS grid added to the right; does not necessarily need to be a square.

- **<u>Class of Shipping lane = Trail of the Sea (ToS):</u>**
  - Small width, no outline
  - Portrayal with port at ToS grid to the right

Figure 12 shows an example of the LTM display mode using the above definitions.

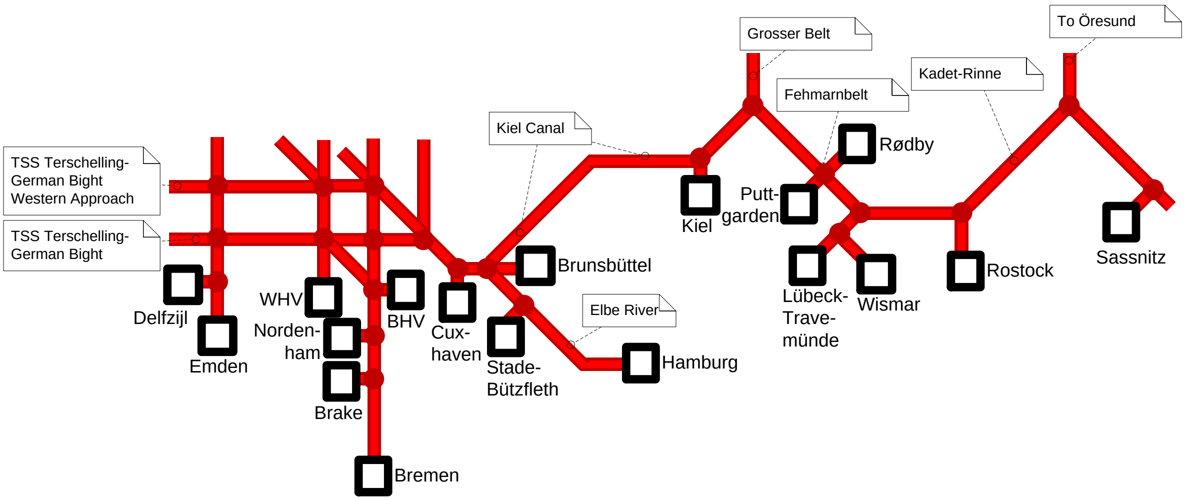


Figure 12: Example of a RTM using the above LTM display style –
MoS class of shipping lanes at the German coast shown only and TSS' simplified
(all seaports from 'key seaports' list contained; see section 4.3.3)

The example of the LTM in Figure 12 showed only the MoS class of shipping lanes. In order to avoid information clutter, the other classes of shipping lanes would become *only visible when zooming in the LTM, depending on scale of display.*

3.4 Portrayal of a RTM for Head-up-Displays / Augmented Reality

Portrayal of RTM data can also be embedded in a *Head-Up-Display (HUD)* and within its *Augmented Reality (AR) Environment:* Here the RTM data would be used to project trajectories, upcoming junctions, nodes (and associated service options, when combined with Maritime Service Portfolios) within the windscreen image of the ship's bridge crew (compare Figure 13). Obviously, this display mode would be geared towards tactical ship handling applications.

Figure 13: Conceptual Study for display of a vessel's route based on the RTM data to the bridge team using Head-Up-Display display mode (dotted line)

3.5 Application of different display modes to different tasks in time

There are two fundamentally different sets of applications to which the RTM display modes can be applied, namely to strategic purposes *at planning time* and to the operational processes of navigation (shipboard) and monitoring/influencing vessel traffic (shore-based) *at run-time.* Planning applications may take place at the policy, management and user levels, both ashore and on-board, while run-time applications are regularly confined to the user level, again both on-board and ashore.

This can be illustrated by using the IMO defined overarching architecture for e-Navigation (compare elaborate descriptions in the 'ACCSEAS B & P Report' (ACCSEAS 2015a) and in the 'ACCSEAS e-Navigation Architecture Report' (ACCSEAS 2015c)) as done in Figure 14.

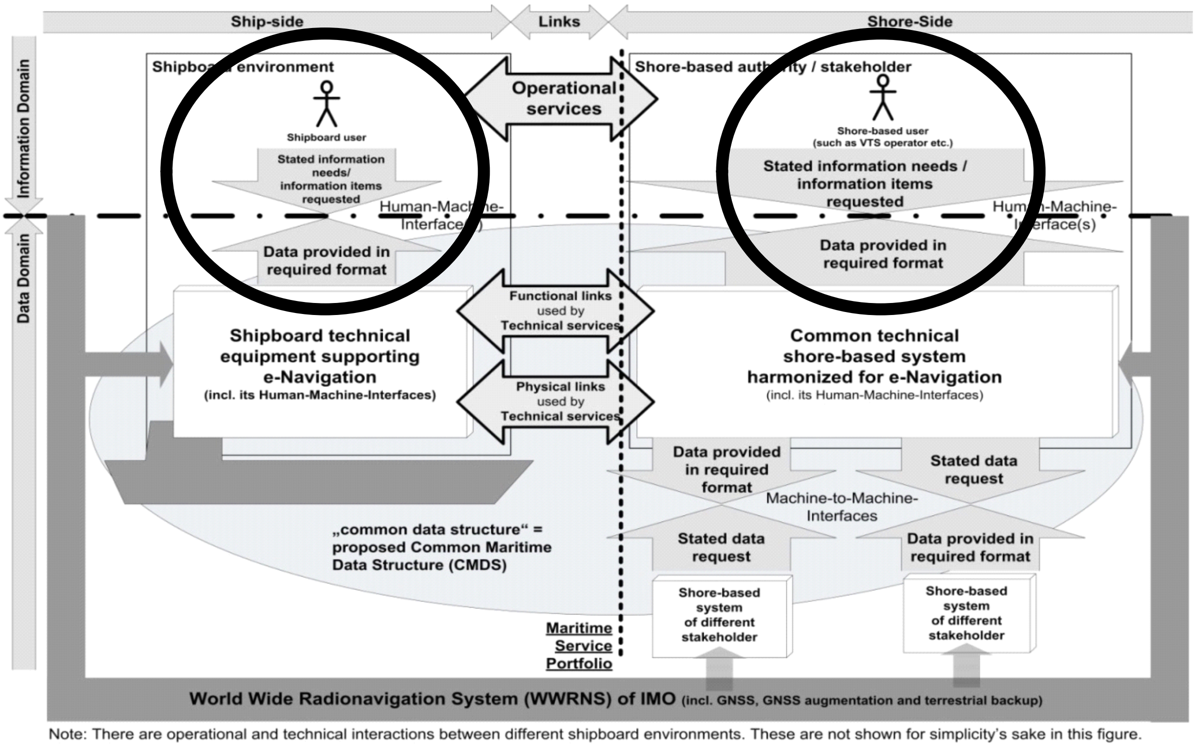


Figure 14: RTM display modes for operational purposes of vessel navigation (shipboard side) and vessel traffic monitoring, for example (shore side) within the IMO defined overarching architecture for e-Navigation

Figure 15 illustrates within the context of the overarching architecture which RTM display modes could *co-exists* at the same time at the same work place in principle, although for different purposes and tasks. Obviously, the ENC display mode as well as the LTM display mode would be available both on-board and ashore, in principle, while the HUD/AR display mode would be meaningful only on the shipboard side.

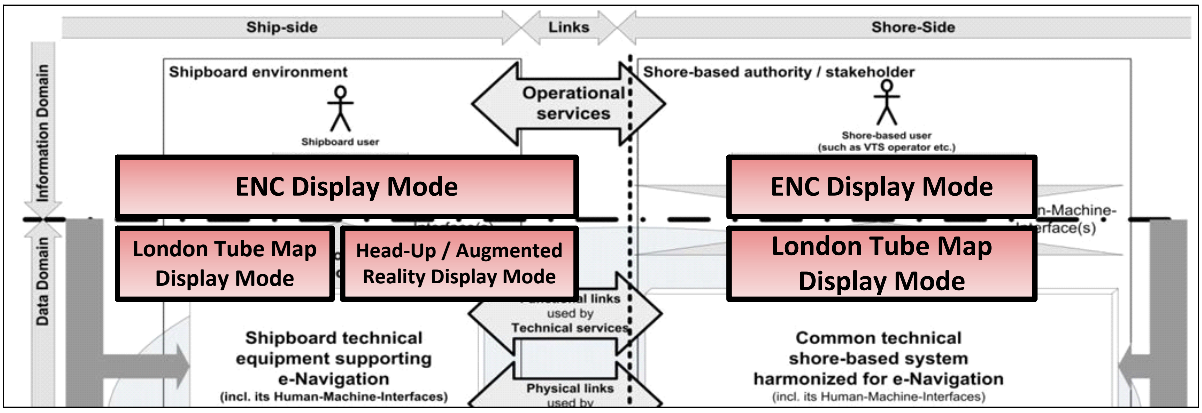


Figure 15: Co-existence of different RTM display modes for different operational purposes, shipboard and ashore, within the IMO defined overarching architecture for e-Navigation

4 Derivation of an instance of a RTM for a given sea area

This chapter describes how to derive an instance of the RTM for a sea area under consideration – here: the NSR – and explains what sources could and should be used to that end. The description introduces generic rules, but is constantly illustrated by examples taken from the NSR. *Thus, the instance of the NSR-RTM for a projected future situation with known MSP measures as identified by the 'ACCSEAS B & P Report'* (ACCSEAS 2015a) *for the time period 2020+ is developed concurrently.*

4.1 Sources for constructing instances of RTM for different points in time

An instance of a RTM is *only valid for a given point in time* which must be determined when starting with that RTM instance. In particular, a RTM instance may be created for the presence, or it may be created as a projection into a specific future. This determines the sources to be used when constructing the RTM instance (compare Figure 16):

- ***Vessel track data*** in essence is empirical data, and therefore can show the past or the present traffic situation with reliability. *Some projection into the future may be legitimate,* however, under the *condition* that there are no relevant foreseeable influences that would change the present traffic patterns and vessel routeing customs considerably.

- ***Planning data,*** on the other hand, as the name implies, can only show a future situation which may not have materialized in the presence:
  - There may be different instances of a RTM for the same sea area for different stages of planning.
  - There may also be instances of a RTM which include a composite situation for both a specific future planning state and the present situation.

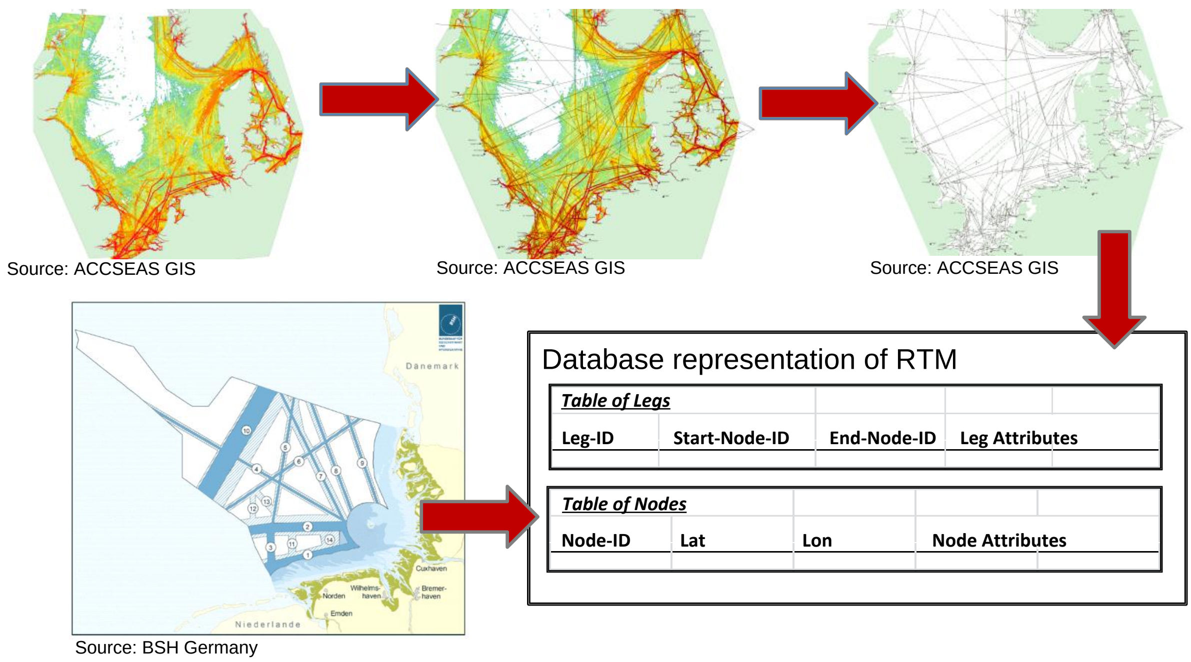


Figure 16: Illustration of the main contributions for the construction of an RTM instance database, i.e. vessel track data and planning data

Particular attention should be given to the usage of the following sources in the order of binding strength as given below:

- ***Geography*** of coasts, coastal territorial waters and inland waterways (under seagoing rules), including the location of ports (different categories) (compare Figure 17);

Figure 17: Illustration of the (simplified) coastal shape of the NSR

- ***Routeing measures*** (including TSS, territorial and EEZ boundaries), as defined by IMO and/or nationally (compare complete ***picture*** of presently existing IMO recognised routeing measures in NSR in Figure 18);

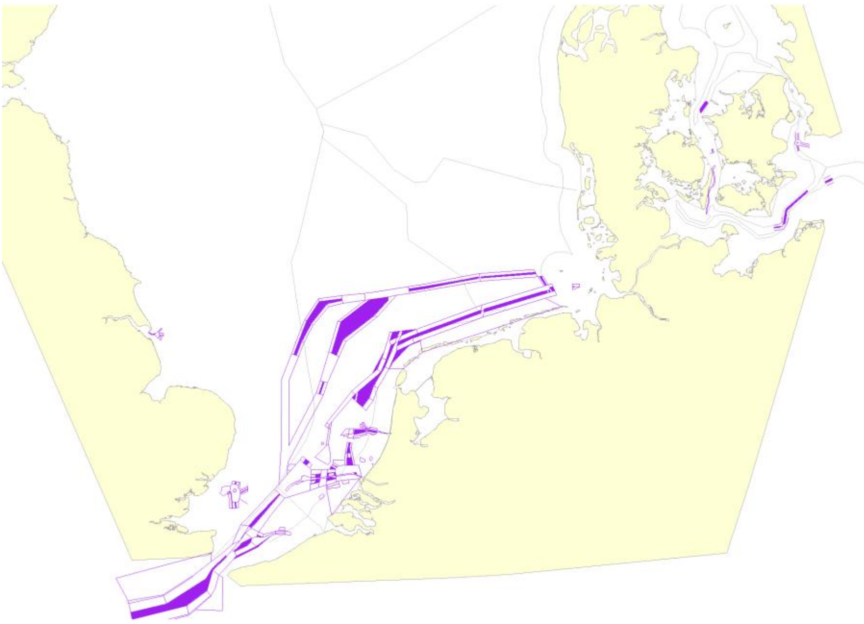


Figure 18: Illustration of the IMO recognized routeing measures in the Southern NSR

- ***Existing areas*** with some legal or regulatory constraints to vessel traffic, such as IMO recognized Particularly Sensitive Sea Areas (PSSA) (IMO 2012a), EU stipulated Natura 2000 reserves (EU 1992), and (temporary) military shooting areas (compare Figure 19).

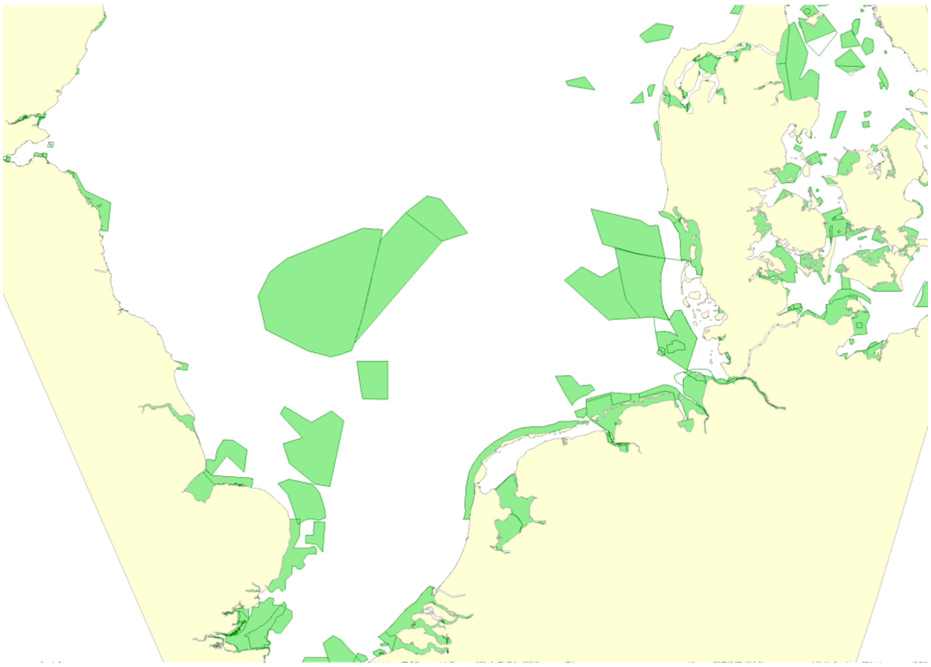


Figure 19: Illustration of the existing EU stipulated offshore Natura 2000 areas in the NSR

4.2 Constructing the NSR-RTM as an ACCSEAS candidate solution

Any instance of the NSR-RTM is a 'flashlight image' of the point in time where the instance is relevant to. These instances should therefore be labeled accordingly, to avoid confusion. For example, such different NSR-RTM instances would be called e. g.

- ***NSR-RTM 2012*** (analysis of 2012 situation) or
- ***NSR-RTM 2020+*** (projection to the 2020+ situation of the NSR-RTM, where all perceived developments with relevant influences at that point in time are superimposed).

If there is no chance to confuse the point in time for which a NSR-RTM instance is constructed, then there could be used abbreviations without carrying the year indications.

4.2.1 Analyse past vessel track data for the area under consideration

The construction of any instance of a RTM for a sea area under consideration for a future point in time always starts with the construction of a past instance of the RTM for the same sea area under consideration.

In order to do that vessel track data *for the entire area under consideration* <u>and</u> *for a specified point or period in time in the past* must be available.

- It is advisable to construct a RTM using vessel track data of a whole year because this would include all vessel traffic variations due to the seasons and would also provide an amount of data which can be considered 'statistically significant.'
- If the seasonal impact on the vessel traffic pattern is the subject of the study in itself, then the duration of e.g. a month is suggested.

For construction of the RTM, it is required to know the routes of *as many vessels as possible* from the *class of vessels* considered relevant for the RTM instance to be constructed, during the period in time and for the area under consideration, to render a statistically significant analysis:

- There may be constructed RTM instances for vessels above a certain size. For example, IMO uses the minimum size of 300 gross tonnage of a vessel to stipulate certain mandatory carriage requirement, such as AIS stations.
- Pleasure crafts usually are smaller in size, and are not required to carry an AIS station in most areas, however, although some may voluntarily carry one. To arrive at a RTM instance which would reflect the vessel traffic pattern of pleasure crafts, a reliable source for statistically significant vessel traffic data of these vessels would be required.

Vessel track data generally is stored in shore-based systems of coastal states monitoring the vessel traffic situation along the coasts of those states. In Europe, the EU member states are required to monitor the vessel traffic along their coast by the VTMIS EU directive (EU 2002). All countries around the NSR, except for Norway, are EU member states, hence are required to monitor the vessel traffic in their coastal waters; Norway, while not being a member of the EU, has committed itself to abide by the *same* standards. Hence, from a regulatory point of view, there may be obtained *vessel track data* from the entire NSR, limited only by the practical coverage considerations of relevant vessel track sensors.

To be precise, *only* vessel traffic *density plots* for the relevant period in time would be required, i.e. a *strictly anonymous and statistical evaluation* of available and relevant vessel track data. This condition would satisfy the requirements of strict data protection legislation established in many countries and/or throughout the EU.

To construct an instance of a RTM, strictly speaking, also only track data of the ***vessels*** *as entities* are required, regardless of how, i.e. by which sensor, the vessel tracks would have been gathered and regardless of how a correlation or fusion of data of the same vessel for the same point in time by several vessel track sensors like radar and AIS would have been achieved in detail. In modern VTS systems operated by shore-based authorities in the coastal states, where there is radar coverage available there is generally done such a correlation or fusion of vessel track data from various sensors thus rendering reliable vessel tracks which are also generally better in quality than the vessel tracks derived from individual sensors. This results in a rule base as follows:

- The *ideal* situation would be to use *vessel* track data which was derived from the best correlation of various vessel track sensors, including radar and AIS, where available.
- In the future, this kind of *vessel* track data may be made available on a broader scale by above mentioned VTS systems by using the *IALA defined Inter-VTS Exchange Format (IVEF)* (IALA 2011) also for purposes of constructing RTM instances.
- *Radar coverage* is available in certain relevant parts of the NSR, in particular in the Dover Straits, along many parts of the coasts of Belgium and the Netherlands including the river and canal approaches to their major ports, along virtually the entire western approaches of the German bight, including the estuary approaches to major German ports, at several UK and Norwegian harbour approaches, and last but not least in several critical points of the western Baltic Sea belonging to the NSR.
- Note, that radar derived vessel track data is, in principle, available for *all* classes of vessel within areas of radar coverage, including those vessel classes not required to mandatorily carry and operate an AIS station.
- Note also, that there is another ACCSEAS candidate solution which suggests to exchange radar tracks gathered on-board vessels by their shipboard radar systems with shore authorities to mutually complement their *vessel* traffic image; compare ACCSEAS candidate solution 'Harmonized Data Exchange – Employing the Inter-VTS Exchange Format (IVEF)'.

- If there is *only available AIS derived vessel track data* or 'AIS track data' for short, in the sea area under consideration for the relevant period of time, than this might be considered the 'best guess' for constructing the RTM instance.
- The above discussion renders some *legacy items* from ACCSEAS (compare Annex C).

For ACCSEAS, the AIS track data of the entire year 2012 was available for the whole of the NSR (ACCSEAS 2015a; Figure 20). Hence, the following ACCSEAS analysis builds on that AIS track data and would thus render the ***NSR-RTM 2012***, as illustrated below.

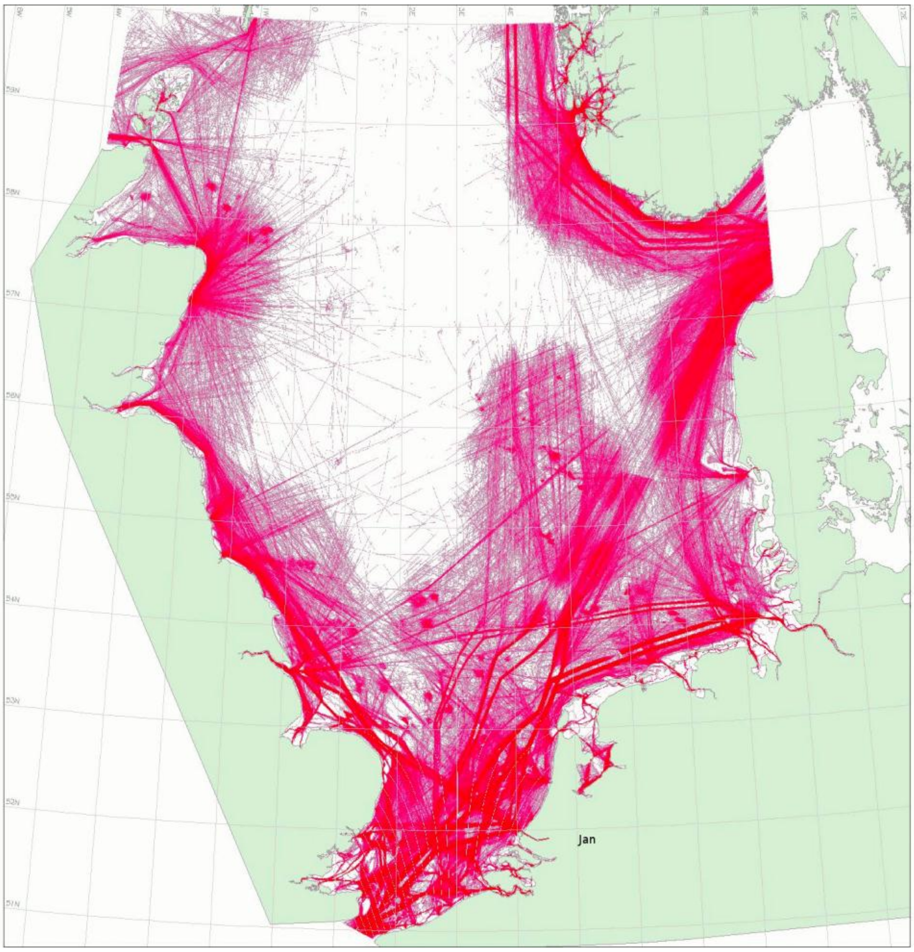


Figure 20: Density plot for the NSR using AIS vessel track data for the entire year 2012 (compare 'ACCSEAS Baseline & Priorities Report' (ACCSEAS 2015a))

To build a RTM on vessel track data, i.e. a model of the routes vessel actually took (for the past), one must assume that the observed vessel track data density has a direct or at least 'some' relation with the vessel traffic actually taking place.

This can be validated by comparing vessel traffic density plots with internationally defined routeing measures such as TSS (compare Figure 21):

- By and large, the two aspects match, as expected.
- Most strikingly, there are vessel traffic patterns with a very high traffic density merging into or diverging from the entrance or exit points of the IMO recognized routeing measures such as TSS.

- There are vessel traffic routes crossing the TSS, also outside the precautionary areas of those TSS.
- There are also clearly identifiable vessel traffic routes in parallel to the IMO recognized routeing measures.
- There are certain individual clearly isolated clusters of vessel traffic located between the TSS lanes with an obvious one-leg-connection to either a more prominent route or to a port. It may be concluded from external knowledge, that these clusters are caused by supply and/or construction traffic to and from off-shore installations.
- There are distinct and clearly identifiable areas where there is either very low and spurious or even no vessel traffic at all. The example presented in Figure 21 is taken from an area with a very high general vessel traffic density: In quarters of the NSR with lesser general vessel traffic density, this pattern is to be expected even more expressively.

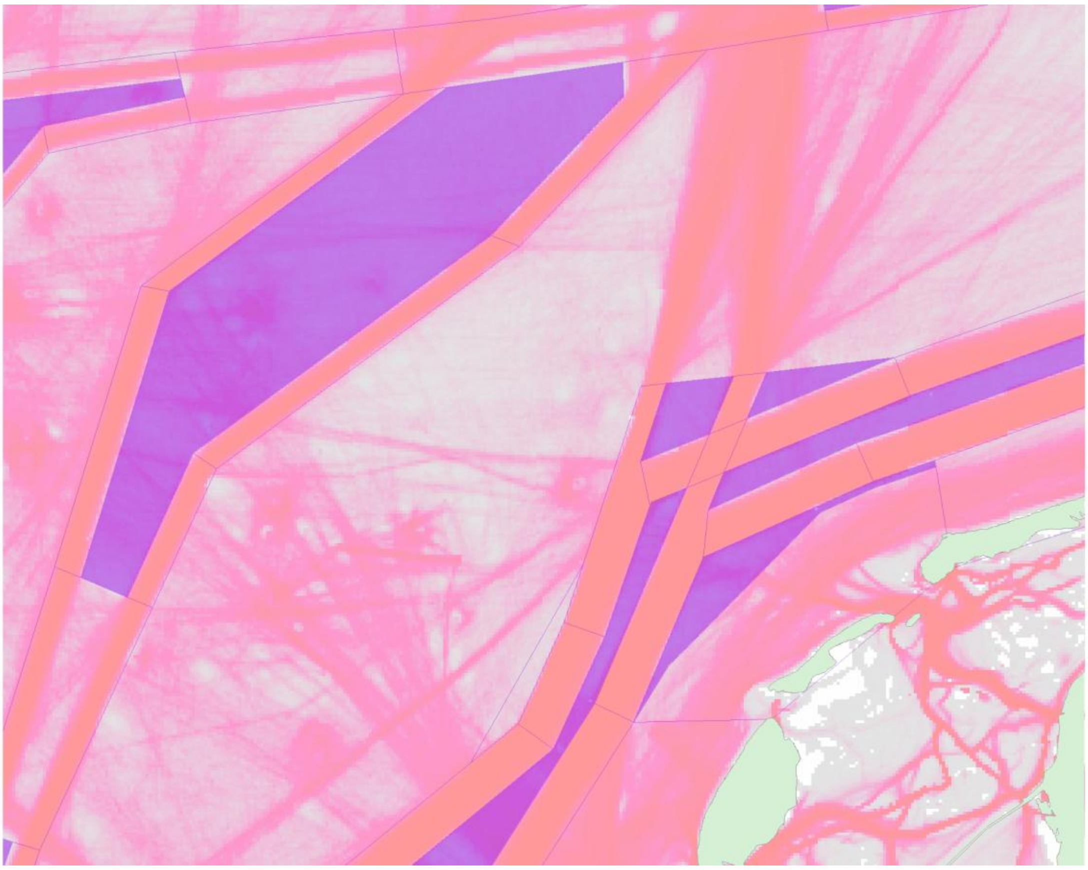


Figure 21: Overlay of vessel traffic density plots with IMO recognized routeing measures off the Dutch coast in an area with a very high traffic density

For the construction of the NSR-RTM 2012, the next step is to find a (semi-)automatic means to more clearly discern between those areas, where there is clearly some vessel traffic density or even a very high vessel traffic density compared to areas with spurious vessel traffic. *This distinction can be achieved by introducing a grid of squares or cells for the whole of the area under consideration and by counting the number of vessel tracks on those squares individually.*

- The relevant square side length needs to be determined with care in order to balance between the required accuracy of the resulting vessel traffic patterns on one hand and the processing time used for the sea area under consideration on the other hand.

- At ACCSEAS a square or cell side length of 400m was used throughout the entire NSR for the construction of the NSR-RTM 2012.

A numerical analysis of the relevant AIS vessel position reports (‘broadcasts’) used in ACCSEAS for the NSR-RTM 2012 is shown as a histogram in Figure 22. It can be clearly recognized that there is

- a very large ‘population’ of cells where there are only 1, 2, or 3 AIS vessel position reports during the whole of the year 2012 (to the left of the curve, left of 10 AIS vessel position reports) and
- another significant ‘population’ of cells with much higher numbers of AIS vessel position reports (the right part of the curve), resembling almost a Gaussian hat distribution with a center maximum in the order of around 50 AIS vessel positon reports in 2012.

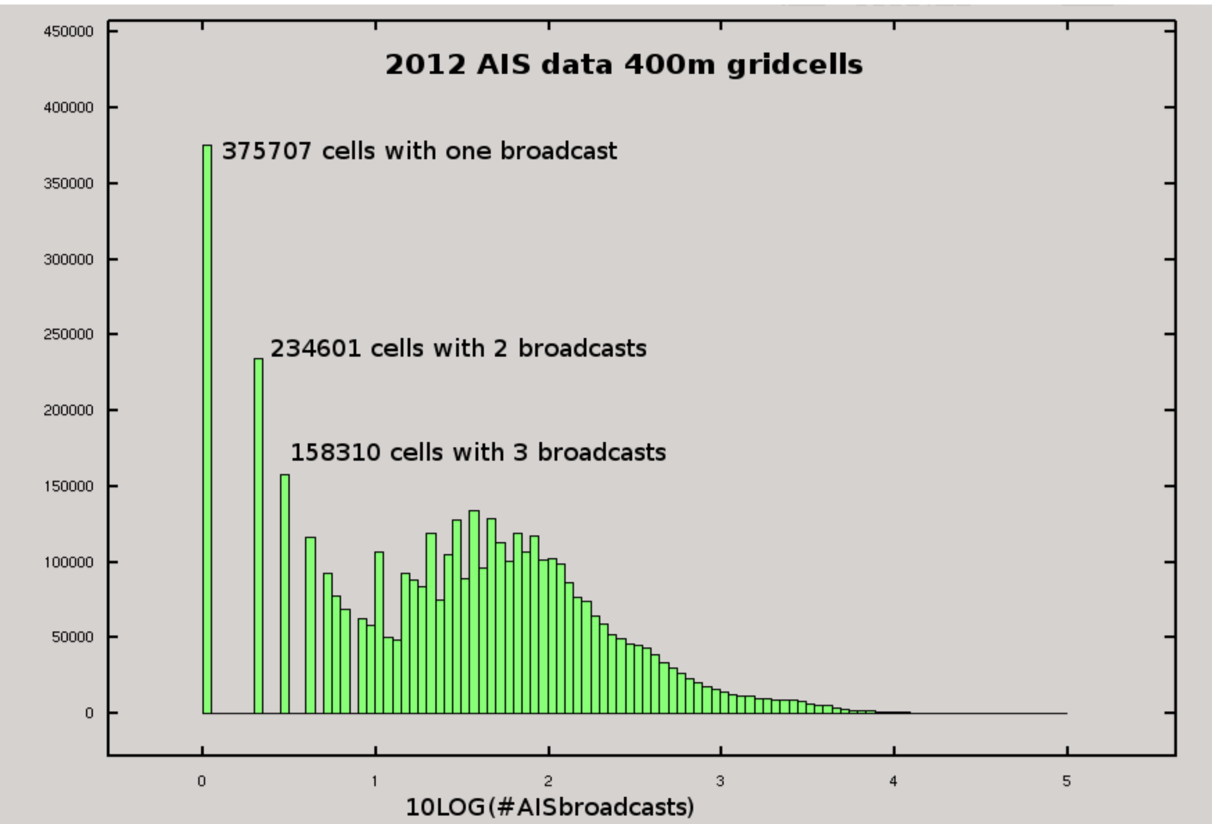


Figure 22: Numerical analysis of the AIS vessel reports (‘broadcasts’) using a grid cell

The desired distinction for the (semi-)automatic derivation of vessel traffic routes can be derived by finding the appropriate boundary of ‘x broadcasts per cell.’

This task can be supported by transforming the above data into a normalized graph, showing the percentage of the total population of AIS vessel reports in a cell as a function of the number of vessel position reports per cell (compare Figure 23).

- To the left hand side, the curve approaches 100% very steeply: The steeper the curve is here, the clearer is it possible to distinguish between vessel traffic routes and areas with spurious vessel traffic by setting a boundary.
- In the example of Figure 23 there are two boundaries set, namely at 180 AIS vessel position reports and at 1300 AIS vessel position reports.

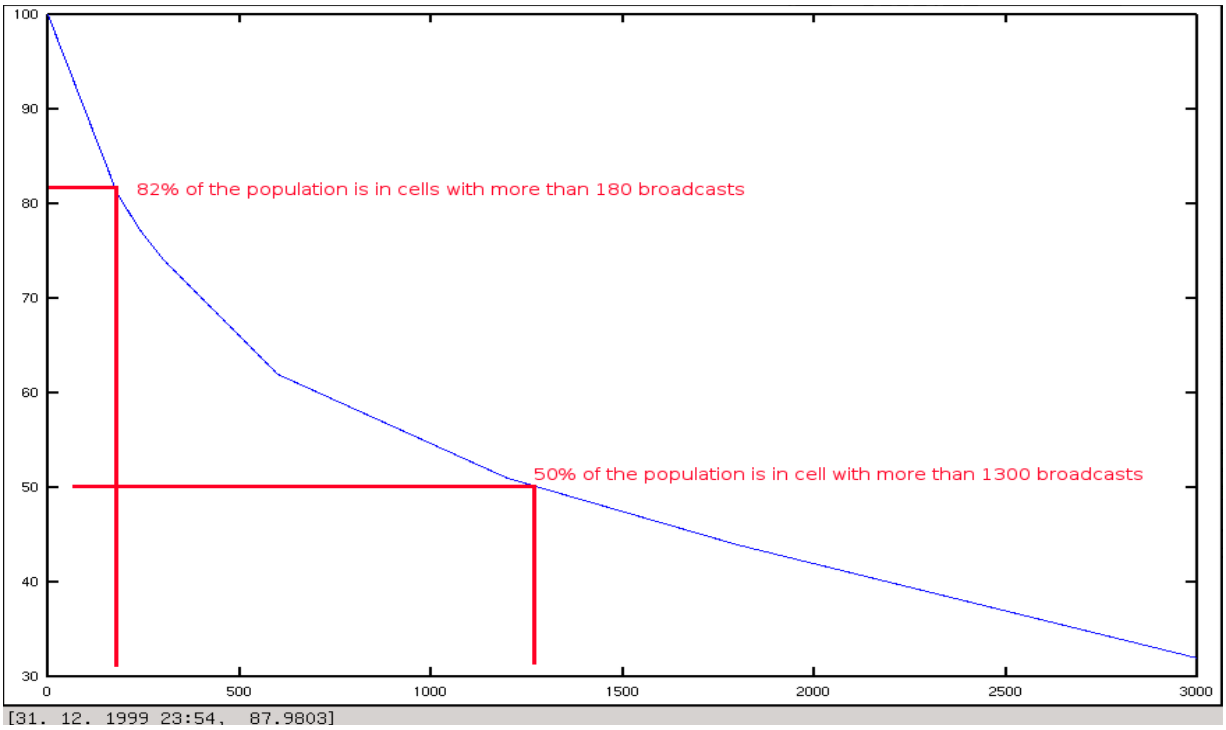


Figure 23: Percentage of total population as function of number of AIS vessel position reports per cell over the year 2012 in the NSR

This graph analysis provides guidance to investigate the vessel traffic density map introduced in Figure 20 *further by an approximation method which could be called 'peeling off'.* This approximation method is further explained by means of an example for the NSR in the following Figures:

- The most important routes – concluding empirically from the highest vessel traffic density – would be those appearing when the boundary is set equal or above a value of 180 (compare Figure 24, Figure 25, Figure 26, and Figure 27). Progressing from boundary set at 1300 down to 800 down to 20 eventually, the additional density plot entries are added with a different colour in each step (dark red, lighter red, orange, yellow, green).
- It may be concluded that these routes, at least, would qualify as Motorways of the Sea.
- Looking at Figure 24 (boundary set to 1300) or Figure 25 (boundary set to 800) reveal the routes in the whole of the NSR with the highest density at all, showing in particular the route grid at the southern entry to the NSR and the two concurrent vessel traffic routes through the North Sea to the Baltic Sea, namely those through the German waters and the Kiel Canal on one hand and through the Danish/Swedish waters on the other hand.
- Setting the boundary to a very low value like 10 (Figure 31) or 20 (Figure 30) prompts the question whether routes are still discernable.
- All figures show, however, that the route grid does not emerge completely from this approximation method, and that substantial manual work is still required to finalize the NSR-RTM 2012 by using additional supportive methods.

The above approximation, together with additional manual work, would render Figure 32 (overleaf) which shows all routes identifiable by the present empirical method using AIS vessel reports. This Figure could be called the ***NSR-RTM 2012*** *– i.e. the NSR-RTM for a specific point in the past.*

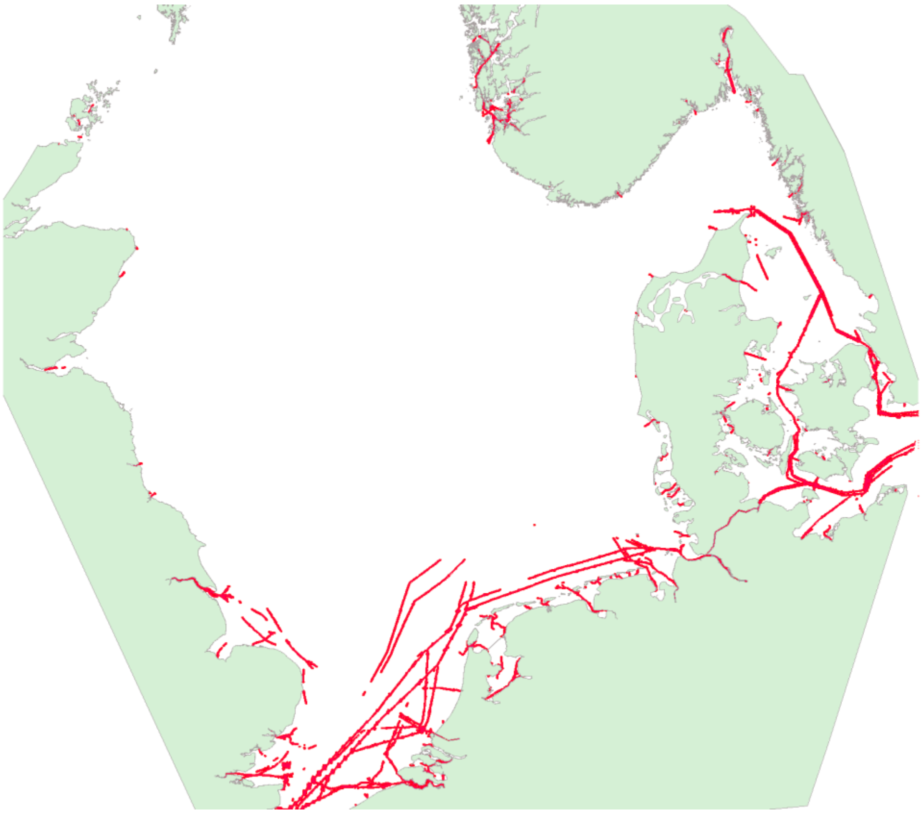


Figure 24: Resulting route grid when setting the boundary at 1300 AIS vessel position reports per cell over the year 2012 in the NSR

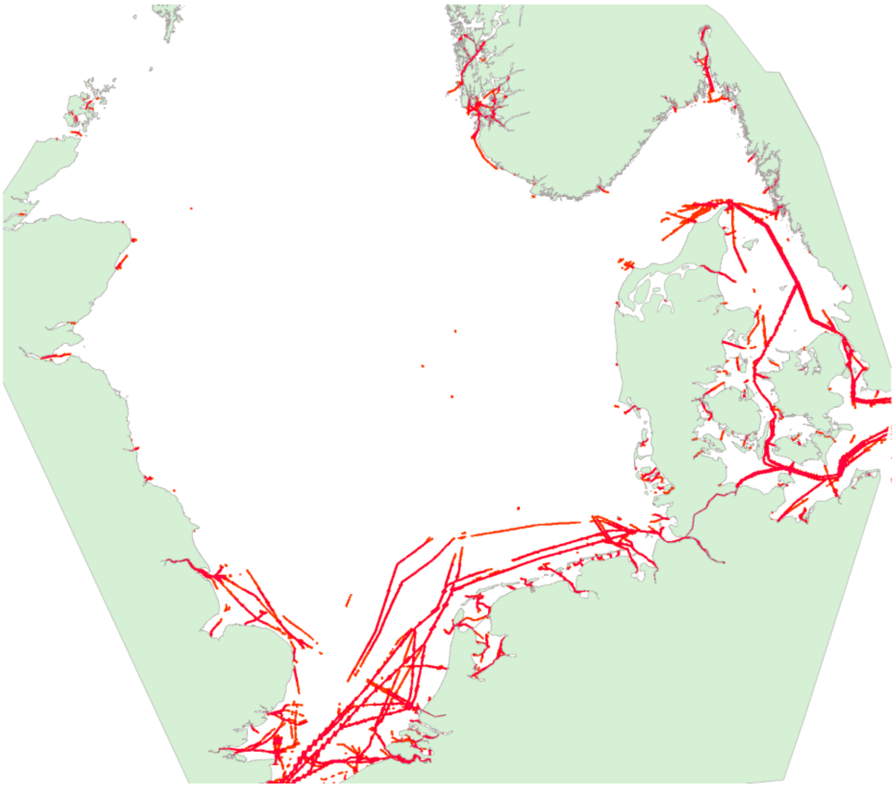


Figure 25: Resulting route grid when setting the boundary at 800 AIS vessel position reports per cell over the year 2012 in the NSR

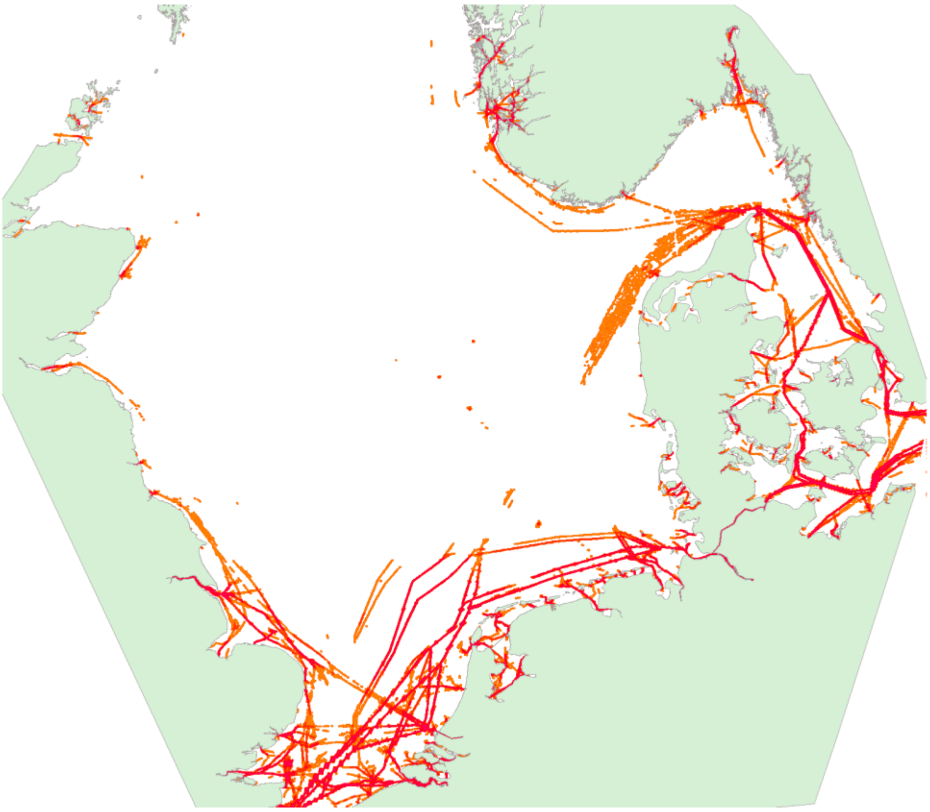


Figure 26: Resulting route grid when setting the boundary at 400 AIS vessel position reports per cell over the year 2012 in the NSR

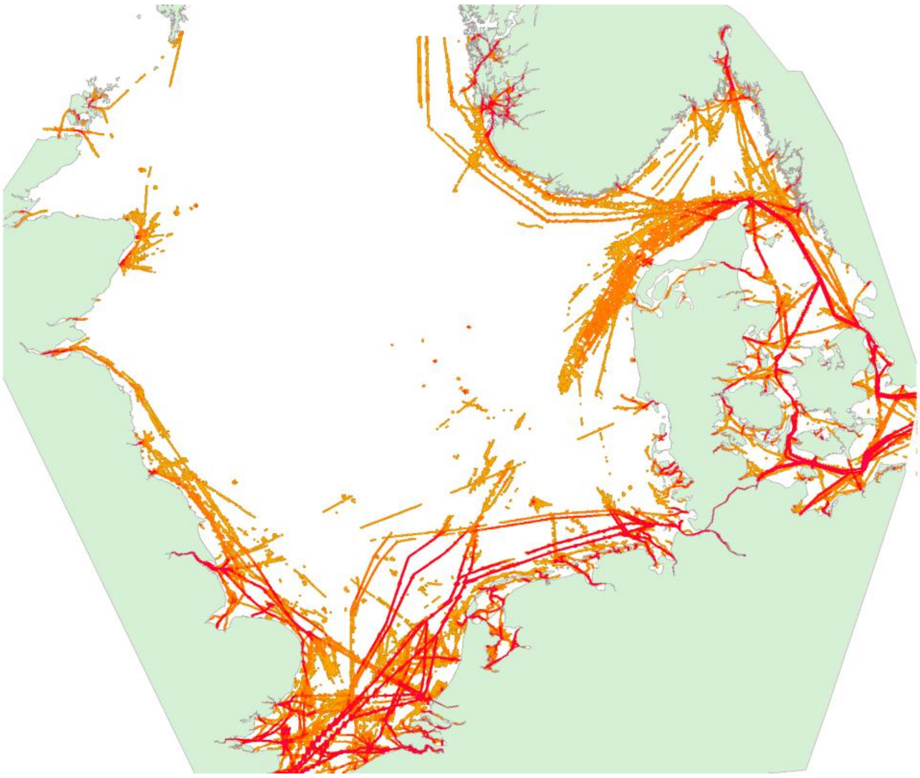


Figure 27: Resulting route grid when setting the boundary at 180 AIS vessel position reports per cell over the year 2012 in the NSR

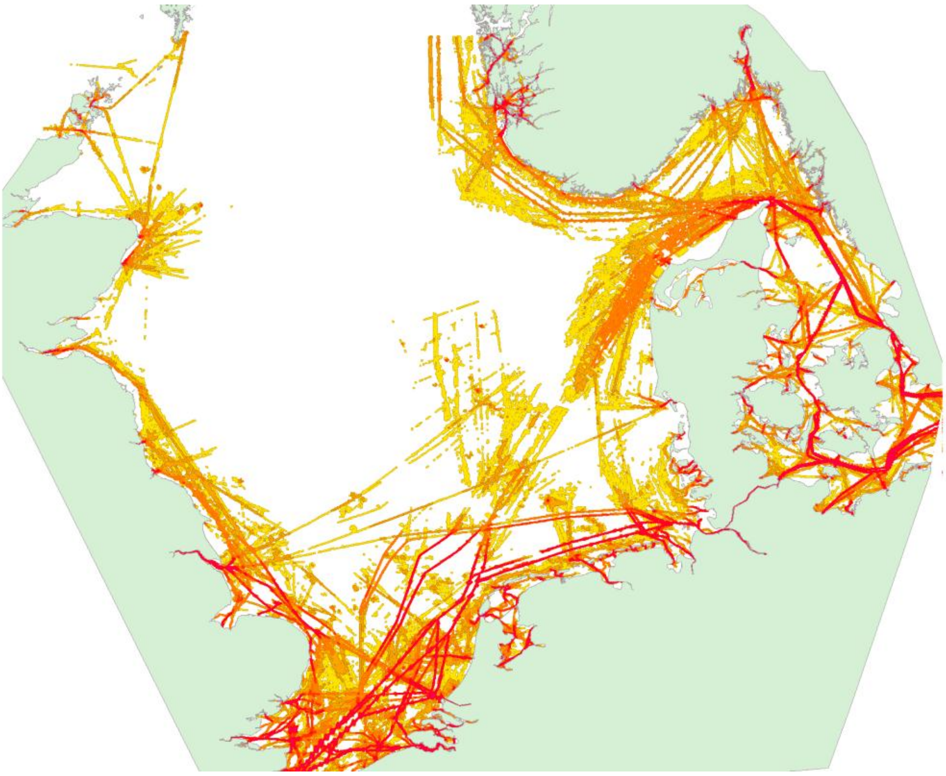


Figure 28: Resulting route grid when setting the boundary at 90 AIS vessel position reports per cell over the year 2012 in the NSR

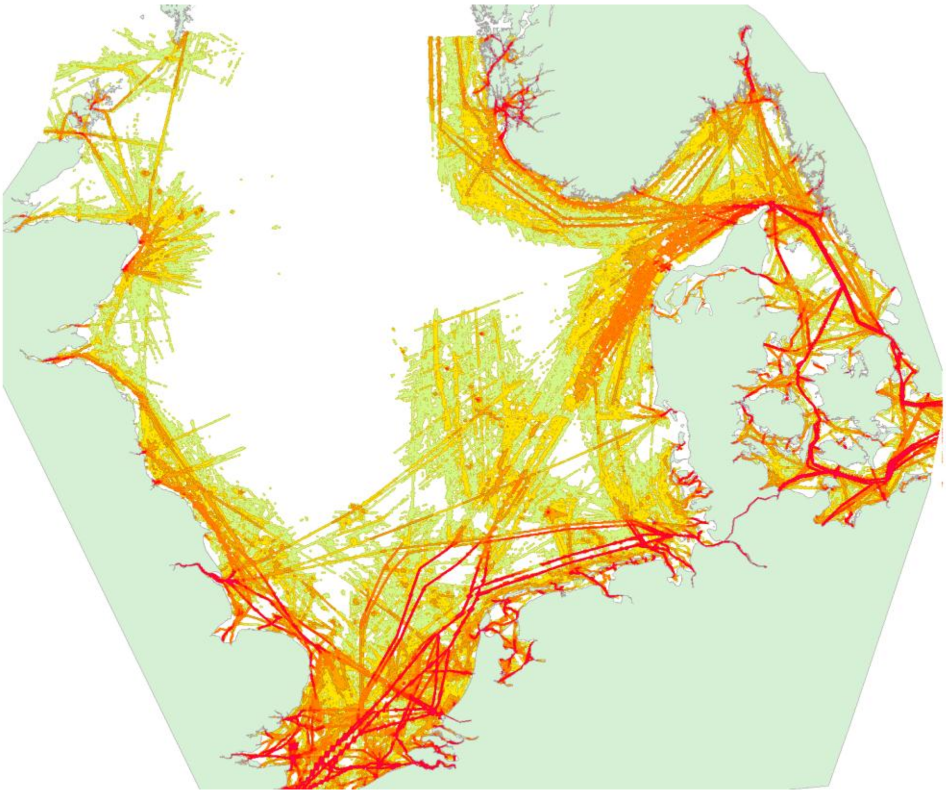


Figure 29: Resulting route grid when setting the boundary at 40 AIS vessel position reports per cell over the year 2012 in the NSR

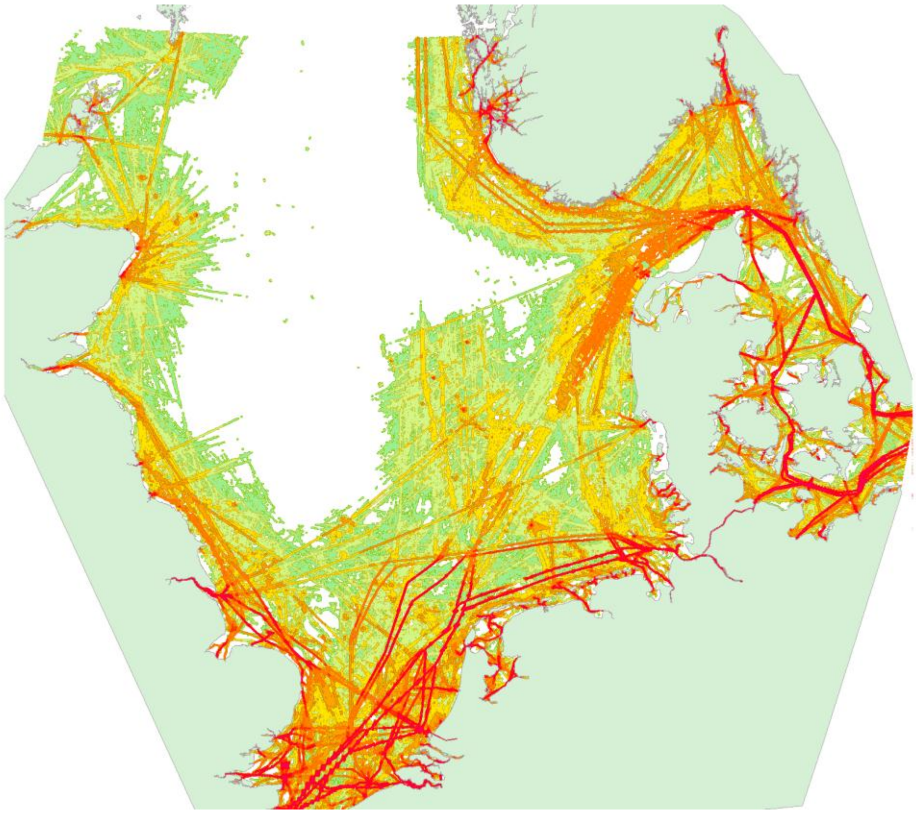


Figure 30: Resulting route grid when setting the boundary at 20 AIS vessel position reports per cell over the year 2012 in the NSR

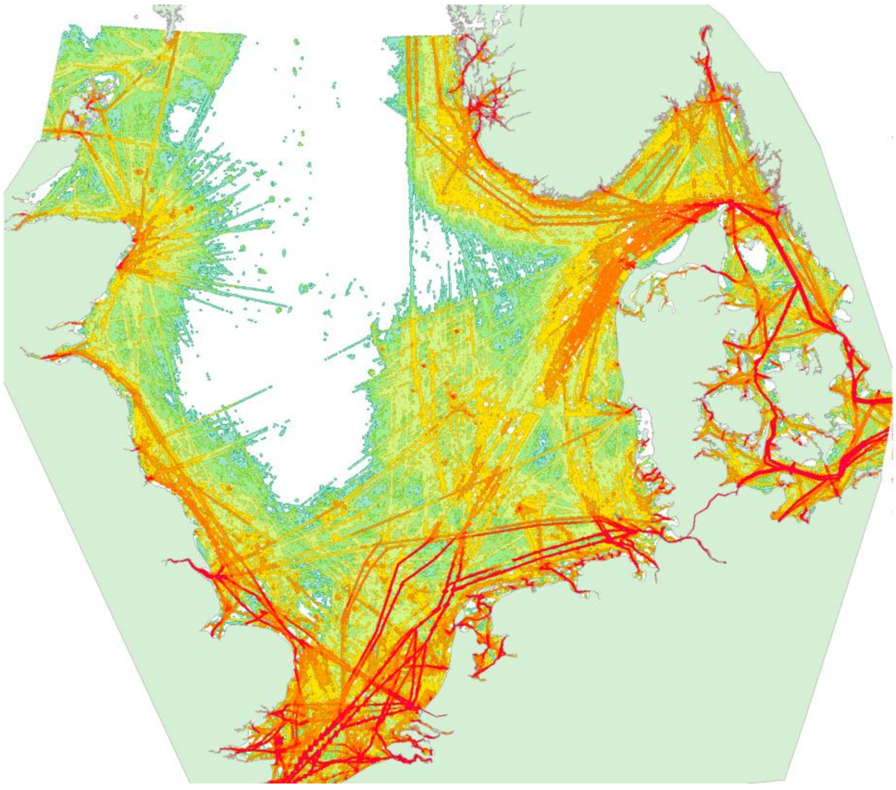


Figure 31: Resulting route grid when setting the boundary at 10 AIS vessel position reports per cell over the year 2012 in the NSR

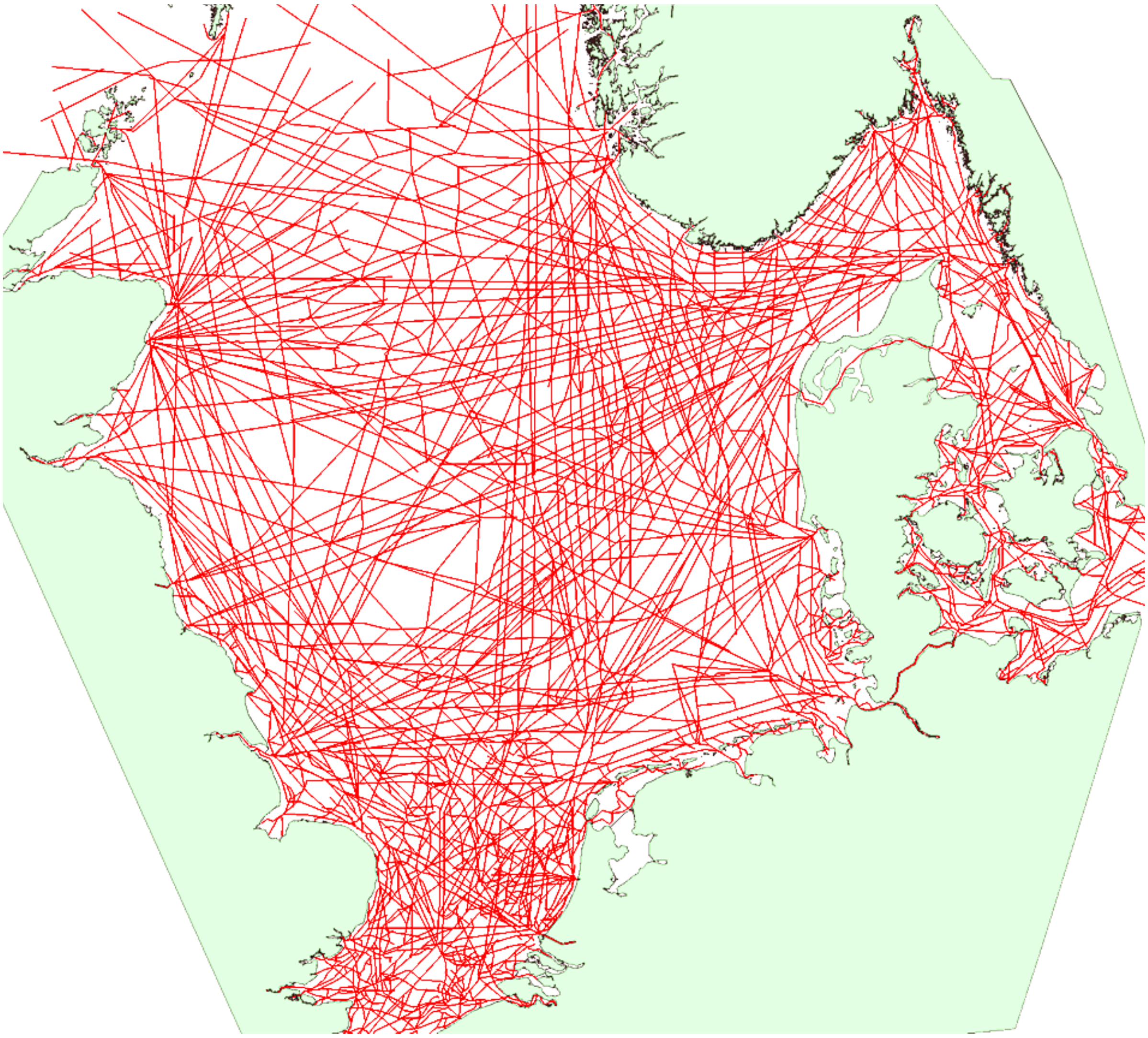


Figure 32: All routes that appear to be used by AIS carrying ships over the year 2012 in the NSR – the NSR-RTM 2012

A *shortest path analysis from any port to any other port in the NSR* (compare Figure 33) may further assist in discriminating between the different classes of shipping lanes thus identified by the above analysis.

Figure 33: Applying a 'shortest path' analysis port-to-port to Figure 32 for the southern entry to the NSR (highlighted in black)

4.2.2 Re-iterate NSR-RTM on a biannual basis to capture recent developments

As mentioned in the introduction to this chapter, the above vessel traffic pattern analysis, based in the case of the ACCSEAS NSR-RTM 2012 on AIS vessel position reports in 2012, needs to be superimposed by developments having taken place in the meantime. Since 2012, most notably, a fundamental change of the TSS grid off the coasts of the Netherlands and Belgium, including the important approaches to Antwerp, Rotterdam and Amsterdam, was recognized by IMO and became effective by 2013 (IMO 2012b). This change of the TSS grid certainly has an impact on the vessel traffic pattern in this area. There are, in principle, two options to deal with this situation regarding the NSR-RTM:

- The above vessel traffic pattern analysis would need to be re-iterated with more recent data, e.g. with vessel traffic data gathered in 2014 or 2015, i.e. with a time distance of two or three years from the year the data used for the last analysis was gathered (2012).
- Because this was not possible within the framework of the ACCSEAS project, this would render a legacy item to create a NSR-RTM 2015 or a NSR-RTM 2016 which would capture the shift of vessel traffic patterns in the NSR due to these influences (compare Annex C).
- For the construction of a projection of the NSR-RTM into the future, i.e. for the NSR-RTM 2020+, the influence of such an amendment may be easily captured using the following methodology.

4.2.3 Superimpose MSP data for a NSR-RTM instance for a future point in time

When considering a NSR-RTM instance for a future point in time, e.g. ***NSR-RTM 2020+***, which is desirable for any future planning purpose (compare chapter on applications of RTM below), available data from the MSP domain needs to be taken into consideration, in particular MSP constraints imposed by coastal states (including offshore installations and PSSA).

Figure 34 illustrates how MSP data may provide input to the construction of an RTM instance database for a future point in time, using the German example introduced above.

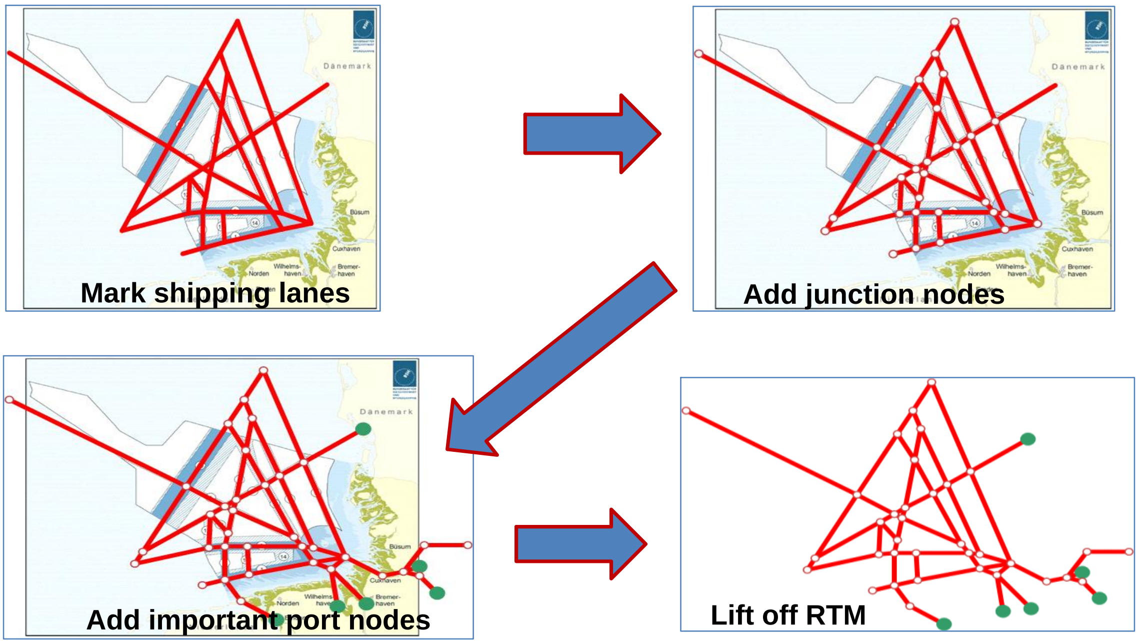


Figure 34: Illustration of the contribution of shipping lane data from MSP for the construction of an RTM instance database

It should finally be noted, that the above contributions exhibit different qualities, such as legal contributions as opposed to the empirical data derived from vessel traffic sensors like radar and AIS. Legal contributions, e.g. for a future situation, may eventually, by their very nature, be stronger and therefore more relevant than existing vessel traffic patterns as manifested in the historical vessel traffic footage.

4.3 Notes on modelling legs and nodes under some specific conditions

It was stated above, that a certain degree of ‘manual work’ would be required to arrive at a valid and even mature NSR-RTM for a given point in time *in the required precision of the node and leg definitions.* This manual work would require expert contributions *from both the navigator’s and the hydrographer’s domain, in addition to engineering expertise for the modelling of that knowledge into the abstract RTM data domain per se.* The following notes reflect certain topics which were recognized during the ACCSEAS work in this regards, with the above expertise assembled in the ACCSEAS RTM team while constructing present NSR-RTM instances introduced in this Description.

4.3.1 Determining the best abstractions of leg locations based on micro-evaluation of vessel traffic data

For the derivation of the best abstraction of leg locations by micro-evaluation of vessel traffic data, the ‘hat distribution method’ can be used. This was already introduced in the ‘ACCSEAS Baseline & Priorities Report’ (ACCSEAS 2015a, Figure 1-10) in the context of the determination of risks using the IWRAP approach. Figure 35 shows two different situations of ‘hat curves’ at altogether four ‘gates’: The vessel traffic density line from NW to SE shows a more ragged ‘hat,’ the different shapes of which also depend on the direction of vessel traffic; however, the route may be clearly identified as such. The TSS in N-S direction (and vice versa) shows ‘hat curves’ which approximate the shape of a Gaussian distribution even (which is to be expected at a TSS lane). *The legs center lines in principle are selected by using the maximum peaks of the ‘hat curves’.* In the case of the NW-SE vessel traffic density line, there appears a to be a subdivision of the NW-gate into two legs, even, implying a junction at of those two emerging legs at the crossing point with the TSS, while the SE-gate exhibits one center 'hat peak' in each direction.

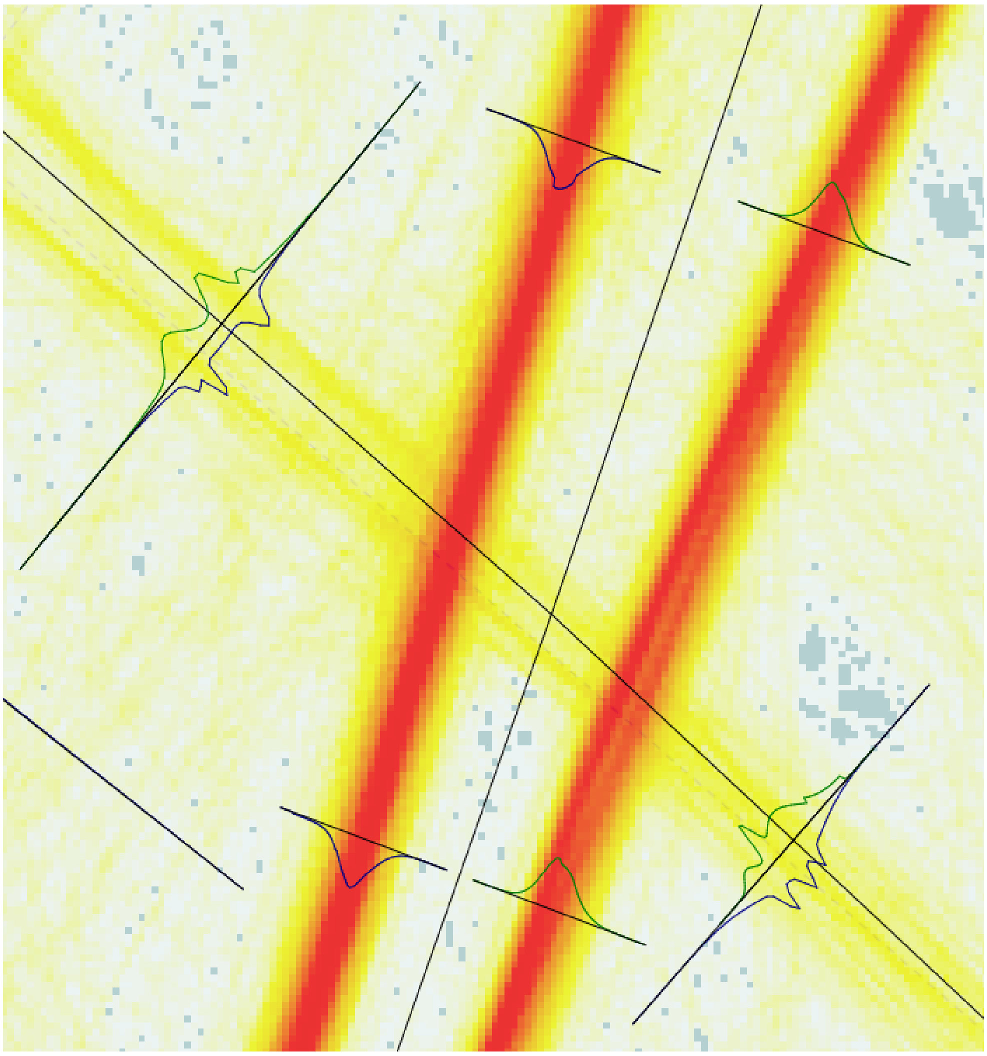


Figure 35: 'Hat curve' used for micro-evaluation of vessel traffic data to find the best abstraction of leg location (ACCSEAS 2015a, Fig. 1-10)

4.3.2 Modelling cross-roads and pre-cautionary areas of TSS

This topic of crossing points at a TSS is particular relevant when modelling RTM as is the junction/leg situation in a Precautionary Areas (PA)**:**

- The crossing lanes need to be modelled as additional junctions/legs and then each of the resulting legs/junctions can be described by the above attributes.
- The junctions lying in a PA can be modelled by following the principle that there may be several *options* for a navigator to pass through the PA, as shown in Figure 36: The point of the RTM is to model the reasonable options for travel. Hence there would be the 'shortcut' leg for the southbound traffic within the SW-corner of the PA as well as the rectangle leg-junction-leg situation from which two legs would protude and leave the PA (in NE-corner) for the east-bound traffic. Note that the modelling in Figure 36 is not complete.

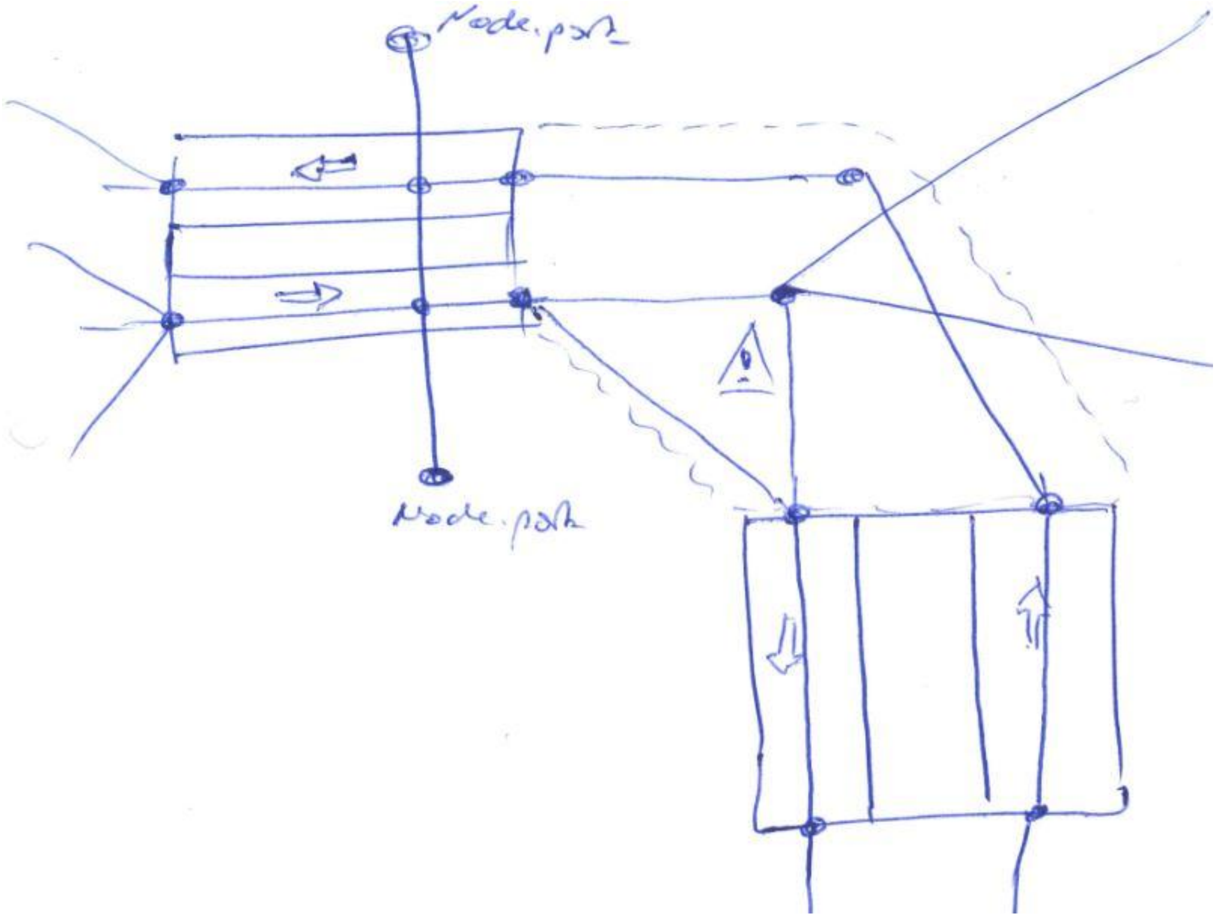


Figure 36: Micro-evaluation of routes at cross-roads and precautionary areas of TSS
(Workshop situation sketch from a RTM-WG meeting)

It should be noted, that this kind of micro-evaluation is best done in a workshop setting with the relevant experts present, as indicated by the sketchy nature of Figure 36.

4.3.3 Recognized 'key European seaports' as immediate destinations of the TEN-T MoS grid

When looking for criteria to identify the seaports that should be immediate destinations of the MoS shipping lane network, it might be advisable to look for recognized European lists of such ports: Already in 2011, the EU Commission identified 319 key European seaports (out of over 1200 commercial seaports) throughout the Union which are considered essential for the efficient functioning of the internal market and the European economy.[6] These 319 ports as a basis for a highly functioning European ports network manage 96% of goods and 93% of passengers which transit through the EU ports (European Commission 2013). Of these 319 'key European seaports' some 83 are recognised as being 'core network' ports. The final number of TEN-T ports will depend on the final outcome of the on-going ordinary legislative procedure (European Commission 2013).

The EU Commission recognized 'key European seaports' *in the NSR* (as used by the INTEREG IVB programm) are (by country):

- *Belgium:* Antwerpen, Gent, Oostende, Zeebrugge;
- *Germany:* Bremen, Bremerhaven, Brake, Brunsbüttel, Cuxhaven, Emden, Hamburg, Kiel, Lübeck, Nordenham, Puttgarden, Rostock, Sassnitz, Stade-Bützfleth, Wilhelmshaven, Wismar;
- *Denmark:* Aalborg, Aarhus, Branden, Kobenhavn, Ebeltoft, Esbjerg, Fredericia, Frederikshavn, Fur, Gedser, Hanstholm, Helsingor, Hirtshals, Kalundborg, Nordby, Odense, Rodby, Ronne, Sjaelland Odde Ferry Port, Spodsbjerg, Tars (Nakskov), Vejle;
- *The Netherlands:* Amsterdam, Beverwijk, Delfzijl/Eemshaven, Den Helder, Dordrecht, Eemshaven, Groningen, Harlingen, Moerdijk, Rotterdam-Den Haag, Terneuzen/Vlissingen, Velsen/IJmuiden, Vlaardingen;
- *Sweden:* Göteborg, Halmstad, Helsingborg, Karlshamn, Karlskrona. Malmö, Stenungsund, Strömstad, Trelleborg, Varberg, Ystad;
- *United Kingdom:* Aberdeen, Cromarty Firth, Dover/Folkestone, Edinburgh Forth, Felix-stowe/Harwich, Goole, Grimsby/Immingham, Hull, Ipswich, London, Medway, Orkney, Ramsgate, River Hull/Barton-upon-Humber, Stornoway, Sullom Voe, Teesport, Tyne.

(European Commission 2011)

Norwegian ports are not included in the above list. However, the following seven Norwegian harbours ('Utpekte havner') are recognized as of the same order of importance than the above 'key European seaports': Oslo, Kristiansand, Stavanger, Bergen, Trondheim, Bodø, Tromsø (provided by Norwegian Coastal Administration).

The assumption is made here, that all 'key European seaports' in the NSR, plus the above Norwegian key seaports, eventually would be immediate destinations of the MoS grid, while other commercial ports (from the above list of over 1200 commercial seaports in the EU) would be connected to the MoS grid by RoS shipping lanes.

4.4 The resulting NSR-RTM 2020+ instance and its specifics

Using the above approach a projection of the **NSR-RTM 2020+** was created – on the level of the MoS shipping lanes (Figure 37 overleaf).

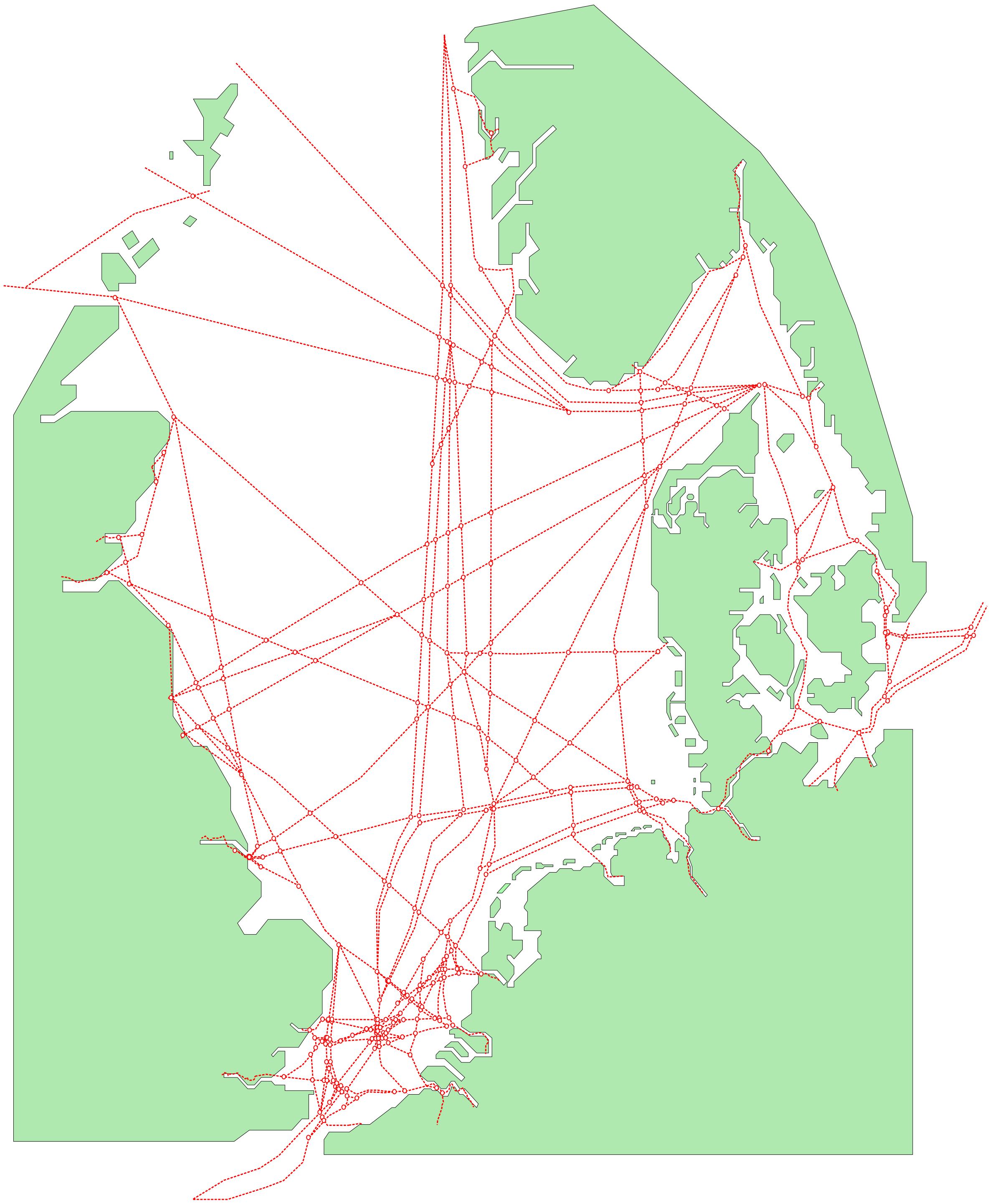


Figure 37: NSR-RTM 2020+ – Motorways of the Sea shipping lanes – complete NSR with generalised coastline; in ENC display mode

This was created by starting with the NSR-RTM 2012 (i.e. based on AIS vessel track data from around the NSR) and was amended, where necessary, to align with the anticipated future situation by using MSP data known from the 2020+ analysis captured in the 'AC-CSEAS Baseline & Priorities Report' (ACCSEAS 2015a).

The alignment was done in such a way that the resulting MoS in those areas, where there will be MSP introduced resulting in a confined sea space for shipping, would still be back-wards compatible with the existing traffic situation: I.e. the present traffic situation, which has allowance for larger sea space includes the shipping lanes of the NSR-RTM 2020+ projection while having margin for additional shipping lanes; the NSR-RTM 2020+, however, would not include all presently existing shipping lanes anymore, because they would be no longer available due to the advent of different sea usages due to MSP imposed.

Annex A shows the *ENC display mode* representation of the NSR-RTM 2020+, MoS level. There are also some enlarged depictions of particularly interesting sea areas within the NSR.

Annex B shows the *LTM display mode* representation of the NSR-RTM 2020+, MoS level.

Within the ACCSEAS project the 'NSR-RTM demonstrator,' as described above, was created. It is fully understood by ACCSEAS that there is work to be done in the future. When taking up this work as a legacy of ACCSEAS the individual *legacy items regarding NSR-RTM* at **Annex C** may serve to guide that future work.

4.5 Alternative methodologies resulting in similar results

ACCSEAS has compared the resulting grid with a similar grid from the BeAware project which was produced by COWI with a different methodology. The COWI method was to connect AIS positions for the same vessels even when these positions were hours apart from each other. Figure 38 shows a comparison of the two approaches.

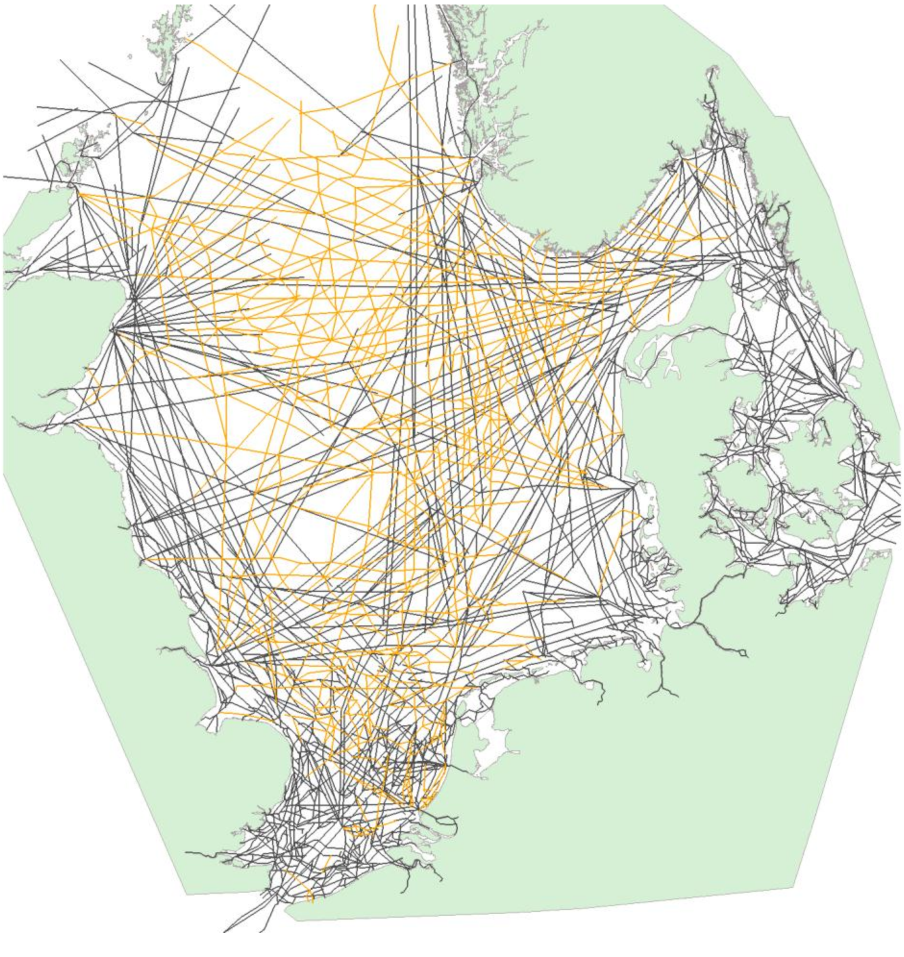


Figure 38: Comparison of the BeAware and of the ACCSEAS projects' analyses (Black lines: ACCSEAS analysis; orange lines: BeAware analysis)

When comparing these grids they resemble for the majority of the area, the relative 'AIS data desert' in the center of the NSR has been filled with the routes from the BeAware model.

5 Potential applications of the (NSR-)RTM and application notes

In the previous chapters, the RTM was motivated, described and its three fundamental display modes portrayed in the generic domain. Also, the example of the derivation of the NSR-RTM 2012 was used to illustrate how to perform a vessel track data analysis for RTM purposes. Eventually, the NSR-RTM 2020+ was derived by superimposition of foreseeable or even already stated impacts of MSP. Several allusions to the potential applications of the (NSR-)RTM were made in the process. This chapter now explores the application domain for the (NSR-)RTMs in more detail.

5.1 Harmonisation of route definitions – the most fundamental benefit

During the third ACCSEAS Annual Conference and in particular during the third e-Navigation User Forum (Rotterdam 2015) and its RTM workshop, some participants stated that they already use a variety of RTM for their purposes and – more or less – successfully, at least on a trial basis. It was made clear, that these stakeholders have developed their own, private version of the RTM. Also, certain limitations such as area of interest were stated. Compare **Annex E** for full transcript of the RTM workshop.

The most fundamental benefit for all stakeholders involved therefore would be that by establishing a RTM for a given sea area, the *features of that instance of the RTM are being agreed by all participating parties.* Thereby, the features are harmonized amongst all stakeholders, thereby *allowing for a common harmonized reference.*

Associated data attributes would also be readily available for data exchange (by electronic means), with the same meaning for the originator and for the recipient of that data.

The following applications apply this benefit to their specific domain, in one way or another.

5.2 Potential useful applications of a (NSR-)RTM – overview

The (NSR-)RTM can be used for at least the following useful applications:

- *(NSR-)RTM may enable (NSR) transport and traffic pattern analysis for policy making:* based on (NSR-)RTM the (NSR) transport volumes, the cargo flows, and the development of the (NSR) vessel structure can be assessed (shore-based stakeholders);
- *(NSR-)RTM may assist in the Marine Spatial Planning* of a given sea area (shore-based stakeholders);
- *Transport management by employing an improved route and voyage planning* on the basis of RTM, both *regarding* initial (pre-trip) and en-route (re-)planning (logistic chain stakeholders, ship-owners and shipboard applications);
- *Traffic planning and management in strategic and tactical terms* for parts of the NSR or for the NSR as a whole may be supported (shore-based stakeholders);
- *Just-in-time arrival processes may be supported* by (NSR-)RTM at planning and at execution time (logistic chain *stakeholders*, shipboard and shore-based stakeholders);
- *(NSR-)RTM supports the Maritime Service Portfolios:* The (NSR-)MSPs can be associated with the (NSR-)RTM in order to arrive at a service provision scenario tailored to the need of specific (NSR) routes (both shipboard and shore-based stakeholders and users);[7]
- *Maritime information dissemination can be tailored to the specific needs of different user groups* based on RTM (shipboard and shore-based users and stakeholders, such as service providers);

[7] The (NSR)MSP provision may be further differentiated to the needs of different user groups within the same route.

- *Improved risk assessment by basing the risk assessment on defined routes* within the sea area under consideration (as opposed to area-based risk assessment), which in turn supports several of the above applications and may facilitate decision making regarding the implementation of safety measures(shore-based stakeholders);
- *(NSR-)RTM may assist in establishing improved Routing Measures,* in particular an improved TSS scheme, for the NSR (via the IMO procedures) (shore-based stakeholders);
- (*NSR-)RTM may assist in extensive or more precise cost / benefit analysis* for the area under consideration. Costs/benefits could be applied both to commercial operators and authorities.

The above applications require appropriate presentation of the (NSR-)RTM data, hence this implies that different applications would require different display modes introduced above.

Since the (NSR-)RTM is a graph model in mathematical terms, this enables the *application of graph related mathematical and engineering tools* which will provide results which cannot be achieved by using geospatial/topographical data. The above applications of the (NSR-) RTM all build on the graph concept in some way.

The following sections will illustrate some of the above applications and spell out their benefits for the respective stakeholders in some more detail.

5.3 Notes on using (NSR-)RTM for route and voyage planning and execution

Obviously, there would be several applications of *Route* Topology Models for *route* planning and execution within the context of a vessel's voyage from berth to berth. Also, (NSR-)RTM would support both strategic and tactical tasks at both route planning and route execution.

- A ***route*** is a set of at least one legs and the associated junctions and/or nodes. A route is existing independently of any voyage of any vessel, i.e. it exists even without a voyage.
- A ***voyage*** is the expedition of a vessel from a starting point (*Node.Destination* in the RTM terminology as given in Figure 8) to an end point (another *Node.Destination* or the same *Node.Destination* in a round-trip-voyage) using a specific choice out of several possible routes. Also, within the same voyage several intermediate destination points (*Node.Destination*) may be included for various reasons.
- There are different relevant points in time, namely ***route planning*** and ***route execution***. Route planning, by nature, is a ***strategic*** task, as well as keeping track of the general aspects of the execution of the route in all required regards. The navigation of a vessel from e.g. node to node via one or several legs proper, falls into the ***tactical*** tasks domain.

5.3.1 (NSR-)RTM to support determination of 'practical least distance' port to port at voyage planning

At both voyage planning time (for initial planning) and voyage execution time (for re-planning), there would be a clear benefit from (NSR-)RTM to mariners: The 'mesh' of – in particular MoS – allows for the *determination of the 'practical least distance'* port to port (the geometrical distance may be shorter, but is either not possible or cumbersome; compare by analogy the usage of shore-based motorways in preference over even shorter national roads) *which in turn renders an economical connection for the mariner* (which is kind of warranted from the outset).

Since a harmonized (NSR-)RTM would be a pre-defined data set, *it does not need to be established by the mariner on his/her own, i.e. reduces work load*.

5.3.2 'Regulatory Almanac' in electronic format applied to RTM and 'VTS Guide' correlated with RTM

For all phases of a voyage planning and execution it may be helpful to have available relevant information regarding relevant regulations, i.e. a 'Regulatory Almanac' in electronic format. Almanacs like this were around since several years in (digitized) paper format, e.g. as 'VTS Guides,' but their updates were sometimes lagging behind, the information provided was not easily integrated into shipboard electronic system, and they were often confined to the territorial waters of a state. An electronic/digital 'Regulatory Almanac' may be more easily and readily distributed, may be more up-to-date, and its data may be more easily integrated into the shipboard electronic systems.

In addition, to tie the available regulatory information closer to the routes identified in the (NSR-)RTM, potentially also taking into account the different classes of shipping lanes (MoS, RoS, ToS), may add some precision to the information/data provided.

Also, the different classes of shipping, i.e. e.g. different classes of professional shipping vs. pleasure craft shipping, using the different classes of shipping lanes may be covered in the same 'Regulatory Almanac' seamlessly, at least as far as the data content is concerned (while the display modes most likely will be different for different classes). This would satisfy the IMO e-Navigation strategy's requirement of scalability for all classes of vessels.

There are regulatory attributes for a leg or node depending on the vessel and its features, including cargo, and regulatory attributes not depending on any vessel feature. When modelling attributes, those should be modelled into separate attributes.

For the application of a 'Regulatory Almanac', the following data objects would be needed to be considered as application attributes attached to the legs and nodes, as appropriate:

- *Applicable regulation and legislation:* This attribute informs about the applicable regulation in UNCLOS terms (e.g. territorial waters);
    - territorial waters vs. EEZ vs. international waters
    - inland waterways, subject to the different rule bases (e.g. IMO shipping rules such as coastal estuaries and Kiel Canal; inland waterways shipping rules proper, as established for example by the Central Commission for the Rhine)
- *Part of a TSS:* A leg or node is part of an IMO defined TSS, or not. If a node is declared as being 'part of a TSS,' this could mean that it is a *Node.Junction* in a PA, or that it is a *Node.Junction* for crossing traffic lanes (compare section 4.3.2).
- *Regulatory Limitations regarding vessel features or cargo features which may prevent the vessel from* using *the leg under certain circumstances* such as:
    - Vessel dimensions;
    - Conditional usage of a leg on the part of the vessel, i.e. specific vessel hull features (such as ice class) or specific vessel equipment required;
    - Limitations due to dangerous cargo carried;
    - It is anticipated that this attribute is a compound of several enumeration types.
    - There may be minimum and maximum limitations.
    - Threshold is the entry into regulation.
- *(Permissible) direction of travel or traffic:* one way only (example TSS) or bi-directional (to/from); uniformity rule applies.
- *(Permissible) speed (speed limit):* maximum speed allowed (by regulation of appropriate competent authority); 'metering/percentage' feature applies.
- *Regulatory Pilotage requirements:* This attribute tells whether there is a requirement at a certain leg to accept a pilot, or what the conditions are which result in such a requirement (such as vessel size, cargo, weather and sea conditions). This attribute would also model the requirement to accept Navigational Assistance Service (NAS) from a pilot in a VTS centre.
- *Regulatory Helmsman reception requirement:* similar to the pilotage requirement attributes.

- *Ship reporting requirement:* At a certain node there may be required a vessel's report to authorities. This attribute would spell out this requirement.

5.3.3 (NSR-)RTM in support of valid, automatic and autonomous ship reporting during voyage execution

Due to a harmonized (NSR-)RTM available for all stakeholders, *ship reporting may be greatly eased for the mariners (to the extent of having it automatically and autonomously)* as follows: While vessels would be underway from A to B they would pass the nodes (*Node.Cross-Border, Node.Junctions* or *Node.Waypoint*), which, by virtue of the harmonized (NSR-)RTM, are all *identically* predefined for all vessels and shore-based authorities. Ship reporting would thus be *node-triggered,* and any automatically and/or autonomous shipboard functionality may be used to transmit the ship report electronically.

One means could be using e.g. ASM reports (of AIS) or other appropriate digital carrier systems, eventually by using the 'Maritime Cloud' once established.

5.3.4 (NSR-)RTM in support of a 'available services almanac' or a 'MSPs almanac'

In accordance with the IMO defined overarching architecture for e-Navigation, the Maritime Service Portfolios (MSPs) are purposefully composed bundles of operational and/or technical services provided from ashore to shipping at a certain point, i.e. a 'point of delivery,' at sea. This 'point of delivery' was understood by IMO to be a sea area in their present description of the MSPs. Due to the recognition that there are sea areas with different functional qualities, several different sea areas have been defined by IMO for the delivery of MSPs namely:

- '1 port areas and approaches;
- 2 coastal waters and confined or restricted areas;
- 3 open sea and open areas;
- 4 areas with offshore and/or infrastructure developments;
- 5 Polar areas; and
- 6 other remote areas' (IMO 2014, paragraph 18).

This concept would render a *blanket coverage* statement, for example 'MSP <x> is provided in sea area <coastal waters and confined or restricted areas>.' Considering, for example, an application of the above six sea area definitions to the functional features of the NSR, the NSR could be subdivided into 'port areas and approaches' (No. 1), 'coastal waters and confined or restricted areas' (No. 2), 'areas with offshore and/or infrastructure developments' (No. 4), and – for whatever sea area remains – 'open sea and open areas' (No. 3). It would be a useful evaluation of the above IMO area concept to perform an assignment to the NSR in its entirety, resulting in falsification or validation contributions. Most likely, based on the findings of the 'ACCSEAS Baseline & Priorities Report' (ACCSEAS 2015a), there would be recognized conflicting assignments between e.g. 'Coastal waters and confined restricted areas' (No. 2), 'areas with offshore and/or infrastructure developments' (No. 4) and even 'port (…) approaches' (No. 1) in several places.

Considering the specific traffic situation of the NSR, both at present and in the future, there may be a need to arrive at complementary, more traffic-specific definitions of 'points of delivery' for the MSPs defined in the NSR, i.e. for the NSR-MSPs. The RTM may come in here as an abstract yet potentially *powerful tool to assist in introducing MSPs in a traffic-sensitive manner,* i.e. *the (NSR-)RTM would allow for applying (NSR-)MSPs to specific shipping lanes which are represented by their respective node and leg and attribute definitions.*

This is by no means an entirely new concept for transportation. In the land mobile sector, for example, there are guides to motorists which correlate specific services provided to motorists with an abstract RTM representation of the highways which is displayed in a fashion which even resembles the LTM display mode (compare Figure 39; Source for land mobile example picture: (Linksundrechts.com 2015); as amended for figure).

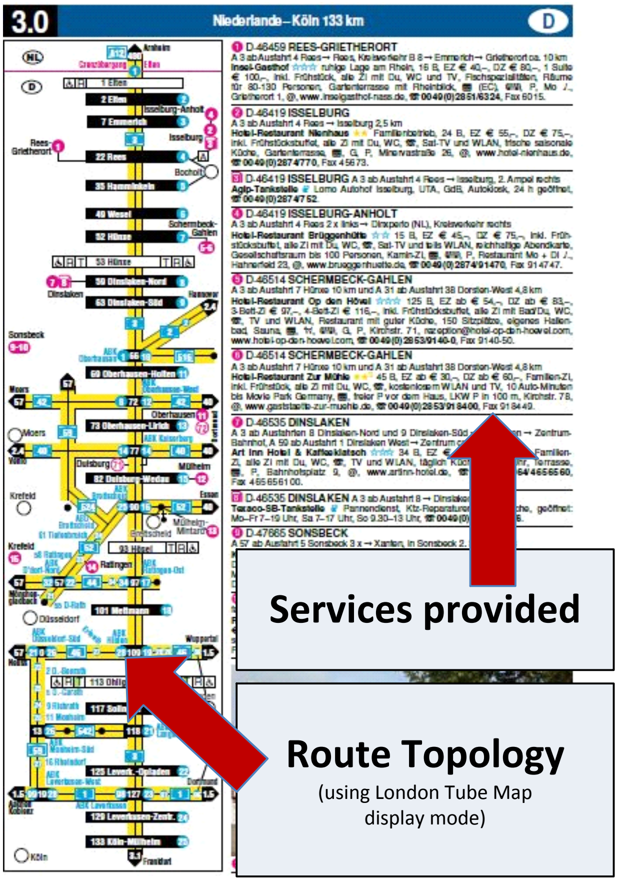


Figure 39: Application of services portfolios to route topology model representation in the land mobile sector (by analogy)

5.3.5 (NSR-)RTM in support of bathymetric applications to a voyage

Bathymetric data is highly relevant for certain vessels, in particular large and/or deep-draught vessels, their voyage plans and the actual routes they can take during the execution of their voyage.

Usually, bathymetric data is made visible as an overlay on ENC. This is a well-known application: The goal is to determine the Under Keel Clearance (UKC) of a vessel for a specific point in the future (at voyage planning and during voyage execution) and show it in the details ENC has to offer at a certain waterway location where there are bathymetric constraints, such as tidal windows. Due to the geospatial precision possible with bathymetric data display on ENC this allows for tactical navigation of a vessel through the locations with bathymetric constraints. Compare the ACCSEAS candidate solution ‘No-Go-Area Service’ for an application of this concept.

The (NSR-)RTM would show the bathymetric constraints of waterways attached as attributes to those legs and nodes to which they apply:

- The necessary geospatial precision of the locations of the bathymetric constraints of the waterways would be captured in the (NSR-)RTM by a precise modelling of the location of the relevant nodes (*Node.Waypoint*, *Node.Junction*, potentially *Node.Cross-Border* and *Node.Destination*)
- The exact time behaviour of the bathymetric constraints would be modelled by appropriated attributes associated with time.
- The strength of the (NSR-)RTM would unfold however, due to its abstraction level, when the 'pace making effect' of a leg or a node is easily identifiable:
  - **Attribute pace making effect on a leg:** i.e. a tidal window is influencing the leg: In particular the estuary waterways around the NSR, such as the approaches to important ports like Rotterdam, some UK ports, and Hamburg, exhibit a strong pace making effect on the legs associated with their approaches. Compare Figure 40 for an example.

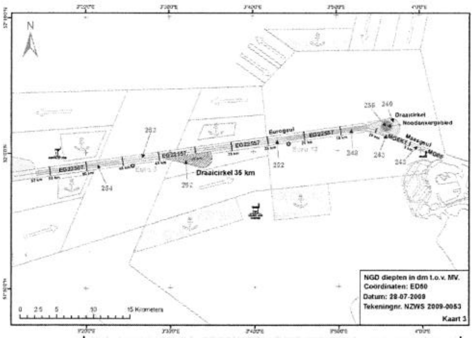
Tidal bound navigation in the Rotterdam access channel

Rotterdam Deep Water Route
Ships with a draught between 17.40 m and 22.55 m for Rotterdam are considered as Deep Draught Vessels and must follow the Deep Water Routes Eurogeul and Maasgeul (in short: Euro-Maasgeul). Vessels with a draught between 14.30 m and 17.40 m are bound to the Maasgeul only. The particulars of the channel are:

	direction	width	Minimum depth	Length
Eurogeul	82.5°	600 m + 2 x 300 m	LAT – 23.70 m	24.6 nautical miles
Maasgeul	112°	600 m - 500 m	LAT – 23.20 m	6.1 nautical miles
Total length: 30.8 nautical miles				

The entrance of ships with a draught of over 20.0 m is always restricted to a tidal window, in case of swell of class 4 or more (HE10 > 0.55 m) tidal windows are also issued for ships with 17.4 m draught or more.

Deep Water Route navigation Euro-Maasgeul
Deep Draught Vessels are constrained by their draught to the width of the Euro-Maasgeul and cannot deviate from their track. According to the International Regulations for Preventing Collision at Sea the appropriate signals must be shown. In addition to the normal navigation lights for a power driven vessel prescribed in Rule 23, the Deep Draught Vessel will, by day, exhibit a black cylinder and by night, three all round red lights in a vertical line, as prescribed in Rule 28. As an extra safety measure, masters are advised to make sure the **Constrained by Draught** status of their ship is entered in the ship's AIS.



Tidal windows
There are tidal restrictions for Deep Draught Vessels using the Euro-Maasgeul. The Dutch Hydro Meteo Centre Northsea (HMCN) defines safe tidal windows during which these vessels may enter and navigate the channel. Tidal windows guarantee a safe Under Keel Clearance (UKC) in every part of the channel. These tidal windows are determined via a method based on probabilistic calculations. That means that for every actual channel passage, the safety of approach will be assessed in advance, using strict safety criteria that are designed and classified according to different levels of risk of touching the bottom. The Euro-Maasgeul has a sandy bottom.

Example of calculation

Deterministic safety allowance
A deterministic UKC method uses a fixed safety allowance related to draught, under all tidal-hydro-meteo conditions. For instance: 15% of 17.50 m = 2.62 m UKC. In the case of flat calm weather, this may be 'too much' safety. But if, during bad

Figure 40: Example of the pace making effect imposed on port approaches (Port of Rotterdam & Rijkswaterstaat 2013)

  - **Pace making effect at the node:** e.g. a *lock* turn *around*, *berth/terminal turn around* (at ports);

Thus time-variants can be introduced. When using a display mode which lends itself readily for strategic voyage planning and for tactical voyage or route re-planning at execution time, such as the LTM display mode, the time-variants of individual legs or nodes can be seamlessly incorporated into the overall picture needed for those purposes. These pace makers of legs and nodes could be made visible in the LTM display mode using different colours of the legs and nodes, thus highlighting the attribute of a leg to be subject to a pace making influence.[8] A 'pick report' would render additional details of the time behaviour of those legs and nodes. This level of abstraction would be sufficient for the above purposes, while the accurateness, precision and actuality of the information provided would be as high as required (timely updates received via telecommunications assumed).

In the NSR there are several places where *pace making effects imposed by the nature of the waterway* are operative:

- ***Tidal windows:*** Generally where the approach to a sea port is only by an estuary with a tidal influence limiting possible passage times for at least certain classes of vessels and/or their load conditions. Approaches to the ports of Rotterdam and Hamburg are prominent examples.
- ***Lock turnaround times:*** Clearly, lock operation introduces a pace making effect. Important lock assemblies are at the Kiel Canal and some port approaches, such as Amsterdam port approach via the Noordzeekanaal.

5.3.6 (NSR-)RTM in support of 'Intended Route / Suggested Route' operational schemes

The 'Intended Route Exchange (ship/ship, ship/shore)' functionality and the 'Suggested Route Service (shore-to-ship)' are two ACCSEAS candidate solutions and are thus described in different reports and descriptions from ACCSEAS. As their name implies, these applications build on route definitions, i.e. there is a direct correlation between the (NSR-) RTM and those applications and therefore a benefit of these applications from the (NSR-) RTM:

- Since the RTM's fundamental intent is to include all *possible* routes for shipping even those which are rarely used but still exist, the(NSR-)RTM, once defined completely and using the different classes of shipping lanes in conjunction with the above 'regulatory almanac' (compare section 5.3.2), *will contain (and show) all possible routes for the vessel under consideration.* Hence, the 'Intended Route Exchange' and the 'Suggested Route Service' can take into account the full potential of routes available for the vessel and for the sea area under consideration.
- As soon as there would be a harmonised (NSR-)RTM available, published in a *commonly* available (electronic) format, *the referencing to specific routes would be easier and less subject to ambiguity and therefore mistakes.* Hence, the *reliability* of both 'Intended Route Exchange' and the 'Suggested Route Service' *in terms of data content* would be improved.

5.4 Potential Applications of (NSR-)RTM for shore-based stakeholders, in particular VTS

A commonly harmonised (NSR-)RTM would also support shore-based stakeholders by the following potential applications of (NSR-)RTM. Key shore-based stakeholders are ports (berth management), waterways infrastructure operators (like at locks), VTS with its three

[8] Thereby the option to express relevant features of nodes and legs in the LTM display mode by colouring them differently than the 'ordinary' colour scheme as introduced above as required by the application, would eventually follow the usage of colour in the 'original' LTM for transporting a specific relevant meaning, namely identification of London tube lines (e.g. 'Piccadily line').

operational services Information Service (INS), Navigation Assistance Service (NAS), and Traffic Organisation Service (TOS), pilots and – last but not least – other allied services.

5.4.1 'Precision-ETA applications' supported by (NSR-)RTM

Since the pre-defined nodes as well as the leg distances between the pre-defined nodes would also be known by the recipient of any ship-report at a node (compare section 5.3.3 above) or during the voyage along legs (because AIS reports all times on its own) the ETA at a certain interesting node can be assessed with more precision *assuming that vessels* stick *to the MoS as defined by the (NSR-)RTM* (very likely they do in most cases; compare by analogy with car traffic, that we, being a stranger in some area, always prefer motorways in favour of all other routes, even if the motorway may be congested at times.).

Thus, the *precision and the reliability of ETA calculation for the recipient of the ship reports increased, i.e. 'precision-ETA applications' would be supported by (NSR-)RTM e.g.*

'Precision-ETA applications' would include any application depending on an *precision-ETA schedule* and/or using *precision-ETA appointments*, which are expected to operate better if and when precision-ETAs would be available.

5.4.2 Introduction of 'time slots' into Traffic Organisation Service (TOS) of VTS

Harmonised (NSR-)RTM would thus allow for a more precise and reliable strategic and/or tactical planning at potential 'meeting points,' *thus allowing strategic and/or tactical de-conflicting using the future projection of vessels* with greater accuracy and certainty.

The (NSR-)RTM would also serve as a *framework for any time-dynamic vessel traffic efficiency measure,* such as the (improved) provision of *TOS based on time-slots* within a VTS environment. This would take into account the impact of pace making entities (such as tidal windows and locks/canals) in the North Sea Region (compare section 5.3.5).

For de-conflicting by a VTS, the Route Suggestion Service as introduced above may also be employed (compare section 5.3.6 above).

5.4.3 Usage of 2D-way/time diagrams for larger waterway grid areas

Today, way-time-diagrams are used in VTS responsible for line-shaped waterways such as canals and rivers. Within the way/time-diagrams the current reported positions of vessels are projected into the foreseeable future and the different ETAs at interesting points along the line-shaped waterway are calculated in order to de-conflict vessel traffic along that single line-shaped waterway. The way/time-diagram is a *schematic* depiction of the line-shaped waterway, in principle following the applicable rules of the LTM display mode (compare section 3.3). Such a way-time-diagram for a line-shaped waterway could be called '*1D-way/time diagram'* as it applies to a *line*-shaped waterway.

With the (harmonized) (NSR-)RTM available for a larger waterways *grid area* such as the relevant approach areas, the territorial waters of a country at large, or even the whole NSR, it would now be possible to design and display a *'2D way/time-diagram' where the future projections of the positions of the vessels would be shown in a similar schematic way, but for a 'mesh' of several routes (instead of just a line-shaped waterway).*

In VTS, it is already presently customary to show the *current* vessel traffic of a larger sea area, most often of the whole of the VTS's area of responsibility, on a single large screen with a VTS-tailored *ENC* as the chart basis. *The '2D way/time-diagram' would extend that by existing custom by showing the vessel traffic with future projection and using the LTM display mode (instead of ENC display mode) in order to maintain overview.*

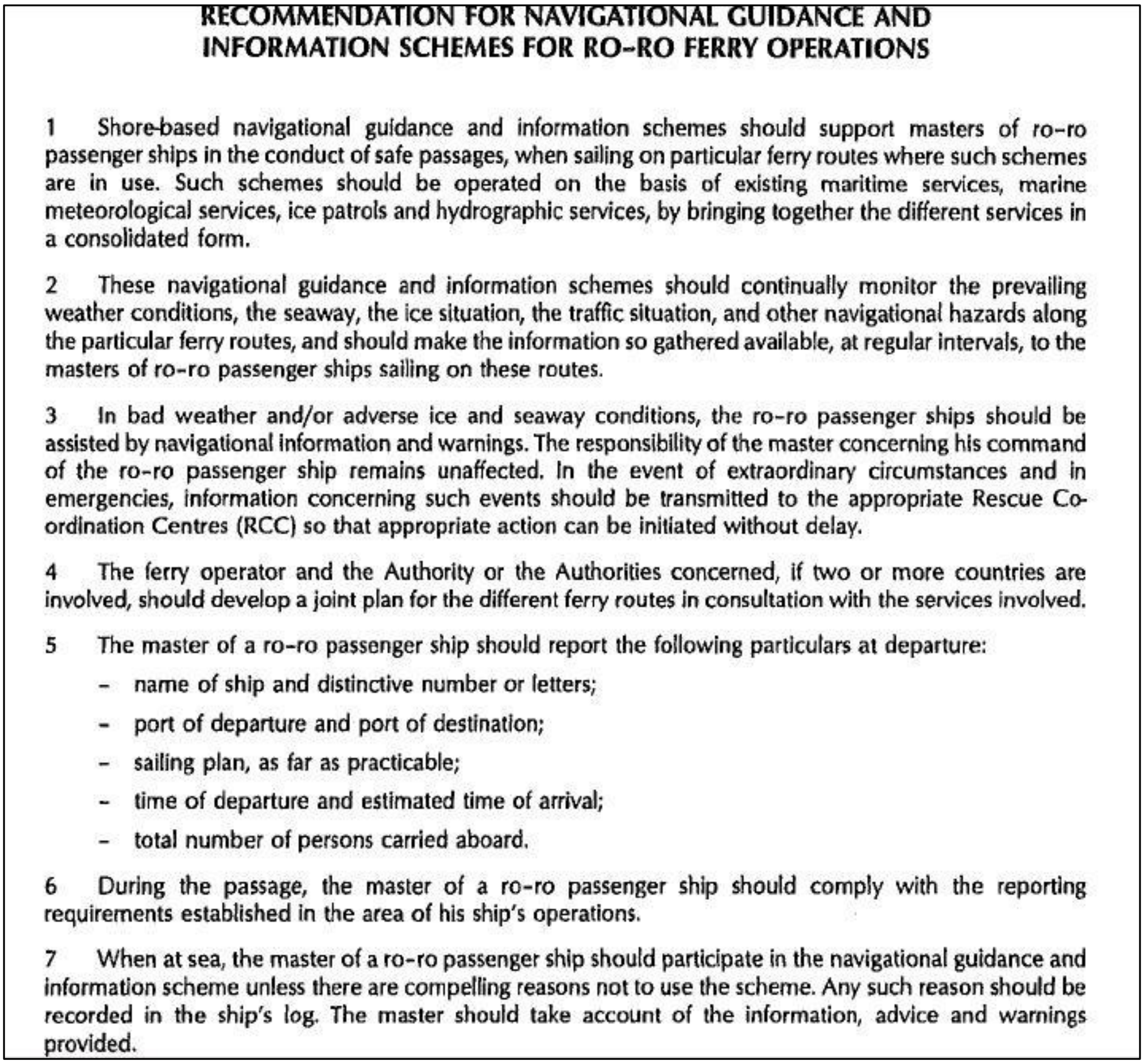
It should finally be noted, that these kind of '2D-way/time diagrams' using the applicable rule base of the LTM display mode are already customary in different modes of transportation for similar applications like Air Traffic Control or Railroad Traffic Control.

5.4.4 Graphical electronic confirmation of previously verbally distributed VTS information based on routes

Within its territorial waters, a VTS has the mandate to inform a vessel about available or suggested routes which are beneficial to the vessel's own voyage and/or to the vessel traffic at large. Also, a VTS may – as a last resort in a given situation – instruct a vessel to follow a specific route. Here, the (NSR-)RTM would be beneficial for the reasons explained at section 5.3.6 above). While this kind of information is generally conveyed verbally via VHF voice communication, the suggested or even instructed route information may be transmitted to the vessel electronically and be displayed on the vessel's displays in an appropriate display mode *after* the verbal communication from the VTS has taken place. The VTS may then reconnect to the vessel for verbal communication via e.g. VHF voice communication, pointing the attention of the mariner to the freshly received route data which would be available on the vessel's graphical display and thus re-confirm the previous verbal communication thus removing potential misunderstandings and/or ambiguities. Because this graphical information would have been received by electronic means effectively only after the initial verbal communication would have taken place, the mariner may be more inclined to accept the route suggestion more readily. Obviously, a commonly available (NSR-)RTM would assist in clarifying any verbal communication regarding routes of vessels.

5.4.5 Support for regional 'shore-based navigational guidance and information schemes'

VTS are responsible in and for territorial waters of a coastal state. Routes of vessels regularly go beyond territorial waters, even beyond the EEZs of coastal states. In the NSR, most vessel voyages go beyond territorial waters but always stay within some coastal state's EEZ. While there is thus a regulatory limitation, at present, to the application of VTS beyond territorial waters of coastal states, IMO has since long created the concept of 'Navigational Guidance and Information Schemes' to be applicable beyond territorial waters by virtue of the IMO Assembly Resolution A.795(19) (IMO 1995). This IMO Assembly Resolution is highly relevant for the topic at hand because it builds exclusively on (pre-)defined routes – of Ro-ro ferries (compare Figure 41 overleaf). Obviously, as with other of the above applications, the (NSR-)RTM may be provided a harmonized route grid and thus support A.795-related applications.



RECOMMENDATION FOR NAVIGATIONAL GUIDANCE AND INFORMATION SCHEMES FOR RO-RO FERRY OPERATIONS

1 Shore-based navigational guidance and information schemes should support masters of ro-ro passenger ships in the conduct of safe passages, when sailing on particular ferry routes where such schemes are in use. Such schemes should be operated on the basis of existing maritime services, marine meteorological services, ice patrols and hydrographic services, by bringing together the different services in a consolidated form.

2 These navigational guidance and information schemes should continually monitor the prevailing weather conditions, the seaway, the ice situation, the traffic situation, and other navigational hazards along the particular ferry routes, and should make the information so gathered available, at regular intervals, to the masters of ro-ro passenger ships sailing on these routes.

3 In bad weather and/or adverse ice and seaway conditions, the ro-ro passenger ships should be assisted by navigational information and warnings. The responsibility of the master concerning his command of the ro-ro passenger ship remains unaffected. In the event of extraordinary circumstances and in emergencies, information concerning such events should be transmitted to the appropriate Rescue Co-ordination Centres (RCC) so that appropriate action can be initiated without delay.

4 The ferry operator and the Authority or the Authorities concerned, if two or more countries are involved, should develop a joint plan for the different ferry routes in consultation with the services involved.

5 The master of a ro-ro passenger ship should report the following particulars at departure:

- name of ship and distinctive number or letters;
- port of departure and port of destination;
- sailing plan, as far as practicable;
- time of departure and estimated time of arrival;
- total number of persons carried aboard.

6 During the passage, the master of a ro-ro passenger ship should comply with the reporting requirements established in the area of his ship's operations.

7 When at sea, the master of a ro-ro passenger ship should participate in the navigational guidance and information scheme unless there are compelling reasons not to use the scheme. Any such reason should be recorded in the ship's log. The master should take account of the information, advice and warnings provided.

Figure 41: Relevant Annex of the IMO Assembly Resolution A.795(19)

The following relevant potential of the existing IMO Resolution A.795(19) should also be noted in this context:

- The above IMO Assembly Resolution transpires the 'e-Navigation spirit' in terms of the IMO definition of e-Navigation where 'harmonisation' features as the key word when e.g. stipulating to the *shore service providers:* 'Such schemes should be operated (…) by bringing together the different services in a consolidated form' (clause 1). Thus, the above resolution could potentially be further developed, in due course by IMO, into a more general 'e-Navigation Resolution' when generalizing the statements contained in the Resolution to 'ships' instead of 'Ro-ro passenger ships' alone.
- A *'shore-based navigational guidance and information scheme' for the NSR* – a 'North Sea Region Ferry Guidance and Information Scheme (NoFeGIS)' (working title –, based on the IMO Resolution, the route concept and the (NSR-)RTM may be further explored as a legacy of ACCSEAS

5.5 Notes on application of (NSR-)RTM for safeguarding the interest of shipping at Marine Spatial Planning

The different instances of the NSR-RTM for the present and for the future situation of the NSR *may assist in Marine Spatial Planning while interests of shipping may be defended* because the NSR-RTM instances would provide all necessary information regarding the existing – and the projected future – shipping lanes. This was a topic at workshops at several ACCSEAS NSR Annual User Fora (compare **Appendices D** and **F**). The resulting feedback loop is shown in Figure 42.

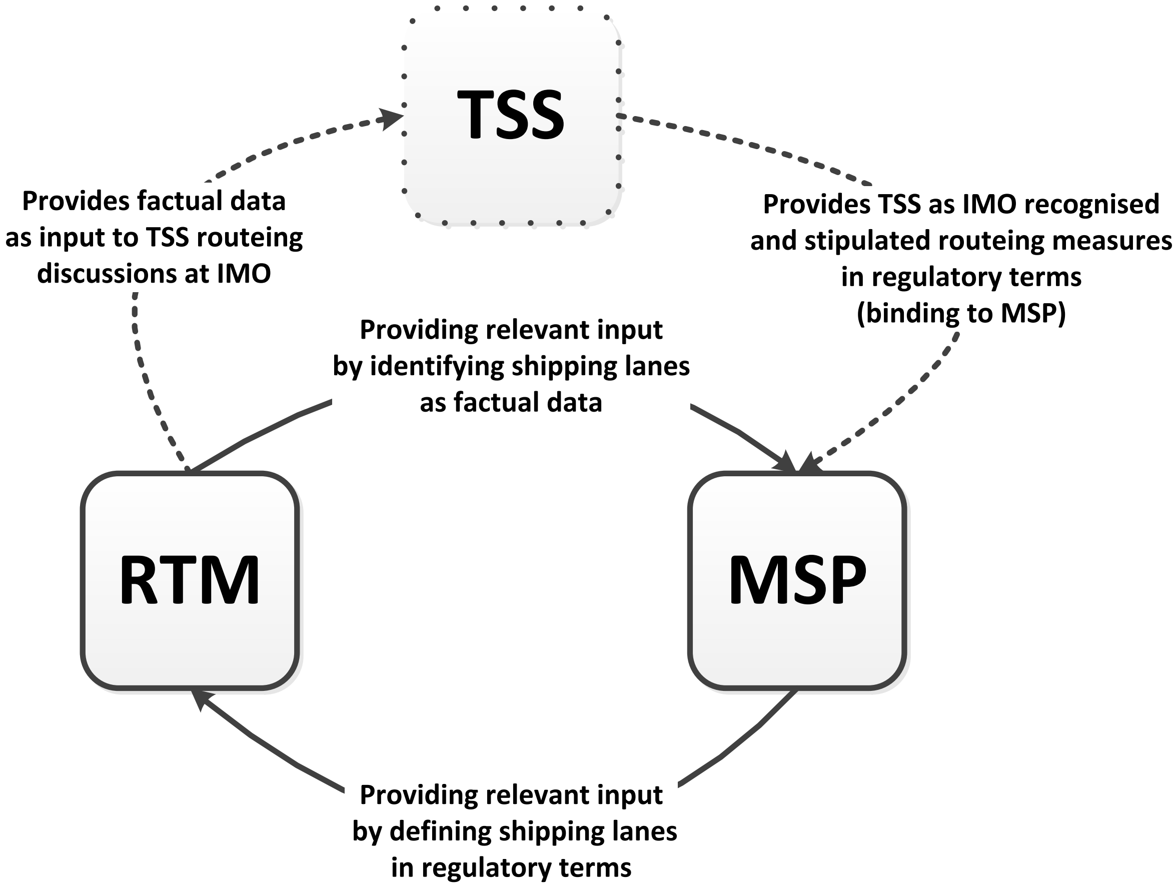


Figure 42: Feedback loop between RTM and MSP (including TSS as side-track)

5.6 Notes on application of (NSR-)RTM for TSS-grid planning

Precise proposals for an *extended network of (future) IMO mandated TSS* in the North Sea Region, following the usual rules of procedure for introducing proposals for new and amended routeing measures at IMO, may be derived from a NSR-RTM. These proposals would have a specific momentum since the very fact of being derived from a NSR wide recognized NSR-RTM would be the *ultimate proof of a harmonization process* between North Sea Region coastal states already taken place.

There would also be a significant momentum for safety of shipping itself as well as for MSP (compare Figure 42).

5.7 Notes on application of (NSR-)RTM for Risk Analysis

In the 'ACCSEAS Baseline & Priorities Report' (ACCSEAS 2015a) there has been employed the IWRAP risk analysis tool in order to determine 'hot spots,' i.e. places in the NSR where additional measures for risk mitigation are specifically justified due to traffic density and traffic constellations. For the IWRAP analysis, there were used a NSR-RTM, while the results of the IWRAP analysis like 'shipping density' and 'risk' were indicated by colour-coding the legs of the NSR-RTM in accordance with a scale ('the redder the more risk'). The thus derived 'risk map' of the NSR was displayed on a true topographical map as background, i.e. using the ENC display mode.

However much of the RTM philosophy has been used already by constructing the NSR-RTM for the NSR-IWRAP analysis implicitly, the NSR-IWRAP analysis in the 'ACCSEAS Baseline & Priorities Report' has used a proprietary NSR-RTM, thus rendering a NSR-IWRAP analysis which can only be re-iterated when having access to the NSR-RTM used for that IWRAP analysis.[9] Here, the harmonised or 'open' NSR-RTM envisaged above could render additional benefits *when IWRAP (or any other risk analysis method) is applied using the harmonised or 'open' NSR-RTM. This would render harmonised or 'open' risk analysis results which could easily be reproduced or subjected to risk analyses considering alternative scenarios in the process.*

For this application '(NSR-)RTM for Risk Analysis' the following attribute definitions for legs will be required:

- *Attribute vessel traffic density* [vessels of specific kind per square-km and time period] – derived from vessel traffic historical track data (compare discussion in section 4.2.1).
- *Attribute Risk at leg:* the risk for shipping when using this leg, if attributable to a leg
- Note: *Risk of crossing traffic* is attributed to the *Node.Junction.*
- Note: There may be further attributes defined in due course, like kind of risks; class of risks or continuous risk figure; possibly 'metering/percentage' feature applies.

Since the (NSR-)RTM is traffic-sensitive from the outset, it may be an appropriate and powerful tool to mitigate the hazards to traffic flow efficiency and safety at bottlenecks and therefore enables accessibility.

[9] It is not the point here to discuss the access to that specific NSR-RTM used for the IWRAP analysis at all. The point here is to discuss the benefits of applying the risk analysis to a harmonised and 'open' NSR-RTM.

6 Introducing the ACCSEAS candidate solution (NSR-)RTM to the international and European domains

The previous chapters introduced the (NSR-)RTM in various regards and explained its different potential applications. This chapter now builds on this by indicating how the ACCSEAS candidate solution (NSR-)RTM may be introduced to, and thereby support, relevant international and European regulatory and standardisation domains and initiatives.

6.1 Interaction with international domain

For the international domain, the *generic* RTM is the most relevant contribution while the NSR-RTM as an instance specific to the NSR may serve as a an example to illustrate the practical application of the generic RTM. Several of the RTM applications introduced in the previous chapter are relevant for the international domain. In the following, their relevance is explained, and relevant international follow-up work is indicated in general terms. More specific items for follow-up work are captured in **Annex C**.

6.1.1 The RTM as a contribution to IMO's e-Navigation strategy implementation

The generic RTM description developed in this Description can, in principle, be applied to any specific sea area globally. Thus, several or even many instances of the RTM may be created, each one specific to the region under consideration. All of those instances are informed by the same generic RTM and are thus *harmonized from the outset.* I. e. this satisfies the aspirations of the IMO e-Navigation strategy in this regard.[10]

While the (NSR-)RTM can be defined and constructed independently of the IMO e-Navigation strategy, the full potential of the (NSR-)RTM can only be released when correlating the (NSR-)RTM with some specific concepts under development already or to be developed as part of the IMO e-Navigation strategy implementation, however. There are three major domains or working areas of the e-Navigation concept to which this assessment would apply, each of which also being a 'dedicated pillar' of the IALA defined '7-pillar model', namely

- Implementing the (NSR-)RTM into the envisaged ***Common Maritime Data Structure (CMDS),***
- Usage of the (NSR-)RTM by the concept of the envisaged ***Maritime Service Portfolios (MSPs),*** and
- Usage of improved ***Communications*** as developed for e-Navigation by applications the (NSR-)RTM.

These aspects will be explained in some more detail in the following sections.

6.1.1.1 Usage of the same international definitions of the envisaged CMDS

IMO has envisaged a future *Common Maritime Data Structure (CMDS)* as part of their overarching architecture for e-Navigation (IMO 2014, Task 14 and several paragraphs).[11]

It is further envisaged that the CMDS should be built on the IHO S-100 standard framework (IHO 2010), thus resulting in appropriate entry of the generic RTM definition into the IHO GI Registry eventually. Namely, it is anticipated that there will be appropriate entries of the generic RTM into the *Feature Concept Dictionary Register (FCD)* of the IHO GI Registry, thus

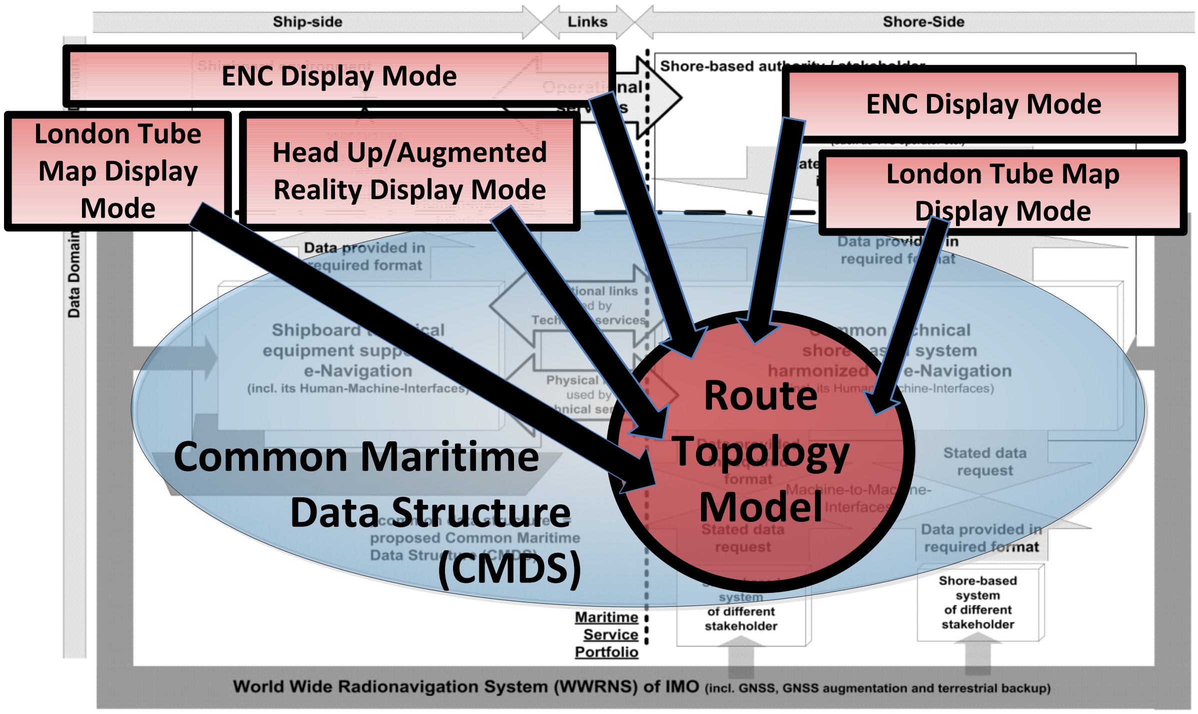
[10] For a more detailed description of the IMO e-Navigation strategy compare descriptions in 'ACCSEAS Baseline and Priorities Report' (ACCSEAS 2015a) and 'ACCSEAS e-Navigation Architecture Report' (ACCSEAS 2015c).

[11] ‚CMDS is at the heart of e-navigation. It has been already agreed to use the IHO S-100 data model' (IMO 2014, S4.1.1).

capturing the generic node and leg definitions and their generic attributes as indicated above. Within the scope of this Description, this is assumed as a given.

By the same token it is also assumed, that the above portrayal options may eventually contribute to the international *Portrayal Register* of the IHO GI Registry (based on S-100).

Assuming that this will happen during the implementation process of IMO's e-Navigation strategy, as stipulated specifically by the IMO SIP Task 14(a) (IMO 2014), this would result in a complete international harmonization of both the generic RTM definition and of its various display modes as recognized above. Figure 43 illustrates this envisaged situation.



Note: There are operational and technical interactions between different shipboard environments. These are not shown for simplicity's sake in this figure.

Figure 43: Illustration of the envisaged international harmonisation of the generic RTM and its display modes due to common reference to the CMDS of IMO's e-Navigation strategy

Translating this to the *instance domain,* i.e. to the application of the generic RTM (and its display modes) to a specific sea area, this would mean, that the *supporting data for all the above RTM display modes would be the same for the same sea area*.

6.1.1.2 The generic RTM as a 'product' in CMDS/IHO S-100 philosophy

Above it was described that the generic RTM interacts intensively with the IMO envisaged CMDS, and that the CMDS should be built by using IHO's S-100 standard. Central to the S-100 framework is the notion of 'products.' An *'RTM product'* would be *an internationally agreed comprehensive description of **all** individual contributions needed to actually allow a competent service provider to produce a RTM* and thus make it available for other international bodies, e.g. system integrators, to build internationally harmonized applications on that 'RTM product.'

A 'product' description 'binds together,' by reference, all required contributions from the various IHO GI Registers and other sources, namely:

- Internationally agreed RTM data object definitions from the *Feature Concept Dictionary Register* (IHO GI Registry);
- Internationally agreed portrayals for RTM display modes to users from the *Portrayal Register* (IHO GI Registry);
- Internationally agreed meta-data descriptions regarding e.g. source and quality parameters for individual data objects from the *Meta-Data Register (IHO GI Registry)*;
- Internationally agreed *application level data encoding schemes for RTM data exchange* via M2M interfaces (see below for the telecommunications aspect);
- Other relevant aspects, as required and internationally agreed.

Such an internationally agreed 'RTM product description' would eventually be submitted to the *Product Register* of the IHO GI Registry to allow broad international access. An 'RTM product description' could be created, tested and thereby matured – in principle – by any interested party globally, e.g. by a joint undertaking of interested partners from the NSR as part of the legacy work of ACCSEAS; this 'RTM product description' would need to be submitted to a relevant, competent international body to achieve international harmonization.

At present, IALA appears to be an appropriate body to that end because IALA is well positioned in the vessel traffic domain to which the RTM obviously is most relevant and is also a recognized contributing organization both to IHO GI Registry and to IMO's e-Navigation strategy implementation. Alternatively, the required international harmonization may be achieved at IHO appropriate bodies directly.

6.1.1.3 Correlating Maritime Service Portfolios (MSPs) with (NSR-)RTM

By employing the concept of shipping lanes and the NSR-RTM, the IMO defined concept of MSPs could be applied with precision to the NSR's shipping lanes (compare introduction in section 5.3.4). This would prompt the following international and/or European activities:

- The IMO recognized concept of MSPs could be further developed and correlated with shipping lanes. This would render a support of the MSPs concept by RTM in the generic domain. Such a concept may be introduced at IALA, IHO and finally IMO as a contribution to IMO's envisaged 'Resolution on the MSPs' (compare IMO SIP).
- Regional-European MSP(s), i.e. in particular North Sea Region Maritime Service Portfolio(s) (NSR-MSPs), could be defined, taking into account the generic, international mandates of IMO, IALA, IHO and other relevant international organisations.
- Shore-based service provision from shore-based service providers could be tied to RTM recognized shipping lanes and be thus provided much more focused together with more precisely defined service level definitions. This may be a topic for the ACCSEAS legacy for the NSR and may be taken up by the organizational framework suggested by the ACCSEAS Sustainability Plan.
- Progressive new maritime services, being recognized within the above NSR-MSPs, could be developed and deployed to one specific, some or several shipping lanes. Examples for those services are e.g. specific vessel traffic information services or voyage planning related services.

6.1.1.4 Communicating (NSR-)RTM data – the RTM Data Sentences and encoding options in the context of emerging e-Navigation telecommunications solutions

There will be a need to exchange RTM data at run-time by whatever appropriate media, most likely by electronic means. This requires *RTM Data Sentences*

- to be composed

- for exchange on appropriate Machine-to-Machine (M2M) interfaces ashore or via appropriate (wireless) physical media between shore and ships
- using the appropriate data exchange protocols.

Firstly, this correlates the RTM both with the above working domain ('pillar') of the CMDS for the definition of the data objects to be exchanged by the necessary *RTM Data Sentences:* By the definitions of *RTM data sentences* the semantics of the RTM data objects are introduced, using the 'vocabulary' of the FCD, as introduced in the previous section. The semantics is dependent on the application under consideration (refer to application chapter below). Since there may be different applications, there may be different equally valid *RTM Data Sentences* defined eventually.

Secondly, also the *encoding details for the RTM data sentences* need to be specified in accordance with the requirements of the M2M interface and/or physical communications medium used for (electronic) data exchange.

Should there be made usage of the 'Maritime Cloud,' another key concept for implementing improved telecommunications within the framework of the IMO e-Navigation strategy implementation (IMO 2014, Task 15 and paragraphs 31 and 39)), then there might be margin to use a reduced number of different encoding schemes for RTM data sentences, i.e. using an abstract but flexible encoding option such as a XML derivative. Eventually, there might be even only one such encoding scheme when using the 'Maritime Cloud.' For details on the technical architecture of the 'Maritime Cloud' compare (ACCSEAS 2015c).

6.1.2 The RTM as a contribution to the SMTS

The RTM may be indirectly and directly beneficial for the SMTS:

- Indirectly by the support to the above applications which are part of 'maritime traffic support systems' which in turn support the SMTS as indicated in the 'ACCSEAS Baseline & Priorities Report' (ACCSEAS 2015a);
- Directly by allowing 'sustainability tags' or 'green tags' (working titles) to be attributed to legs and nodes of the (NSR-)RTM, thus directly contributing sustainability metrics to the routes vessels take. This in turn is in support of applications within the SMTS which use those metrics.

6.2 Potential proposals from the NSR-RTM to the European domain

The interaction with the European domain has been identified in the previous chapters. The ACCSEAS candidate solution (NSR-)RTM represents a transport network relevant for several European initiatives and working areas:

- Looking back at the motivation for the (NSR-)RTM in the first chapter of this Description, the ACCSEAS candidate solution NSR-RTM is in a position *to close the 'maritime gap in the NSR' in the pan-European Trans-European Networks (Transport) (TEN-T), most prominently on the MoS level.*
- Through *INSPIRE* the first pan-European initiative was made for a common model for maritime transport networks. The findings of the generic RTM, as validated by its application to the NSR, may *contribute to further the Transport Networks module of INSPIRE.*
- The NSR-RTM, as an example instance for the identification and modelling of vessel traffic relations, in the seas surrounding Europe may assist at MSP issues in the NSR but also beyond the NSR in other sea basins across Europe and thus *may potentially contribute to the successful implementation of the European Integrated Maritime Policy* (Directive 2008/56/EC). Also, the European Integrated Maritime Policy adds additional requirements

which reinforce the need for common maritime transport network modelling in Europe, in particular considering the MoS.

- In addition, the present generic and NSR instance RTMs may *assist further developing the EU Commission's e-Maritime initiative.*
- Since the RTM is a contribution to a more intelligent maritime transportation system – e-Navigation and SMTS as international initiatives refer -, it may *assist in the creation of the maritime part of an European Intelligent Transport System (ITS).*
- Last but not least, the *further development of the regional-European NSR sea basin strategy may be assisted* by the NSR instance of the RTM.

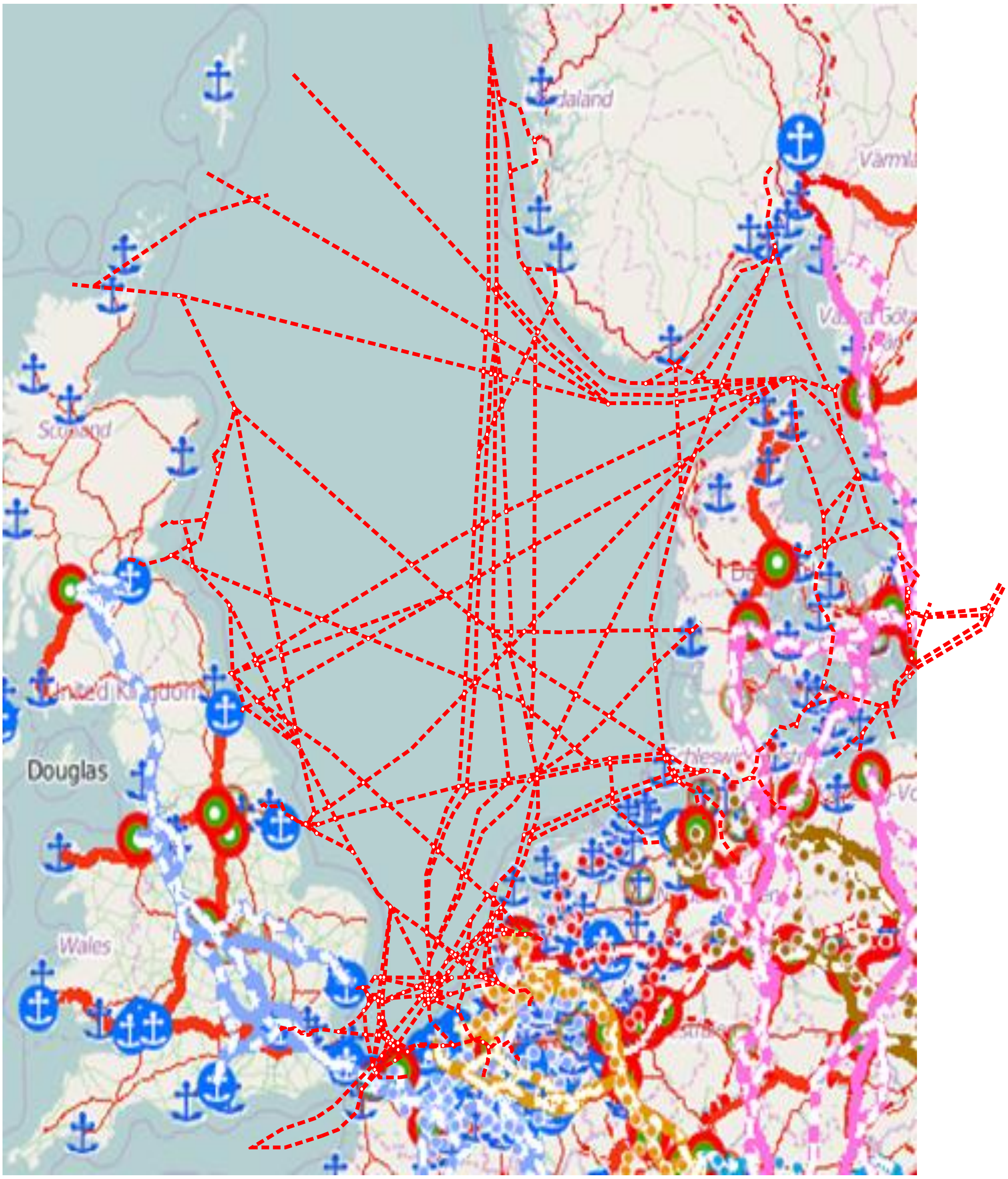
The following sections elaborate the above aspects and provide relevant references for further consideration, as appropriate. Since the scope and duration of ACCSEAS is limited, a substantial part of the work needed to arrive at concrete proposal implied by the above aspects needs to be done as part of the legacy work (compare Annex C for a capture of relevant items).

6.2.1 Identifying the Motorways of the Sea (MoS) in the NSR – closing the gap

The ACCSEAS candidate solution NSR-RTM is in a position to close the 'maritime gap' in the NSR in the pan-European Trans-European Networks (Transport) (TEN-T), most prominently on the MoS level. The instance of RTM for the NSR, i.e. the NSR-RTM, brings in the missing link for a regional intermodal transport network as part of an European transport network (see Figure 44).

The connections between road/railway and waterways are established by port nodes (*Node.Port*) of the RTM, eventually modelling ports in more detail following the atomic principle presented in section 2.3.1 above. The connections between the waterways in the different EEZs of the NSR, in particular at the EEZ borders of the participating countries, need to be seamlessly established by cross-border nodes (*Node.Cross-Border*) resulting in the complete intermodal transport network.

It should also be noted that the EU Commission's memo directly references the 'e-Maritime' initiative (European Commission. 2013. Action 4); see below.



(Figure created by graphical superimposition of ACCSEAS NSR-RTM, MoS level, with land transport network from (INEA 2015); due to different projections/scales of two contributing maps only best fit shown).

Figure 44: Closing the gap – the MoS level of the NSR-RTM interconnected to the land and railroad transportation modes via the port nodes

The applications presented in chapter 5 justify the effort needed to bring up common MoS for the North Sea, together with the European Commission's action plan (European Commission 2013), especially Action 4 to support administrative simplification in ports, especially referring to the e-Freight initiative which aims to facilitate the exchange of information along multimodal logistics chains and which will contribute to improve port efficiency as ports are important multimodal platforms (EC 2013).

6.2.2 The Transport Networks (TN) Module of the INSPIRE directive

Common European geospatial information is defined in the INSPIRE framework with an implementation of 34 spatial data themes, whereas Transport Network (TN) is in the group given the highest priority (Annex 1[12]). The RTMs from ACCSEAS have been modelled to conform with the data specifications given for Water Transport Network, consisting of legs and nodes.

Common interfaces for web services have been specified for discovering, viewing, downloading and transforming INSPIRE data sets, to assure interoperability and accessibility. Eventually establishing a continuously updated network of MoS, RoS (and ToS) for the NSR, this should of course use the same MoS and RoS (and ToS) submitted from each country of the NSR to the common European Geoportal for INSPIRE-data[13].

As requirements from IHO S-100 and INSPIRE standards both are based on existing and well established standards for spatial data, e.g. those of the Open Geospatial Consortium (OGC) and ISO/TC211, the requirement to follow the guidelines is obvious to maximise the interoperability of INSPIRE spatial data sets and services as well as guarantee interoperability with other sectors.

6.2.3 The Marine Spatial Planning in Europe

The Integrated Maritime Policy for EU identifies maritime spatial planning as a cross-cutting policy tool enabling public authorities and stakeholders to apply a coordinated, integrated and trans-boundary approach in maritime spatial planning (Directive 2008/56/EC).[14] The application of an ecosystem-based approach will contribute to promoting the sustainable development and growth of the maritime and coastal economies and the sustainable use of marine and coastal resources. The newly adapted directive on MSP (2014/89/EU)[15] establishes a framework. The application of the (NSR-)RTM to the MSP in general (compare section 5.5 above) would apply to the MSP in European waters as well:

- Quality assured information on sea transport for the NSR and other European oceans is of major importance to have a sustainable planning of the maritime space, also safeguarding the MoS of the NSR.
- The NSR-RTM introduced here as a prototype of the maritime transport network can as information bearing element bring quality assured information into the national and regional processes of ocean management and maritime governance.
- Data from maritime risk assessments, on environmental foot prints and on transport work in the different routes can, by utilizing a common transport network, better support decision making in integrated ocean and coastal management.

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[12] INSPIRE Roadmap (http://inspire.ec.europa.eu/)

[13] http://inspire-geoportal.ec.europa.eu/

[14] For the discussion on ‚Marine Spatial Planning‘ vs. ‘Maritime Spatial Planning’ compare footnote 3 above. In brief: As long as it is not a direct quotation from an external source, ‘Marine Spatial Planning’ will be used in this document.

6.2.4 (NSR-)RTM – a potential contribution to a maritime application of the ITS directive and to the EU Commission's 'e-Maritime' initiative

A NSR-RTM as suggested from ACCSEAS will set grounds for development of a maritime Intelligent Transport Network, an infrastructure for further development of traffic services parallel to services present in land-based navigation equipment. This gives the basic framework for both public and private services to utilize static transport data and dynamic (+predictive) transport data for the MoS. Useful applications both for strategic route planning and more tactical route planning could in the near future take benefit from this development (see chapter 5.1).

Figure 45 shows an example of how the NSR-RTM, once established, could assist in moving cargo transport from road (black line) to sea (Short Sea Shipping; red line): The example shows cargo transport from the Netherlands (A) to Norway (B) by (mostly) road transport (black route) to (mostly) sea transport (red route). The NSR-RTM would provide a harmonised and predictable database for any relevant intermodal logistics planning.

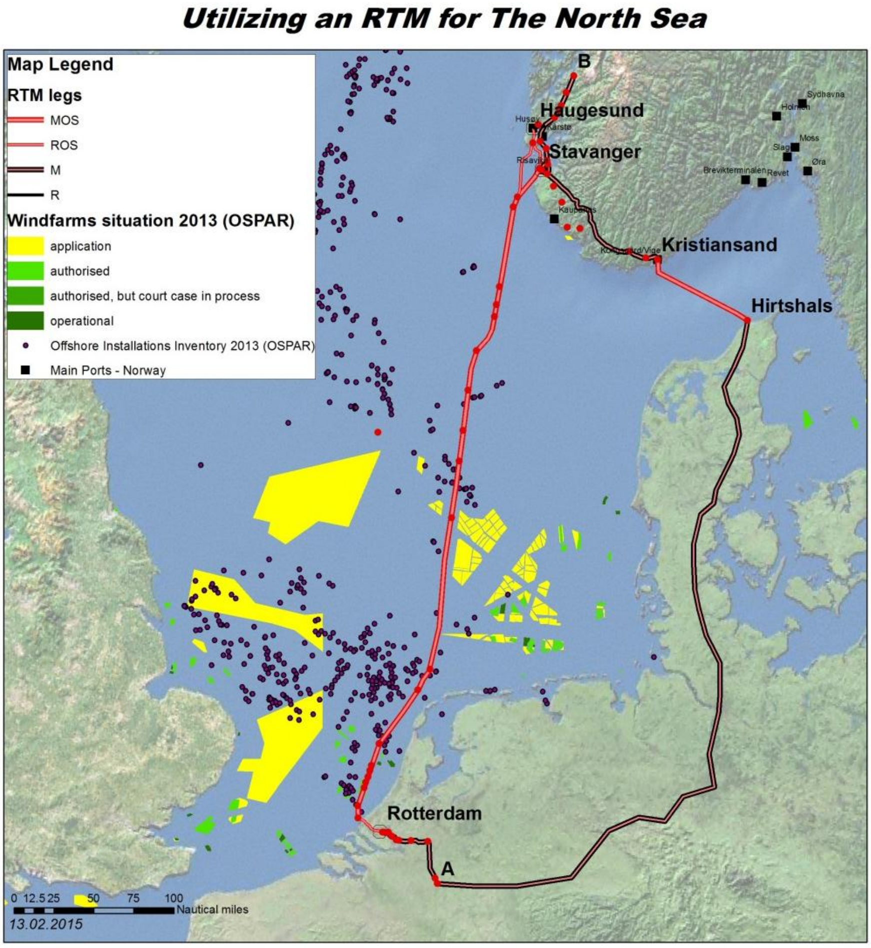

Figure 45: Example of potentially moving cargo transport from land to sea based on a NSR-RTM (Klingsheim 2015)

The NSR-RTM as an important element for intermodal information systems would thus be well positioned to be a natural part of the European e-Maritime Initiative for an integrated EU system providing 'e-services' at the different levels of the transport chain, allowing the users to track and trace the cargo not only during the waterborne part of the journey, but across all transport modes in a true spirit of co-modality, also promoting safe, secure and efficient intra-European and international shipping on clean oceans and seas, and the adaptation of the entire seaborne transport system to the challenges of the 21st century (Integrated Maritime Transport Strategy, 2009-2018).

6.2.5 The regional-European sea basin strategy for the NSR

A regional-European sea basin strategy for the NSR would comprise statements to any and all of the above application domains which need not be re-iterated here. It was made clear, that in particular the MoS and RoS shipping lane classes, as identified by the NSR-RTM, would be highly relevant.

In addition and last but not least, when considering all aspects for a regional-European sea basin strategy, also the ToS shipping lane class as identified by NSR-RTM would have a significant role, namely regarding tourism in the region: The ToS grid (potentially using parts of the RoS and even MoS grid, too) could be used to create touristically meaningful and attractive pleasure boat round trips in the NSR (or to base existing ones into the common reference scheme of the NSR-RTM).

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8 Abbreviations

AIS Automatic Identification System

AMSA Australian Maritime Safety Authority

AR Augmented Reality

ASM Application Specific Message

AtoN Aids-to-Navigation

CMDS Common Maritime Data Structure

IEC International Electrotechnical Commission

ECDIS Electronic Chart Display and Information System

EEZ Exclusive Economic Zone

ENC Electronic Navigational Chart

ETA Estimated Time of Arrival

EU European Union

FCD Feature Concept Dictionary (of the IHO GI Registry)

GI Geographic Information

GIS Geographic Information System

HMI Human Machine Interface

HUD Head-Up Display

IALA International Association of Aids-to-Navigation and Lighthouse Authorities

ID Identifier (generic)

IEC International Electrotechnical Commission

IEHG Inland ECDIS Harmonization Group

IHO International Hydrographic Office

IMO International Maritime Organisation

INEA Innovation and Networks Executive Agency

INS Information Service (within VTS)

INSPIRE Infrastructure for Spatial Information in the European Community

IWRAP IALA Waterways Risk Assessment Program

ITS Intelligent Transport System

IVEF Inter-VTS Exchange Format

LTM London Tube Map

M2M Machine-to-Machine Interface

MBS Marine Buoyage System

MoS Motorways of the Sea

MSP Marine Spatial Planning

MSPs Maritime Service Portfolios

NAS Navigational Assistance Service (within VTS)

NSR North Sea Region

NSR-RTM RTM for the NSR

OOP Object-Oriented Paradigm

PA Precautionary Area (of a TSS)

PIANC Permanent International Association of Navigation Congresses

PSSA Particularly Sensitive Sea Area

Ro-Ro Roll-on/Roll-off

RoS Roads of the Sea

RTM Route Topology Model or Route Topology Modelling

SMTS Sustainable Maritime Transportation System

TEN-T Trans-European Networks - Transport

TN Transport Networks

ToS Trails of the Sea

TOS Traffic Organisation Service (within VTS)

TSS Traffic Separation Scheme

UML Unified Modelling Language

UK United Kingdom

UKC Under Keel Clearance

UN United Nations

UNCLOS United Nations' United Nations Convention on the Law of the Sea

UTM Universal Transverse Mercator

WGS-84 World Geodetic System 1984

VTMIS Vessel Traffic Management and Information System

VTS Vessel Traffic Services

XML Extended Markup Language

Annex A NSR-RTM as represented in ENC display mode

This Annex provides the NSR-RTM representation in ENC display mode based on the way-points and legs contained in Annex A.

Figure 46 shows the complete Motorways of the Seas level of the NSR-RTM 2020+ in ENC display mode.

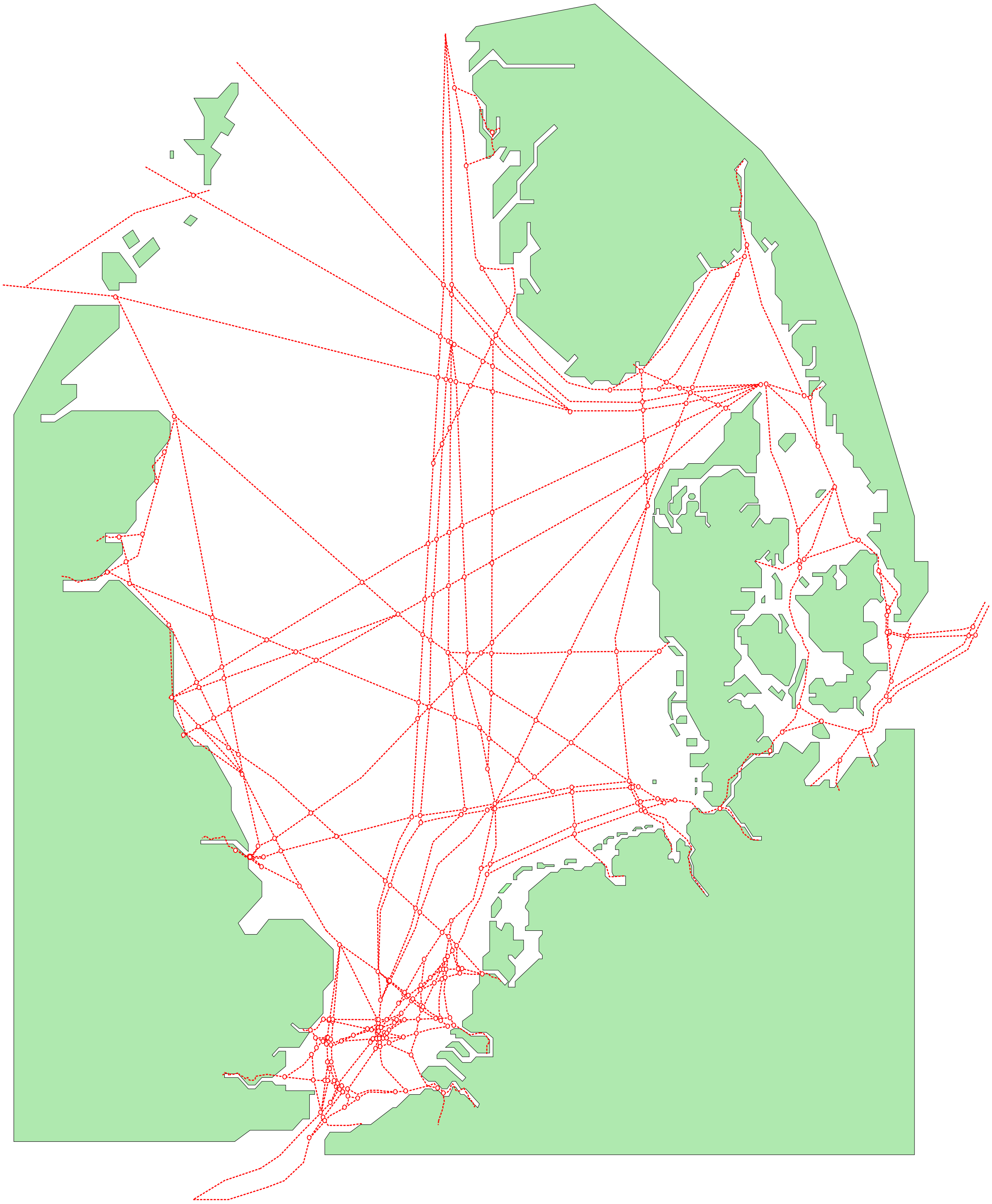

Figure 46: NSR-RTM 2020+ – Motorways of the Sea shipping lanes – complete NSR; in ENC display mode with generalised coastlines

The following zoom-in depictions are provided to reveal some details of the above Figure 46.

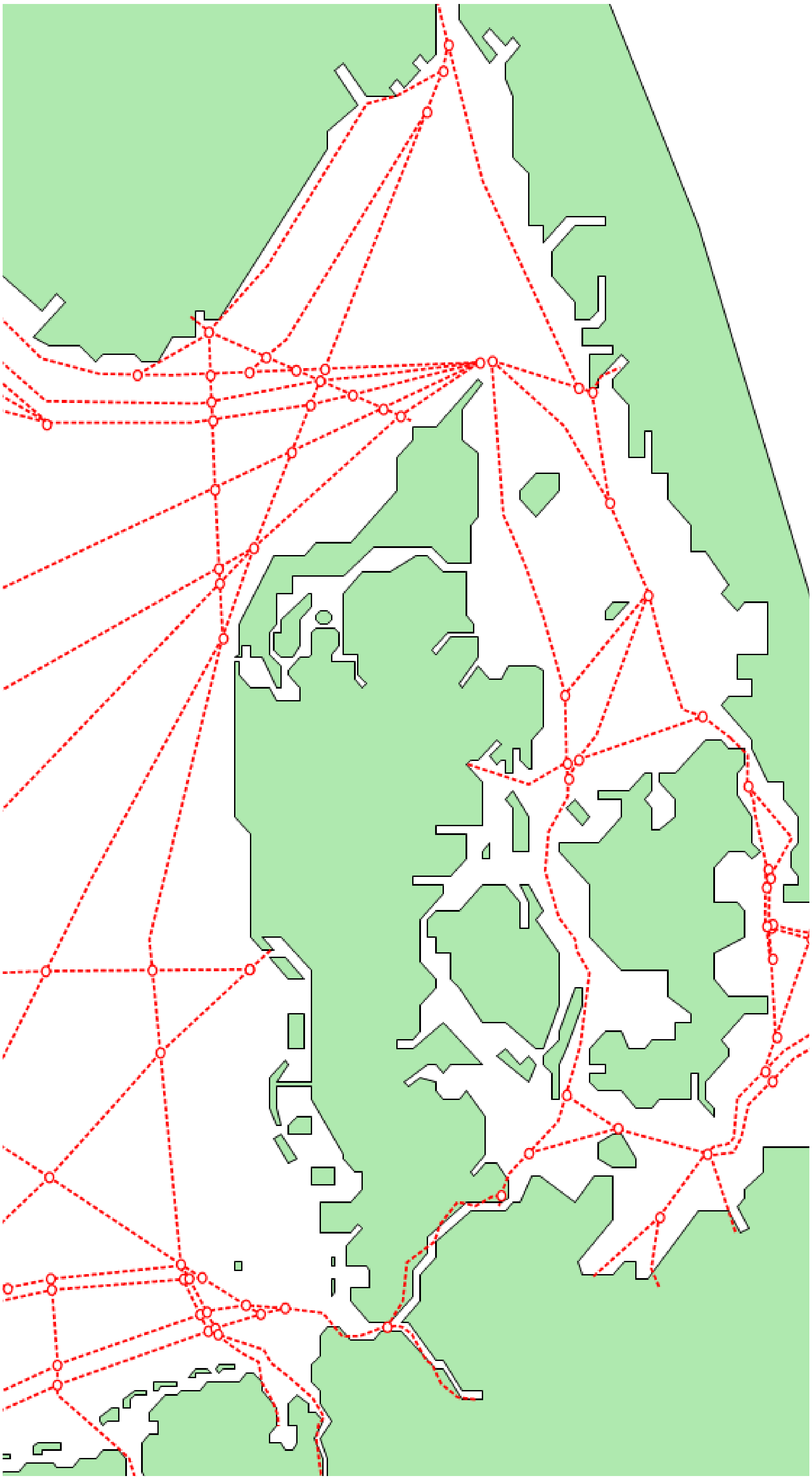

Figure 47: NSR-RTM 2020+ – Motorways of the Sea shipping lanes around Jutland peninsula; in ENC display mode with generalised coastlines

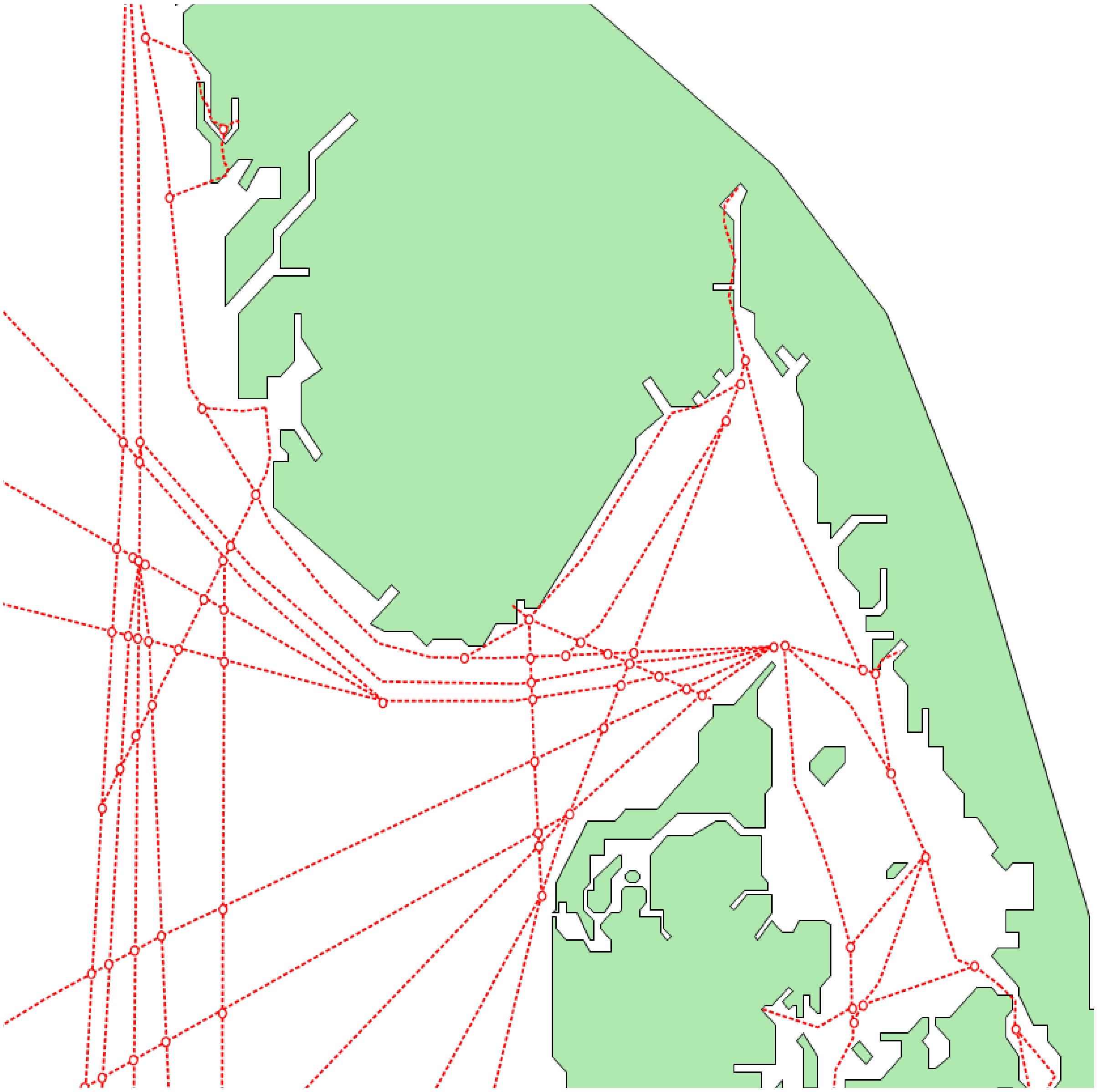

Figure 48: NSR-RTM 2020+ – Motorways of the Sea shipping lanes at Skagerak; in ENC display mode with generalised coastlines

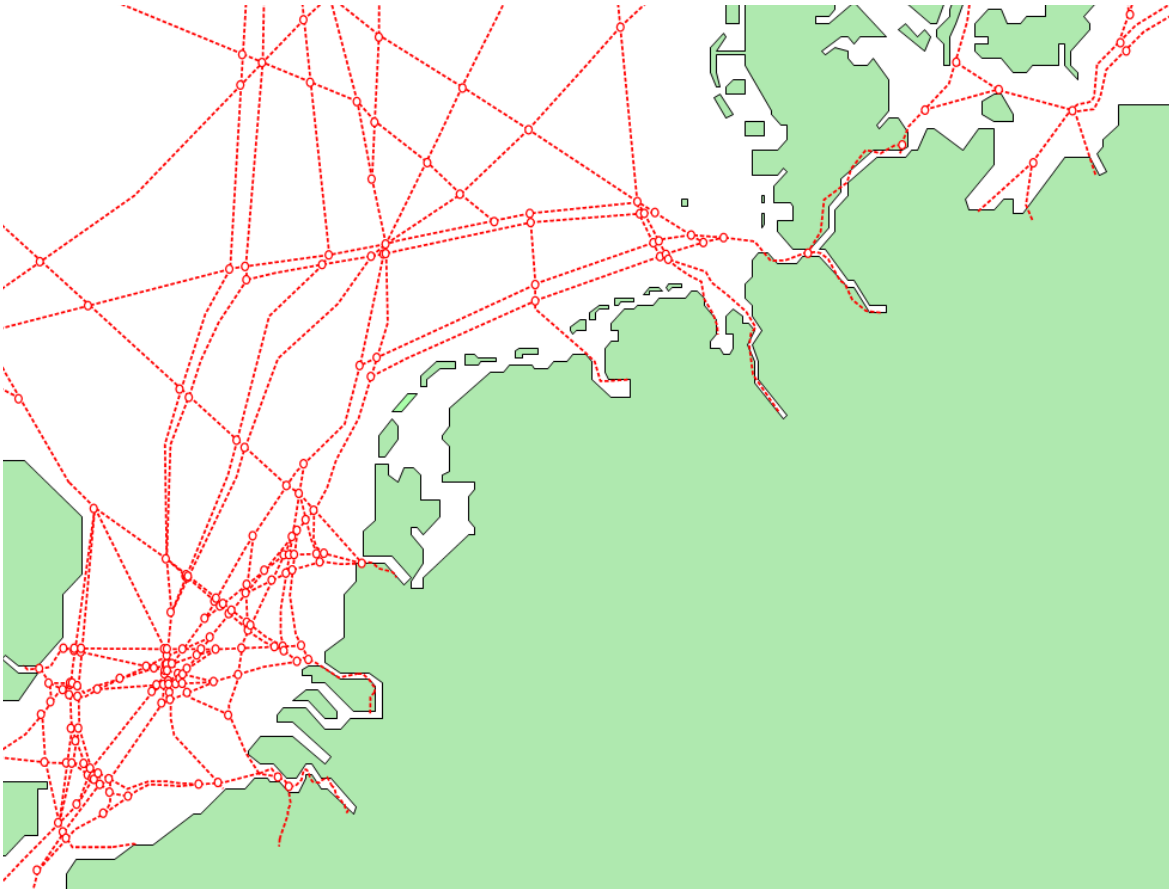

Figure 49: NSR-RTM 2020+ – Motorways of the Sea shipping lanes off the coasts of The Netherlands and Germany; in ENC display mode with generalised coastlines

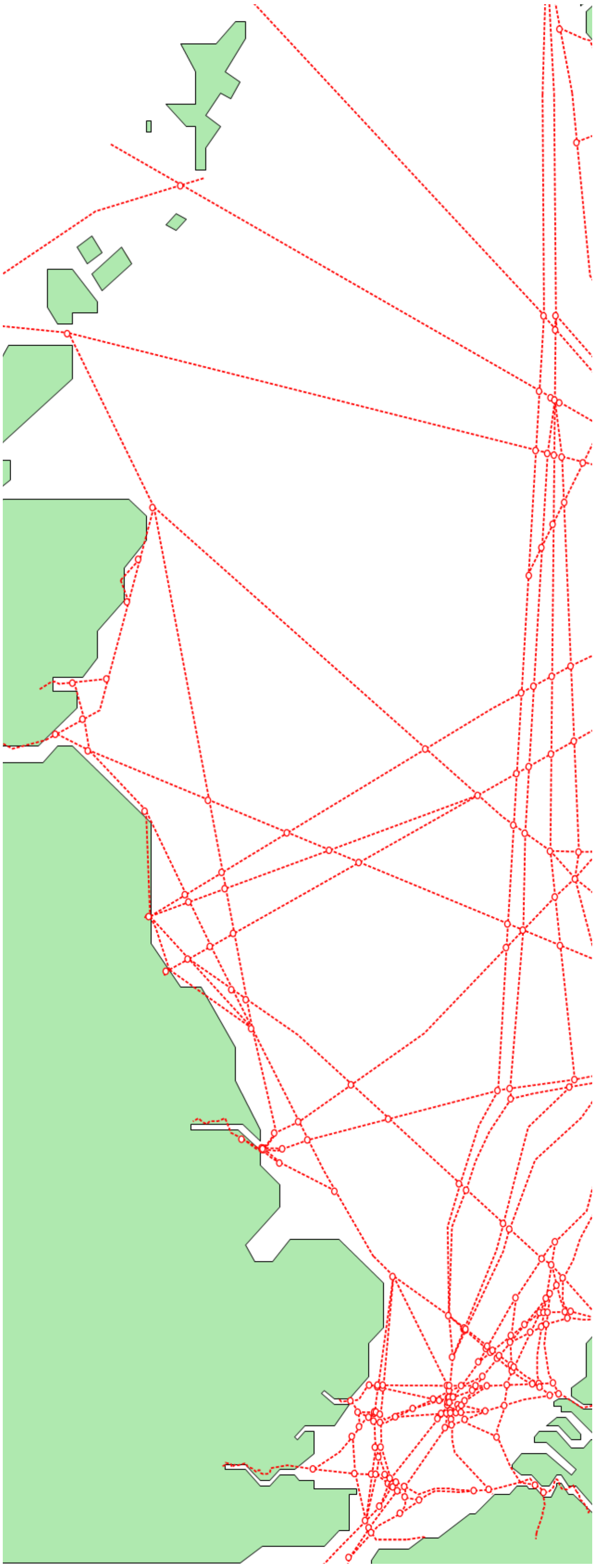

Figure 50: NSR-RTM 2020+ – Motorways of the Sea shipping lanes off the East coast of the UK; in ENC display mode with generalised coastlines

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Annex B NSR-RTM as represented in London Tube Map display mode

This Annex provides some NSR-RTM representations in London tube map (LTM) portrayal mode based on the waypoints and legs contained in Annex A.

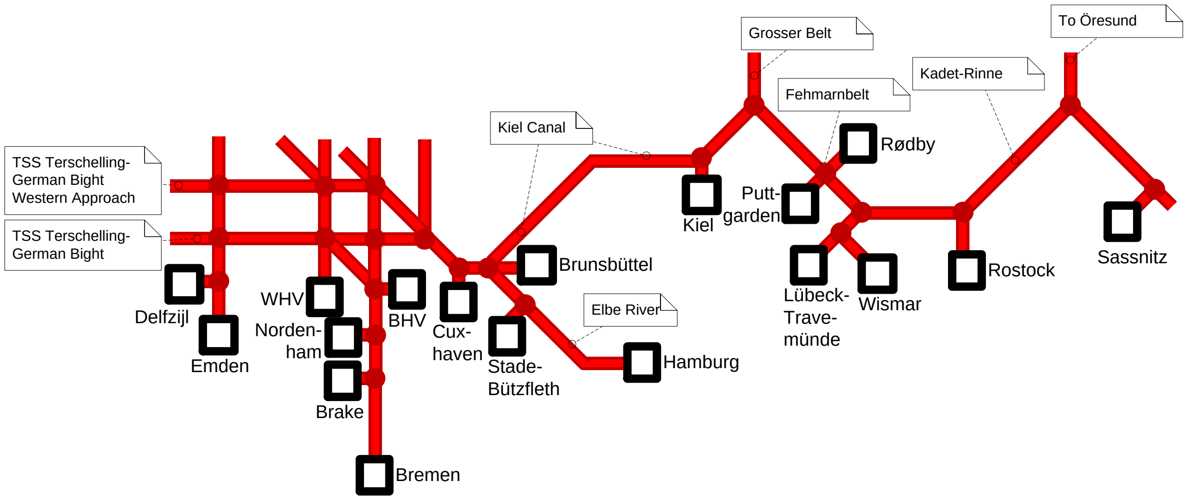

Figure 51: NSR-RTM – Motorways of the Sea off the German coast and through the Kiel Canal, in their connection to German sea ports; in LTM display mode

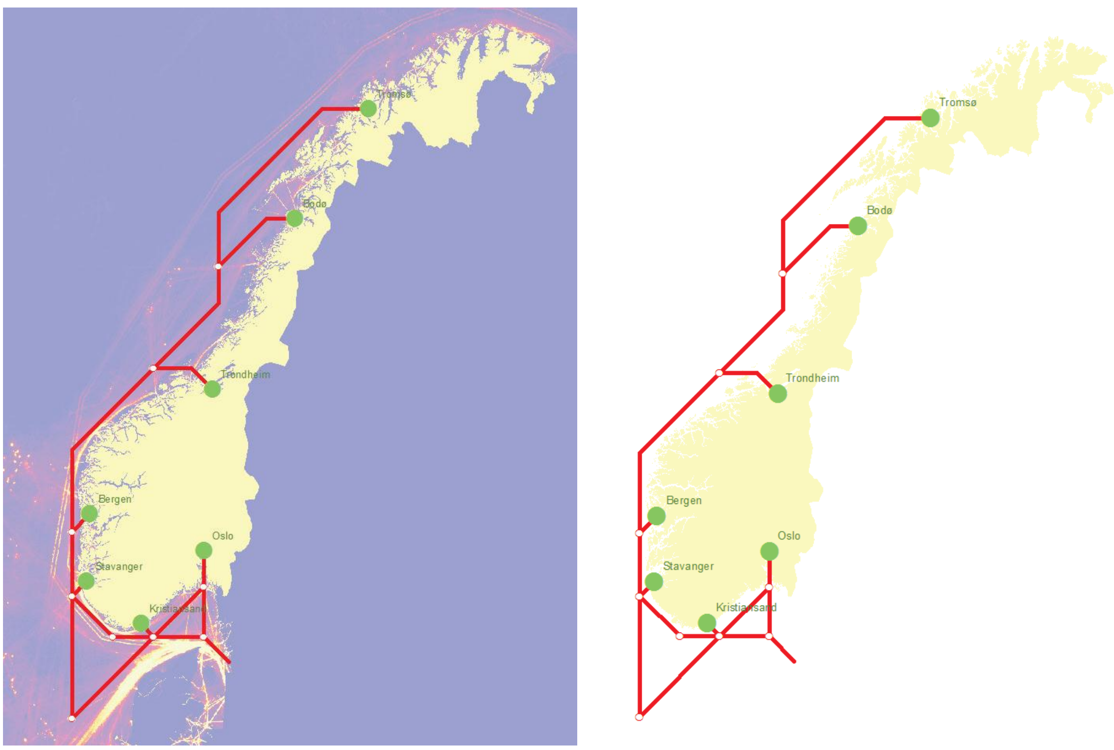

Figure 52: NSR-RTM – Motorways of the Sea off the Norwegian coast; in LTM display mode (with and without vessel traffic density plot overlay)

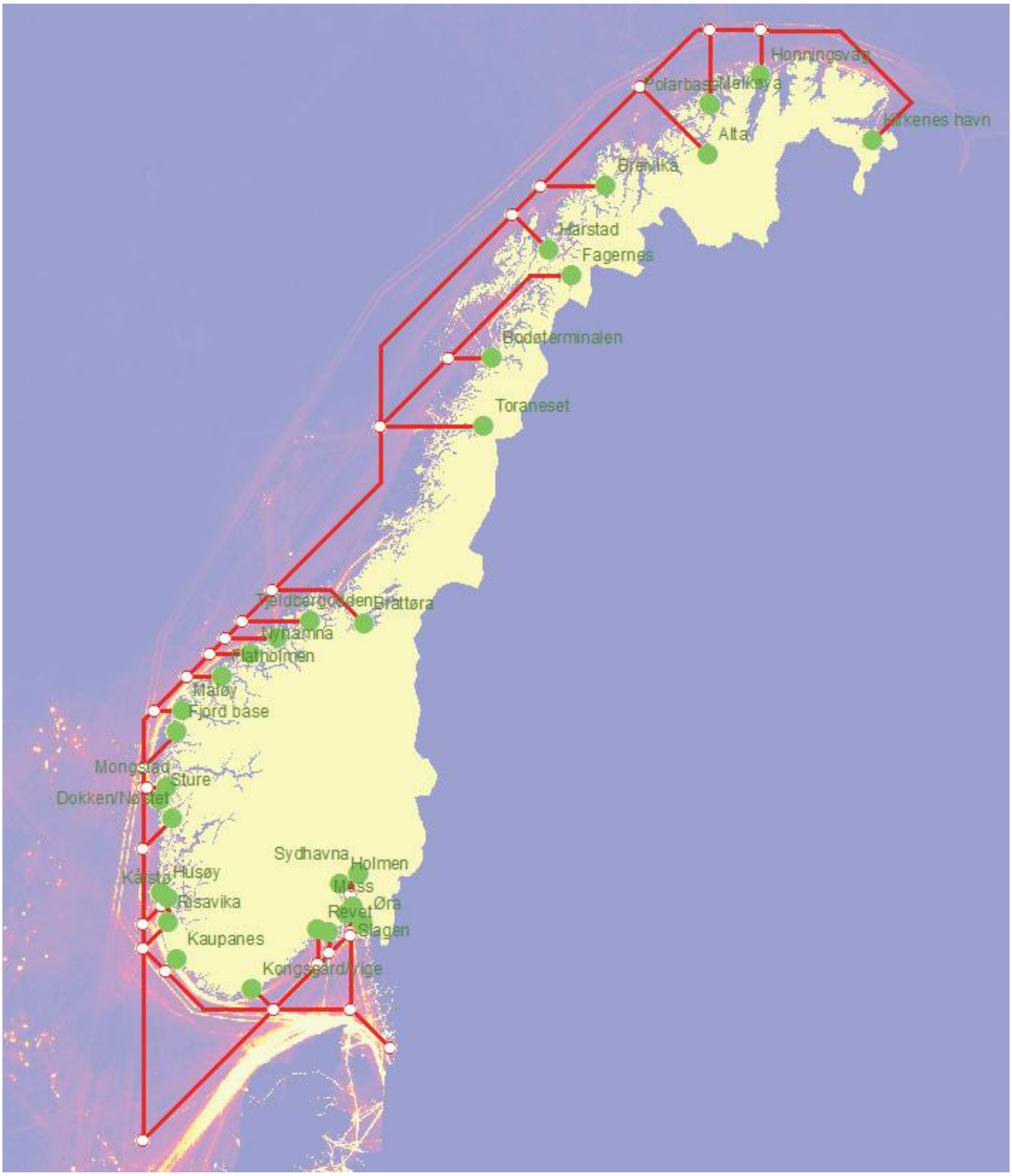

Figure 53: NSR-RTM – MoS and RoS shipping lane classes in a combined image off the Norwegian coast; in LTM display mode (with vessel traffic density plot overlay)

Figure 54: NSR-RTM – MoS and RoS shipping lane classes in a combined image off the Norwegian coast; in LTM display mode

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Annex C List of legacy items from the NSR-RTM work at ACCSEAS

This Annex captures in a list of items the actions required for a potential implementation of the NSR-RTM in a fuller scale *after* the ACCSEAS project. This Annex thus directly feeds into the ACCSEAS legacy which needs to be addressed by an appropriate organisational setup. Both is addressed in the 'ACCSEAS Sustainability Plan' (ACCSEAS 2015b).

C.1 Re-do construction of present and future NSR-RTM instances to consolidate ACCSEAS findings for the benefit of the NSR

The intend of the ACCSEAS candidate solution NSR-RTM was to create a 'blueprint' of how to create a NSR-RTM and to show its relevance and importance. The ACCSEAS derived NSR-RTMs 2012 and 2020+ are thus to be construed as 'demonstrators.' In order to be reliably used by different stakeholders and users, even to the extent of using a NSR-RTM for navigation, the NSR-RTM work needs to be re-done after ACCSEAS taking into account the following considerations.

By doing this, the NSR may create benefit for itself but also provide relevant input to pan-European projects and initiatives as described in the main body.

C.1.1 Re-do construction of present and future NSR-RTM instances using vessel track data derived from various sensors instead of AIS track data alone

In the main part of this document it was concluded, that it is *vessel* track data which is required to derive a NSR-RTM instance and that it would be ideal to have available such track data from shore-based systems, in particular from VTS systems operated by shore-based authorities around the NSR, that would have been derived from *several* vessel track sensors, i.e. not just AIS track data. Hence, future partners of an undertaking to re-do construction of NSR-RTM instances may wish to agree *to refer to vessel track data derived from various sensors and thus consolidated instead of AIS track data alone.*

C.1.2 Re-do construction of present and future NSR-RTM instances using vessel track data encoded in the IALA defined Inter-VTS Exchange Format (IVEF)

Following from the above, from both a data quality and a data processing point of view, it would be beneficial to have this vessel track data available in a sensor-independent and therefore more abstract encoding format, as opposed to the binary encoded AIS track data. Since IALA has created a recommendation on *Inter-VTS Exchange Format (IVEF),* future partners of an undertaking to re-do construction of NSR-RTM instances may wish to agree to use the IALA defined IVEF format, possibly with relevant amendments, instead of the binary encoded AIS track data used in ACCSEAS.

C.1.3 Re-do construction of present and future NSR-RTM instances using 'official' node data

Use the 'official data' for the node definitions, where available, of various countries around the NSR, such as 'official data' submitted to hydrographic services and/or to INSPIRE publications of those countries;

C.1.4 Re-do construction of present and future NSR-RTM instances including all three proposed classes of shipping lanes

Complete the NSR-RTMs for all three classes of shipping lanes, i.e. Motorways of the Sea (MoS), Roads of the Sea (RoS) and Trails of the Sea (ToS) identified in this Description.

C.1.5 Re-do construction of present and future NSR-RTM instances using an improved organizational framework

It is a specific feature of the NSR, as opposed to the 'high seas' in most oceans, that the *entire* NSR is distributed to EEZs and/or territorial waters (even inland waterways) of coastal states surrounding the NSR. This means, that there is some responsibility of some coastal state everywhere. The benefit of this situation for the construction of NSR-RTM instances is that this would allow the distribution of work amongst the coastal states of the NSR without leaving any 'white space' of the NSR.

In order to arrive at a NSR-RTM instance for the same point in time with the same underlying rule base, coordination amongst the coastal states around the NSR would be required. Ideal coordination may be achieved by employing the e-Navigation NSR body of organisation(s) proposed in the 'ACCSEAS Sustainability Plan' (ACCSEAS 2015b) once it has been activated.

However, as an intermediate step or as a fallback arrangement, it might be sufficient to mutually agree between adjacent countries on the *Node.Cross-Border* at the borders of their national EEZs in order to allow for a seamless development of a NSR-RTM eventually while working independently within the waters of each participating country.

C.1.6 Feed agreed NSR-RTM data to the public via the appropriate channels

The result of the above of the construction of present and future NSR-RTM instances would not be an end in itself but rather needs to be disseminated to the interested public using the appropriate channels. The relevant channels may depend on the required quality of the NSR-RTM data to be published which in turn would depend on the intended purpose of usage.

This would prompt to create an RTM exchange format, based on XML, to provide the RTM data; stay compatible with the emerging S-100 framework and correlated international standardisation.

C.1.7 Re-do construction of present and future NSR-RTM instances due to amendments made to routeing measures and to MSP in the NSR

In the main part of this document it was recognized that the *existing* vessel traffic patterns in the NSR leading to the definition of routes are subject to changes by e.g. routeing measures introduces by e.g. amended TSS as recognized by IMO. Thus it is clear, that there will be a need to regularly create a new NSR-RTM due to the changing situation. This could be done e.g. bi-annually.

It is also worthwhile to overlay the different instances of the NSR-RTM to recognize the historical development and potential arrive at additional conclusions.

For each iteration it is important, though, that only data is taken in, which is valid/relevant for the point in time under consideration. Therefore, the relevant above legacy considerations should be implemented before the next iteration of the NSR-RTM (e.g. NSR-RTM 2016 based on vessel traffic data gathered in 2015) is done.

By the same token it would be desirable to extend the future projection forecast by the same time span into the future, i.e. when creating a NSR-RTM 2016 a future projection for 2025+ should be created, too, thus rendering NSR-RTM 2025+.

In order to minimize the workload when creating NSR-RTMs for the different points in time (iterations of current analysis' and future projections) it would be desirable to have (semi-) automated means to construct the different instances of NSR-RTMs. Research into those tools seems to be necessary.

C.2 Proposals to relevant international organisations

In parallel to the above, there may be proposals considered as an ACCSEAS legacy in regards to relevant international organisations to provide for international harmonized understandings of the generic RTM and its applications.

C.2.1 In search of a lasting depository and stewards for (NSR-)RTM - Potential proposals to IHO GI Registry e.g. via IALA

ACCSEAS as a regional-European project under the INTERREG NSR IVB program is limited in scope and duration. The ACCSEAS candidate solutions need to find lasting depositories and stewards to further live work on them. This applies to the generic RTM and to the NSR-instance of the RTM, too.

This ACCSEAS legacy item refers back to the discussion of further developing the generic RTM into a proposal to the IMO's envisaged CMDS under their e-Navigation strategy, but specifically to the potential contribution to **IHO's GI Registry,** various registers, including the notion of a ***'RTM product'*** at the 'Product Register.' It is proposed, that the generic RTM work done within ACCSEAS should be progressed with the goal to have proposals for the relevant Register of the IHO GI Registry ready and/or to bind them, together with other already existing entries, together to a 'RTM product' submitted to the IHO GI Registry and eventually accepted therein.

This submission process could be done by a submitting organisation, such as, on the international plain, **IALA** which would also be identified as the 'owner' (or 'stewards', rather, as the content of the IHO GI Registry strictly speaking is 'owned' by the public once released) of the 'RTM product.' Alternatively to IALA as a submitting organisation, **an organisation from within the NSR** could submit the 'RTM product,' as long as it would have been recognized by IHO as an 'submitting organisation' under their S-99 standard rules (IHO 2011).

Hence, a lasting depository in the international domain would have been found for the generic RTM, namely the IHO GI Registry in support of the IMO envisaged CMDS, as well as a steward, namely the 'submitting organisation.'

Obviously, this kind of work and the (lasting) responsibility associated with it would need to be investigated and agreed to by the management of the 'submitting organisation.' Since this cannot be taken for granted, this forms a legacy item from ACCSEAS.

The following questions and statements may provide additional guidance for future work in this regards.

- ***Product Register:*** Do we have a NSR-RTM product description? Which format would it have? That depends in turn on the recognized organisation or body that is supposed to be the steward of that NSR-RTM product in the future, if not a distributed product which would be co-ordinated by several bodies; see next section below for more discussion.
- ***Feature Concept Dictionary Register:*** a must in principle, but to what extent, i.e. to what extent can existing entries used for RTM.

- ***Portrayal of display modes at Portrayal Register:*** While the ENC display mode appears to be well covered due to present international standardisation, there needs to be developed a portrayal for the LTM and the HUD/AR display modes.

C.2.2 Potential proposals to IMO

C.2.2.1 Evaluate the blanket area concept of the MSPs application

In the present IMO SIP (IMO 2014), the MSPs are applied to six sea area definitions (see description in main body of this Description). It would be a useful evaluation of this IMO MSPs area concept to perform an assignment to the NSR in its entirety, resulting in falsification or validation contributions. It would require an interested party of partners from around the NSR to undertake such an assignment and arrive at an assessment which could be eventually contributed to IMO's ongoing definition work on the MSPs.

C.2.2.2 Propose the RTM as a complementary scheme for 'points of delivery' of shore-provided services at MSPs

Similarly, as interested partner from around the NSR continue work on the NSR-RTM, the generic features there may be extracted findings for a complementary scheme for designating 'points of delivery' for the MSPs, namely at legs and nodes of the RTM. This complementary scheme would be validated by the NSR-RTM instance as a live example from a vibrant and relevant sea area and would thus potentially carry substantial weight as a proposal to IMO.

C.2.2.3 Propose additional TSS in the NSR

It may need to be considered by the NSR coastal states to submit a harmonised proposal for additional TSS as based on the then established harmonised NSR-RTM to IMO in the future. Compare for this proposal user statements suggesting this as well as pointing out caveats for such an approach in Annex D.

Annex D Relevant Results at the MSP-Workshop at the 1st e-Navigation User Forum

The Workshop was held on the occasion of the first ACCSEAS Annual Conference, Flensburg, 15th March 2013. The Workshop dealt primarily with the application of Maritime Service Portfolios (MSPs) in the NSR. This is an application of the NSR-RTM, as described in section 5.3 in the main body of this Description. Also, the topic of the TSS was touched upon, which is another application of the NSR-RTM, as described in 5.6 in the main. A part of the discussions of this Workshop therefore touched upon the RTM. The full transcript is reproduced here to provide the context of those discussions. The transcript is editorially adapted to fit the format of this Description.

<begin quote transcript>

RESULTS – interspersed below –

“Q:” designates a question to be further investigated

"This workshop focuses on what services should be provided in the North Sea Region (NSR) in the light of the future developments as part of a future NSR Maritime Service Portfolio. Participants will be invited to give their views on required services, required service levels and required service coverage. Participants will also have the opportunity to share their ideas regarding innovative services for the NSR which would - once implemented - improve accessibility to NSR ports." (Quote from the Conference programme)

D.1 Introduction

Canadian e-Navigation MSP example (IALA e-NAV7/10/2) distributed on paper and introduced

Should a future NSR MSPs plan as adapted from the Canadian example to the NSR be desirable? (pro / cons)

- Yes: There was a general support for taking the Canadian example as a starting point in terms of the format of a future NSR MSPs plan, while there may be different assessments in terms of content.
- Q-1: The question was raised whether there are other MSPs plans available globally. This would require some research.
- Q-2: The feasibility to create a NSR-MSPs plan which would reflect the user-desired/needed service provision would be needed to be demonstrated.
- While the NSR should be construed as one region, this raises the questions
- Q-3: how it interfaces to potential national MSPs plans?
- Q-4: how and, if at all, a migration might be possible?

Would it be a desirable goal to create a first draft of such a future NSR MSPs plan within the remainder of the ACCSEAS project?

- Yes: There was general support that ACCSEAS, during the remainder of its project duration, should strive to create a first draft of a future NSR MSPs plan.
- Q-5: It was advised that individual services considered within ACCSEAS’ first version of the NSR-MSPs plan should be prioritized.
- Q-6: It was requested, that the dependencies between services within the NSR-MSPs plan should be determined and described. As an example the real time tidal data provision service would be required for any Under Keel Clearance service; hence any UKC service would depend on an appropriate real time tidal data provision service.
- Q-7: How are existing services (such as NAVTEX, ice charts) migrated into the ACCSEAS created NSR-MSPs plan?

- Q-8: How are new services introduced into the ACCSEAS created NSR-MSPs plan?
- Q-9: How is the 'best practice approach' being incorporated when crafting the NSR-MSPs plan?
- Q-10: How does the outcome of ACCSEAS affect the work of VTS centres in the future?
- Q-11: How could mariners/crews familiarize themselves, or being trained to cope / to engage with the MSPs?

D.2 A future NSR Maritime Service Portfolios (NSR-MSPs)

Let's assume the future NSR MSPs plan would be adapted from the Canadian example to the NSR, how would it need to be structured in general terms.

I.e. we turn to the *columns and their headings* first.

Which structuring principles should be applied for the columns?

- Geographical areas of the NSR (as with the Canadian example)?
- Traffic-analysis based (present / future) using a Route Topology Model approach?
    - Categories of routes: Motorways of the Sea / other layers of routes?
- Combination of both?
- Other approach?

It was suggested to correlate voyage phases (compare appropriate slide of Richard Hill's presentation on Day 2) with the Route Topology Model and area coverage.

It was further suggested, that the structuring principle for the columns should not be any rigid geographical areas, based on whatever definition, but rather voyage- and/or traffic situation related as follows:

Finally, it was suggested to identify different traffic pattern regions, thus being sensitive to the traffic, for the NSR-MSPs plan in order to arrive at the sets of services required for those traffic pattern regions.

There was suggested a precise priority scheme for the column structuring principle:

- 1st priority: consider traffic pattern + phases of voyage the structuring principle;
- 2nd priority: only if this leaves margin for the need to further structure, then the coverage area concept should be employed.
- Rationale was presented as follows: It is required to step back and re-consider the origin of the area definitions, namely that the area definitions for service provision stems from a time when they designated feasibility of technological service provision rather than reflecting actual user needs. Since the technological progress may now allow to provide services in a much more differentiated way, traffic-sensitive and voyage-phase related structuring principles to define service provision may and therefore should be employed.

- Q-12: This raised the matter of granularity / scalability of such definitions.
- The future NSR-RTM should allow to assign attributes to its "legs" which take into account the above considerations, namely the traffic patterns and the voyage-phases as opposed to (coverage) area. Examples for such attributes were given as follows:
    - "estuaries" (river approaches to ports)
    - "along coast"
    - "crossroads"
    - "canal / inland waterway"
    - "open sea" (as little as left in the future NSR)
    - List not complete.
- (The notion to create an area such as "The Channel/Dover Strait" was abandoned after this discussion because it is assumed that the above principles would render a traffic pattern / voyage phase structure class fully appropriate for the situation in The Channel or the Dover Strait.)

- It was concluded that the above principles applied to the elements of the NSR-RTM would lead to the required services and required service levels, i.e. the above methodology would render a seamless derivation and thereby a strong justification for the MSPs associated with those elements of the NSR-RTM.
- Q-13: Consequentially, it was recognized that this approach would need to be reconciled in one way or another with the present proposal of the IMO e-Navigation Correspondence Group to employ five area definitions only. There may be a need to investigate how the above findings may be introduced into IMO's e-Navigation strategy.
- Q-14: The question was raised what the legal backing for such a NSR-MSPs plan would be (i.e. within international waters), and how it could be reconciled with UNCLOS specifically?

How would the interfaces to MSPs in national waters of the NSR's countries be designed?

- It was concluded, that if a NSR-MSPs plan would be set up employing the above methodology both for the NSR at large and for the MSPs in national waters, there would be no visible interface, i.e. there would be a natural and seamless continuation.

If traffic-analysis based routes and the Motorways of the Sea concept would play an important part of that, ***should Motorways of the Sea in the NSR, in the future, be protected by a NSR-TSS-Network as adopted by IMO?***

- Yes: There was general support that the COLREG privileges of TSS should be aligned to Motorways of the Seas throughout in the NSR. Such a NSR-TSS-Network would provide a robust protection of shipping lanes and shipping interests against overwhelming interests of other uses of sea space.
- Caveat: When applying for a TSS at IMO, the "compelling need" needs to be demonstrated to IMO, and the risk to restrictions of innocent passage elsewhere globally, as implied by reciprocal action due to such ship routeing measures, should be mitigated. Also, the density of traffic needs to be demonstrated, too, to justify a NSR-TSS-Network.
- Caveat: Efforts should be taken that such NSR-TSS-Network should not be construed as an opposition against Renewable Energy. It was stressed that such a notion would not be the true intention of creating a NSR-TSS-Network aligned with the Motorways of the Sea concept.
- Caveat: To achieve a NSR-TSS-Network unity amongst administration bodies, across the NSR and within countries, would be required.

D.3 The services of a future NSR Maritime Service Portfolios

In this part of the Workshop we discuss the ***future NSR MSPs' spectrum.*** I.e. we turn to the ***lines and their headings*** of the Canadian example now.

Category MSPs level: The categories constitute in themselves MSPs, again (generic category MSPs).

Are the Category MSPs of the line headings OK as they are, or are amendments needed?

If so, what would be the amended Category MSP?

- It was felt, that the line headings of the Canadian example were not fully appropriate, as the distinction of operational and technical service spectra does not appear to be observed.
- It should be avoided "mixing" operational vs. technical MSPs / service spectra. The categories of services should be reviewed and made consistent.
- It should also be avoided to introduce shipboard functionality (such as "Radar Positioning") in MSPs, which is considered as a shore-based service provision catalogue/plan.

- It was suggested to introduce as an attribute a “general connectivity indication”, such as “ship-shore”, “shore-ship”, “ship-ship” etc.

Individual services level:

Are the identified services OK as they are, or are amendments needed?

If so, what services would be

- added?
- deleted?
- amended?

Are there particularly innovative services which are missing?

Which services are particularly important thus to be highlighted?

- Q-15: Information services from ports (to ports) such as berth related services should be included, e. g. information services on port facilities (i.e. metadata services).
- Q-16: Appropriate “handshaking”-methods, i.e. acknowledgments on the application layer, should be associated with appropriate MSPs/services.
- Q-17: It was suggested that the voyage related intentions of (individual) ships should be received / known by shore (at runtime) in order to provide optimum MSPs / services for those vessel approaching.
- Q-18: Offshore installations operators should be considered as service providers in a future NSR-MSPs plan (for e. g. “keep-away” information services; e. g. at cable crossings).
- Q-19: It was suggested to introduce a model, based on the well-established system engineering concept of ‘finite state machines’, of “information states of vessel” during all phases of a voyage, including voyage preparation of voyage. Such an “information state of a vessel” would show, as a summary token, whether the vessel has acquired the necessary information relevant for the next phase of the voyage.

D.4 The way forward with the future NSR MSPs

In this part we turn towards collecting ideas as to the way forward in procedural terms.

What would be the steps towards a future NSR MSPs during the duration of the ACCSEAS project? How could the work on a future NSR MSPs plan be further facilitated?

- It was suggested, that ACCSEAS would create descriptions of the above concepts and notions as “living documents”, which would be promulgated to the NSR communities for regular or even “constant” review.

<end quote transcript>

Annex E The Results of the RTM-Workshop at the 3rd e-Navigation User Forum

This Annex captures the user statements made at the RTM Workshop at the 3rd NSR e-Navigation User Forum on the occasion of the Final ACCSEAS Annual Conference, Rotterdam, 17 February 2015.

Q1: What potentials of employing RTM are there for the NSR and beyond, considering in particular European initiatives like e-Maritime, Motorways of the Seas and INSPIRE?

- RTM have 'lot of potential'
- Topic at hand = port authorization for ULCC; 'too many large vessels arriving'
    - RTM have a role for port traffic management;
    - pilots in the Schelde region have established their own RTM already and use incoming AIS data (as soon as in reach for AIS data provider)
    - assumptions to where the ships will be
- Important is a 'connectivity with brain of mariner':
    - as soon as in touch upon arrival, it would be desirable to have a constant stream of dynamic route and ETA updates from vessels for the Port Community System;
    - It is important to exchange a maximum of data between ship and shore, so that the other side may use that data at their discretion; this is better than to keep data at its origin. Demand for this will increase with 'internet of things.'
- standardization of RTM formats would result in improved mutual understanding of the routes (by common designators and commonly known features) which would be helpful.
- Current and weather data should be applied to the routes as well.
- Incentive for shipping to participate: Talks with major ship owner have indicated that optimization of departure, i.e. punctuality of scheduled departure, is more important than arrival punctuality: Being late is not considered bad as long as in port and as long as known (in advance).
- Big difference in requirements in different sectors of shipping, illustrated by example of differences between bulk carriers and gasoline carriers.
- Trade-off between capacity and predictability needs to be taken into account.
- Influence of tide on RTM: How stable are the routes? Stable RTM as long as all possible options (including tidal-dependent variations) have been includes. The dependency of certain legs/nodes on sea conditions to be used need to be mapped into their attribute domain. When using RTM data there should be done some contingency planning.
- Clarification on the data sources for construction of RTM: TSS, depth information, port of destination.

Q2: **How could employing RTM specifically contribute to solutions for issues introduced to shipping by Marine Spatial Planning?**

- Potential of RTM, once established, to influence Marine Spatial Planning in turn was recognized.
- Natural development foreseen in the NSR that shipping will take place in the future more or less only in pre-defined routes (whether protected by TSS or not) due to the advent of MSP.

Q3: **What would be the relevant user requirements for the graphical display of RTM data to become meaningful information in the three portrayal modes for RTM namely ENC, London Tube Map, and Augmented Reality/Head-Up Display?**

- For mariner's use the passage planning in ENC mode (implemented in ECDIS) was considered useful; at planning station.
- 'All modes of portrayal got a place' under different conditions; HMIs need to dynamically adapt the display mode to context.
- Usefulness of in particular *Re*-planning of a schedule at port would be supported by RTM HMI on the ship's side.
- Need to deal with the uncertainties at information exchange of RTM data.

Q4: **What RTM-related topics should be further explored after ACCSEAS?**

- Integration of RTM into 'e-Navigation': Adaptable advance route planning.
- Relationship between routes and collision avoidance: Can there be introduced wrong behavior due to route designations?
- Difference between strategic and tactical use of RTM
- Assessment of safety impact for navigational use of RTM

Compare (ACCSEAS 2015d) for an elaborate description of the context of this transcript.