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Inland Electronic Navigation Charts: a new approach or new purpose

1. Background information

Our world digitizes day after day in a fast and peerless speed. PC’s, laptops, smartphones and other devices have made their entry into everybody’s daily life and internet of things became commonplace amongst the homes and businesses.

This digitisation pursued in the world of inland navigation as well. Locks and bridges are being automated, messages (or notices to skippers) are send digital throughout AIS or other means. All kinds of river information services delivers route planners, ETAs or unique calling points. All in a digital form but related to geometric data.

A next step in the evolution of inland navigation is the investigation and implementation of the possibilities of autonomous sailing or smart shipping. All kinds of initiatives are set up to make this possible. Together with the development of these “smart ships”, the waterway authorities need to examine if their infrastructure needs to be more intelligent or smart…

As a waterway authority we can support all research by taking the necessary legislative initiatives or by making adjustments to the infrastructure.

And although these developments are very important for the future for environmental and economic reasons, this can only succeed if the systems can rely on accurate and trusted data.

2. A new approach or new purpose for IENCs?

An important aspect on which autonomous sailing will rely, is the availability of data. All kinds of data from river banks over vertical clearances as well as the operating hours of locks and bridges. This data is usually available as an IENC (Inland Electronic Navigation Chart) but the initial purpose of these charts is about the safety of navigation and not about making autonomous sailing possible. Therefore the accuracy of the features is not always the most important thing in the production of the charts. An accuracy of several decimetres will be acceptable in some cases.

A current research program at the university of Leuven is investigating whether the S-57 data model offers sufficient information and possibilities in relation to autonomous sailing and how to upgrade the charts. What kind of informations/features are needed? What are the accuracy requirements for these features? Can
the quality of data be defined and how can this quality be indicated in the charts? A lot of questions which needs an answer.

The waterway authorities are faced with new challenges regarding the Inland ENCs. How can they offer the IENCs to the skippers with all the information needed and with the best possible quality with respect to the initial purpose (safety of navigation) and with smart shipping in mind.

This brings up another (and probably more important) question. Should we, waterway authorities, change the way we produce our IENCs (a new approach) or should we change the purpose of IENC?

In the study of De Vlaamse Waterweg regarding the production of “real-time IENCs” these questions needs to be answered before we can determine the procedures and processes we need to follow for the encoding and production of real-time IENCs. Are we going to use the IENCs only as a means for the safety of navigation? Or are we changing the purpose in such a way that the data collection needs to be redefined? Or is a combination of the two also possible?

3. Current approach and purpose

The European RIS-directive from 2005 compelled all waterway authorities to produce and distribute digital navigation charts in the S-57 format. These Inland Electronical Navigation Charts (IENCs) had to be encoded with a minimum of required features. For some waterway authorities it became a challenging task to collect and encode all data. De Vlaamse Waterweg nv decided rather quick to outsource the production of the charts. After a first set of cells of all waterways of CEMT IVa and higher, De Vlaamse Waterweg nv choose to encode all navigable waterways in Flanders in usage 7.

The base on which our waterway authority has taken all her decisions for amending features in the charts was related to the safety of navigation. This was and still is the most important parameter to decide whether an update of the cell is needed. Accuracy information is still not an issue.

4. Influence of smart shipping on the approach

If the Inland charts are used as a source of data for autonomous navigation, the quality of data becomes a very important factor. The quality of data can be described by four properties:

- Accuracy (is the uncertainty of the features and attributes low enough);
- Correctness (is the content of the chart in accordance with the real world);
- Punctuality (are the charts up-to-date);
- Completeness (are all required features available).

At the moment it is not possible to get information about the quality of data out of the S-57 data model specific for inland features. This means that the calculations in the view of autonomous sailing have to take
into account that the position of all features have a big uncertainty although this isn’t necessarily so. If the Inland ENCs also provide the uncertainty information in one way or another, the reliability of autonomous sailing vessels will increase tremendously.

Adding quality information into the charts, means that the IENC needs to have at least relevant data available about the four parameters. Although it is very difficult to collect and give information about the correctness and completeness (how can we decide if a chart is complete or correct), the accuracy and punctuality are two attributes which can be described in the S-57 data model.

In the current edition of the Inland ECDIS standard (edition 2.4) there is no possibility to even define the accuracy or punctuality. Therefore a new proposal has been submitted to add new features (in accordance with the new S-101 standard) and new attributes which will be added to certain existing features which are important for autonomous sailing. The discussion about the proposal is at the moment of writing this paper still going on.

5. Conclusion

In our research regarding the update process of the obliged production of IENCs, we had to conclude that our current approach and the current purpose of the charts aren’t sufficient anymore. By using the charts and data model as basis for any solution within autonomous navigation or smart shipping, the requirements regarding the quality of data increases. Therefore we, as waterway authority, need to define new requirements for the production of the IENCs. Surveying and measuring features have to be done with required accuracies and these accuracies needs to be known. Which requirements we need, will be defined within studies and it’s also my opinion that this will take a while until we manage to have a consensus regarding these requirements.
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Keywords:  
River Information Services (RIS), Geographic Information Systems (GIS), Spatial Database, RIS Corridor Services, Electronic Chart Display and Information System (ECDIS), Vessel Tracing and Tracking (VTT), Notices to Skippers (NtS), Automatic Identification System (AIS), Reference Network Model

Title:  
A Spatial Database as the backbone of RIS  
*How to bring spatial awareness to flat-file nautical data*

Full Paper:  
Intelligent Transportation Systems (ITS) have revolutionized the organization of traffic. Above all this has affected road and rail transport. Increasingly however, ITS technologies also extend to the realm of inland shipping. Over the last decade River Information Services (RIS) have been deployed in several European countries in order to enhance the reliability, efficiency and safety of Inland Waterway Transport (IWT). Whereas rivers are not bound to national borders, RIS differ strongly with regard to scope and technical implementation across regions. Skippers who use inland waterways to navigate seamlessly across borders are required to draw on multiple information sources and systems to make use of RIS. This results in additional effort and poses a major obstacle to the use of those services.

This lack of standardization was detected early on and since then several large-scale projects were conducted with the goal to harmonize RIS across Europe. The biggest of those is the ongoing CEF funded project RIS Corridor Management Execution (RIS COMEX), which aims at tackling the identified issues through the definition, specification, implementation and sustainable operation of harmonized corridor services across 13 European countries. A number of those services, providing information on the fairway, traffic and logistics as well as supporting services have been identified and are in the course of implementation.

As the RIS COMEX services, previous RIS implementations relied heavily on the availability and quality of the underlying reference data. Therefore the RIS Index was established well over 20 years ago as the first harmonized RIS reference dataset. The RIS Index comprises a collection of objects, which are relevant for IWT in a single table. Each row represents a single real-world-object, which can be described with a large number of possible attributes defined in the columns. Among these are columns for the geographical latitude and longitude, in order to locate the objects on the surface of the Earth. Additionally each object has a unique object ID, the so called ISRS location code, which is compatible and used in all RIS key technologies. Each object also belongs to an object class, defined with a function code.

This simple kind of data encoding can be referred to as a flat file database. A flat file database consists of a single table. The specific attributes of all object classes are appended to this table as columns, so that every object has a uniform format and shares the attributes of every other object. Therefor it is for example possible to define a maximum clearance height for a berth, opening hours for a gauge station or a VHF channel for a bridge. In practice attributes would be left empty, if they don’t apply to the object class. Nevertheless, every object is stored with the possibility to define all these attributes, which increases the storage size and the processing effort of the database. All together there are currently 84 columns or possible attributes in the RIS Index, which can be defined for every object and object class.
The big number of object classes with its associated attributes as well as the increasingly sophisticated services of RIS COMEX however, require a more complex form of data encoding. All objects share some form of relation with each other. Some are hierarchically structured, like bridges and their bridge openings. Others have changing parameters, depending on a related object, like the clearance height of bridges which is dependent on a reference gauge. In addition to that all objects have an exact location from which a spatial relationship to each other can be derived.

The RIS COMEX services make extensive use of those relations. Several of the services like the ones related to Vessel Tracing and Tracking (VTT), Estimated Time of Arrival (ETA), route and voyage planning or Inland Electronic Chart Display and Information Systems (Inland ECDIS) depend on some form of relational awareness of the reference data. Flat file databases however are not very efficient in encoding spatial or attributive relations. They may be inferred from the data itself, but the format of the database does not make the relationships explicit. For example, a bridge object may have a reference to a gauge station, encoded with the ISRS location code in one of the bridges attributes. Similarly, it got two coordinates in the designated columns, referencing it to a specific location on the Earth. A human reader can then make the connection to the reference gauge by looking up its ISRS location code in the RIS Index or he could locate the object with the help of a map. But this information cannot be processed efficiently by a computer, because the relations are not implicitly encoded into the structure of the database. Very basic forms of relation derived from hierarchies or spatial configuration can therefore not be modelled efficiently by the RIS Index.

Relational databases as compared to a flat file database use internal indexes to quickly locate data without having to search every row in the database every time it is accessed. The data is stored in multiple tables, each representing a unique object class, which are related to each other via a unique identifier. Each table consists of the attributes of the respective object class only, which helps to keep down file size and avoids redundancies. The index is an additional internal table in the database, which stores a copy of selected attributes and a direct link to the full row of data. With the help of relational Algebra, like SQL it can be used to search and manipulate the database very efficiently and fast.

A spatial database can be seen as an extension to a relational database. In addition to the attributive index a spatial database offers a spatial index, which structures the data along topological criteria and allows the querying and manipulation of data based on geographic location. Geodata stored in a spatial database also has an associated shape, to enable the representation of multidimensional objects like lines and polygons. Through indexing the data, spatial databases are able to implicitly encode attributive and spatial relationships, which is a prerequisite for a lot of the COMEX services.
A geographical reference data model was therefore developed in RIS COMEX, which is derived from the RIS Index and supplemented with geometric network data. While the RIS Index was only able to describe one dimensional point objects, the COMEX reference network model is able to represent interconnected linear and areal objects. The linear network allows for the calculation of routes for which different parameters such as the maximum depth or width of the fairway can be taken into account. Furthermore, objects along the route, like bridges or locks can restrict the passage of vessels with certain dimensions. Dynamic impacts from Notices to Skippers (NtS) such as a reduced clearance height of a bridge due to maintenance work can temporarily be applied to an object or fairway.

The reference network data can be joined with data from the Automatic Identification System (AIS) to determine the position of a vessel along the route, relate it to objects in its proximity and continuously calculate and update the ETA. With the help of passage lines and geofences certain events can be triggered as soon as a vessel crosses a specific point or enters a certain area. All those services and many more rely on a spatial data model or geodata to perform their calculations on. The COMEX network reference model is the first attempt to establish such a standardized spatial database, from which all the above-mentioned services can be realized.

As such it combines the most important objects found in the RIS Index. Bridges are encoded as hierarchical models with one bridge area object and at least one bridge opening object. The same is true for locks, where there is one lock complex object and at least one lock chamber object. Additionally the model allows the encoding of berths, terminals, radio calling points and areas of competence, which are primarily used for geofencing, map display and geographical querying. In the future they may also be used to define areas of impact for NtS and other services.

The network itself is comprised of fairways sections and nodes. Every part of the fairway with uniform parameters (e.g. same allowed vessel dimensions, sailing speeds or CEMT class) forms one fairway section. As soon as at least one parameter changes the fairway is split and a new section begins. For every fairway section there are two nodes delineating the section. Every object of the reference network data has an unambiguous reference to the fairway section it belongs to. Additionally, the ISRS location code from the RIS Index is included to serve as a unique ID for connecting RIS key technologies like NtS, VTT or Inland ECDIS.
The COMEX reference network model was developed in a joint effort by all members of RIS COMEX and accounts for the particular needs of countries as diverse as Luxemburg and Hungary, Serbia and France or the Wallon region and Flanders. It stands on a solid base and can serve as a starting point for the replacement of flat file databases in RIS. While the establishment of the RIS Index certainly was a major step towards cross-border RIS, the advancement of services in COMEX calls for a profound revision of the 20-year-old model. The capabilities of the COMEX model for storing, processing and manipulating data are not at all exhausted by the new services. More so it could combine currently fragmented flat file data and develop into the successor of the RIS Index and a capable backbone of RIS.
NAISSANCE DU PROJET


Cette volonté décline la politique nationale de l’établissement public VNF. Ainsi, VNF gère et exploite à l’échelle nationale environ 6700 km de voies d’eau. A ce titre il exploite l’écluse de Gamsheim sur le Rhin. Mais VNF a également pour mission de développer la logistique fluviale durable et est l’opérateur national des Services d’Information fluviale (SIF). L’une des actions est d’améliorer la compétitivité de la navigation fluviale en facilitant son insertion dans les chaînes logistiques et en mettant à disposition davantage d’informations pour optimiser le transport.

Sur cette portion de fleuve, EDF assure seule la gestion, l’exploitation et la maintenance de 8 centrales hydroélectriques, représentant une puissance de 1400 MW, équivalent à un réacteur nucléaire. Au-delà de la production d’électricité, EDF apporte son savoir pour gérer globalement le fleuve et les usages qui en découlent : sûreté hydraulique, surveillance et maintien des digues, continuité piscicole, exploitation et maintenance de 8 écluses, garantie des tirants d’eau et tirants d’air en pilotant les niveaux dans les biefs et en réalisant en tant que de besoin des campagnes bathymétriques et de dragage. Afin de développer l’usage de la voie fluviale et ainsi porter les valeurs du développement durable, EDF Hydro Est a engagé depuis 2012 un vaste projet de modernisation des ouvrages qu’il exploite et des services liés à la navigation.

Initier l’aventure e-RIS en partenariat avec VNF apparaissait donc comme une évidence.
OBJECTIFS

L’objectif de cette démarche est de mettre à disposition des navigants, bateliers, chargeurs, ports, mais également aux commissionnaires, acteurs institutionnels et exploitants d’écluses une information fluviale efficace et moderne pour contribuer à l’essor de la navigation sur le Rhin et moderniser sa gestion.

Les services d’information fluviale permettent de répondre aux attentes des usagers de la voie d’eau en bénéficiant d’informations sur les conditions de navigation pour une meilleure anticipation et planification des voyages. Ils contribuent en ce sens à fluidifier le trafic et à améliorer la sécurité et la sûreté de la navigation, notamment au passage des écluses. La compétitivité du transport fluvial est améliorée grâce à l’optimisation des temps de trajets, une meilleure gestion du trafic ou l’économie de carburants (exemple : adaptation de sa vitesse au vu des temps d’attente aux écluses).

Aujourd’hui, les informations nécessaires ne sont pas toutes disponibles ou accessibles, ou alors dans des formats qui ne sont pas homogènes. Compte tenu du caractère international du Rhin, les sources de ces informations sont multiples et originaires de plusieurs pays.

Si la langue usuelle pour les bateliers rhénans est l’allemand, l’accès à l’information à tous les usagers (hollandais, allemands, français et suisses) doit être facilité par une application multilingue.

Il s’agit enfin de réduire la charge administrative en facilitant et en optimisant les échanges d’informations.

Ce projet s’inscrit également dans une démarche européenne et a contribué aux projets européens CoriSMa, puis COMEX qui visent à faciliter à l’échelle d’un corridor l’accès à l’information. Ainsi, ce projet contribue à la politique européenne et à la politique SIF de la CCNR.

HISTORIQUE DU PROJET

La première phase du projet, achevée mi 2015, a consisté à répertorier les besoins des usagers de la voie d’eau (plus de 60 entretiens ont été réalisés avec des représentants des usagers rhénans), puis à analyser les systèmes d’information déjà existants au sein des deux établissements afin de mettre en œuvre les outils les plus adaptés.

La seconde étape (2ème semestre 2015) a eu pour but de développer un « prototype » expérimental et moderne contribuant à l’amélioration de l’information fluviale des usagers de l’eau, avec tests et expérimentations auprès d’un panel représentatif d’usagers transfrontaliers.

Initiée en 2017, la troisième étape a consisté à développer de nouvelles fonctionnalités au plus proches des besoins des usagers et en créant une application numérique adaptée aux usages d’aujourd’hui.

Cet outil, e-RIS est donc en constante évolution pour répondre aux mieux aux attentes des différents utilisateurs

UN OUTIL MODERNE ET INNOVANT AUX FONCTIONNALITÉS MULTIPLES

e-RIS, via le portail web ou l’application mobile, comprend de nombreuses fonctionnalités répondant à des besoins réels des usagers rhénans :

En accès libre
a) La mise à disposition d’informations "statiques" liées à la voie d’eau : écluses, quais, aires de stationnements, contacts d’administrations etc.

b) La mise à disposition d’informations dynamiques :
   - Le temps d’attente estimé aux principales écluses
   - Les niveaux d’eau aux principales échelles limnimétriques, mouillage et hauteurs libres sous les ponts,
   - La position des bateaux. Ces données sont anonymisées en raison de la réglementation sur la protection des données personnelles ou le secret commercial. Il n’est ainsi pas possible de connaître le nom du bateau, son voyage ou sa cargaison, la disponibilité des ouvrages ou des interventions en cours sur la voie d’eau (avis à la batellerie français, allemands et suisses,
   - Un calendrier prévisionnel sur l’année des chômageaux écluses

Accessible après identification
   - Les données relatives à un bateau
   - L’organisation et le suivi des voyages,
   - Les heures d’arrivée prévisionnelles des bateaux (ETA) au prochain port,
   - Les niveaux d’eau prévisionnels

La politique qui sous-tend les données libres ou accessibles à tous s’explique comme suite :
   - Les données AIS ont un caractère personnel. A ce titre, le nom du bateau, son numéro ENI ne peuvent être publiés de façon accessible à tous. Ainsi, le propriétaire d’une flotte après identification peut voir où naviguent ses bateaux.
   - La cargaison transportée ou le trajet effectué sont des données sensibles d’un point de vue commercial. Elles ne sont donc pas librement accessibles En revanche, sous réserve d’avoir saisi les voyages dans l’application, un port peut savoir où sont les bateaux qui ont prévu de charger ou décharger des marchandises sur l’un de ses quais. La publication de telles données permet d’améliorer la compétitivité de la chaîne logistique et du transport fluvial. A titre d’exemple, a prise en compte des niveaux d’eau prévisionnels permet aux chargeurs d’optimiser les voyages, le chargement des bâtiments et de prévoir le nombre de bâtiments nécessaires ou barges nécessaires. Par exemple : le transport de 5000 tonnes nécessite deux barges s’il y a “suffisamment” d’eau et jusqu’à quatre barges en période d’été. De même, en connaissant le temps d’attente aux écluses, il est possible d’optimiser un remplacement d’équipage ou la vitesse du bâtiment (et donc la consommation de carburant) sans que l’heure d’arrivée finale ne soit impactée.

Par ailleurs, les gestionnaires d’e-RIS développent également des produits “à la carte” comme par exemple un calcul de temps d’arrivée dans chaque port dans le cas d’un voyage ayant plusieurs étapes. Ce service est payant au vu des développement spécifiques.

Pour pallier aux difficultés de connexion internet (zones blanches) ou d’adaptation de son site web aux écrans standards des smartphones et des tablettes, VNF et EDF ont également développé une application numérique pour les supports mobiles (Android, iOS). L’application mobile remporte un franc succès et compte (à fin avril 2019) plus de 1500 téléchargements dont une majorité de hollandais et une utilisation quotidienne soutenue.

**L’ARCHITECTURE DU SYSTEME D’INFORMATIONS RETENUE**
e-RIS a été construit sur la base de briques logicielles standard Open source (Talend, Postgres, Apache, Tomcat etc.) éprouvées. Ces briques sont des logiciels développés par une communauté d’informaticiens mis à disposition pour une réutilisation gratuite. Ceci a permis de répondre aux contraintes budgétaires du projet sans faire de concessions à la disponibilité de l’application et aux performances.

L’alimentation des données se fait via Talend. Une vingtaine de sources de données sont nécessaires pour alimenter e-RIS. Les formats de données et les modes de mise à disposition des données sont hétérogènes. Un ETL (Extract, Transform and Load) comme Talend facilite la mise en place des interfaces. Toutes les données dynamiques sont intégrées automatiquement dans e-RIS.

Les données sont stockées dans une base de données Postgres qui s’avère très efficace, même avec des volumes importants (exemple : l’historique des positions des bateaux qui représente plusieurs centaines de millions de lignes par an sur le périmètre du rhin supérieur)

Les données sont mises à disposition de l’application mobile et d’autres applications externes via un web services selon la norme SOAP (Simple Object Access Protocol) pour la mise à disposition des données en accès libres et selon la norm REST (Representational State Transfert) pour la mise à disposition de données accessibles après identification comme l’ETA.

Le front end (serveur web qui gère l’affichage du portail) s’appuie sur le couple Apache / Tomcat et la partie cartographie a été mise en œuvre sur la base d’un système d’information géographique Geoserver.

**UN OUTIL INTERCONNECTE AVEC D’AUTRES: la COOPERATION AVEC LES PORTS DU RHIN SUPERIEUR**

Les ports du Rhin supérieur projettent de mettre en œuvre un logiciel commun de gestion de planification des arrêts aux terminaux : RPIS (Rhine Ports Information Service). Son déploiement est actuellement en cours au sein de différents ports.

VNF, EDF, RHEINPORTS et le PAS (Port Autonome de Strasbourg) travaillent de concert, dans le cadre d’une convention de coopération, sur un projet d’interconnexion entre les deux plateformes e-RIS et RPIS afin d’affiner le planning d’utilisation des terminaux sur la base des heures d’arrivées prévues des bateaux et de la durée prévisionnelle des escales des bateaux. Ainsi, e-RIS permet de calculer le temps de passage aux écluses ou la durée de la navigation. RPIS permet d’estimer le temps d’escale, de chargement et de déchargement. Grâce à l’addition de ces données, l’ambition sera à terme de pouvoir calculer un temps d’arrivée estimée (ETA – Estimated time of arrival) à un port pour un voyage comportant des escales.

Les avantages pour les ports sont de prévoir les moyens logistiques nécessaires pour le chargement et le déchargement des bateaux. Pour les bateliers, de faciliter la planification du voyage et de réduire les attentes.

Les échanges de données entre e-RIS et RPIS vont se faire dans le cadre de dialogues de machines à machines : les web services.
Lorsque des formats standards européens existent, ils sont privilégiés. Mais il n’existe pas à ce jour de standard européens pour une transmission des ETA par voie informatique.

A ce jour une phase de test a été réalisée pour s’assurer de la faisabilité informatique. A terme, le processus envisagé est le suivant :
- Deux jours avant l’échéance, les bateliers saisissent les arrêts prévus aux terminaux dans RPIS. Le nombre de conteneurs devant être manipulés est précisé ; cela permet d’estimer la durée de l’arrêt.
- Les opérateurs de RPIS gèrent les éventuels conflits de demandes d’utilisation de quai (RDV) au même moment et le cas échéant reviennent vers les bateliers.
- RPIS met à disposition les heures d’arrivées convenues et la durée des arrêts aux terminaux à e-RIS.
- e-RIS prend en compte les durées prévisionnelles des escales pour affiner l’ETA.
- L’ETA de e-RIS est transmis à RPIS. Les opérateurs de RPIS sont informés des éventuels changements de planning et conflits de RDV aux terminaux.

Les données (durée du chargement / déchargement, ETA) pouvant évoluer au fur et à mesure de l’avancée du bateau, plusieurs cycles de calculs sont réalisés de manière itérative, jusqu’à l’arrivée du bateau au terminal.

**CONCLUSION ET PERSPECTIVES**

En 2015, le projet a débuté avec 10 utilisateurs clés qui sont restés fidèles ! Depuis, de nombreux autres utilisateurs les ont rejoints et se nourrissent régulièrement des informations mises à disposition pour préparer ou suivre les voyages. Cet outil a donc facilité la mise à disposition d’informations et a rencontré un véritable succès comme le montre le nombreux téléchargements de l’application mobile

e-RIS n’est pas un outil figé. Le but est bien d’offrir encore davantages de services sur le Rhin. Parmi les pistes envisagées :

- Travailler sur les temps d’attentes moyens aux écluses et sur les durées de navigation sur le Rhin supérieur en fonction des créneaux horaires, outil qui pourrait contribuer à une optimisation des temps de passage
- Renforcer encore les liens avec les ports pour une meilleure intégration dans la chaîne logistique.

D’un point de vue national, VNF crée actuellement un SIF sur le Bassin de la Seine. Son déploiement, sur la base de e-RIS est en cours avec l’intégration de quelques spécificités (marées, alternats)
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Project Masterplan Digitalisation of Inland Waterways

Paper

Digitalisation is an important source of growth, innovation and new business, transforming our economy and society at a rapid pace. Inland Waterway Transport requires a digital transition of the business processes of stakeholders in Inland Waterborne Transport (IWT).

In 2016 the European Commission – DG MOVE - commissioned a study for investigating the potential for digitalisation in the IWT sector and to define a concept for the Digital Inland Waterway Area – DINA. In the DINA study [1] it has been concluded that it is essential for the future competitiveness of inland waterway transport to follow the trends in digitalisation: in some cases IWT competes with other modes of transport whilst in other cases IWT is part of a larger multi-modal chain making collaboration an essential prerequisite.

An important pre-condition for a successful digital transition is the availability of digitalised Inland Waterways supported by the fairway authorities. The digital infrastructure of Inland Waterways will support the digital transition of business processes in IWT and will facilitate the IWT stakeholders with the required harmonised and standardised digital services on the European network level.

In order to meet this challenge, five national fairway authorities of the Member States Austria, Belgium, France, Germany, Netherlands are embarking on a joint project to create a Masterplan Digitalisation of Inland Waterways. The masterplan will result in a roadmap for fairway authorities for the digital transformation of Inland Waterways to support navigation, traffic and transport management and logistics.

The roadmap will be based on a joint and integral digitalisation strategy for Inland Waterways under the responsibility of the participating fairway authorities, ready for execution in the period 2022 till 2032. Such a digitalisation strategy is believed to be shaped by three main forces:

1. Business developments related to the IWT domain.
2. Technological developments with respect to digitalisation.
3. Facilitators necessary for viable business and technological developments.

Ad 1. Business developments
In the coming years the authorities responsible for the inland navigation network will be confronted with a large amount of requirements caused by business driven developments. These developments will lead to specific requirements on the availability of digital information services related to the IWT network:

Smart Shipping: Smart Shipping is the highly automated navigation of vessels on the waterway network. Smart Shipping will make waterborne transport more competitive and therefore more attractive. Because
autonomous vessels need to load and unload cargo and pass safely through locks and bridges, the infrastructure on the shoreside will need to be adapted to accommodate the data exchange needs of these vessels. Within the context of Smart Shipping, the role of the fairway authorities is expected to focus on the provision of safety related services of very high quality. The quality aspects will be related to availability, accuracy, completeness, actuality and integrity of data.

**Synchro-modality** is seen as the optimal, flexible and sustainable use of road transport, rail transport, inland shipping and maritime shipping. Multimodal logistic services will require information services over the complete transport chain with the goal to create reliable transport services independent from the modes of transport. Digital information services related to the inland waterway network e.g. for transport planning based on the requirements of the multimodal logistic chain, are the basis for a successful integration of inland waterway transport in the logistic information chain.

**Port and Terminal (logistic) information Services** are in operation since many decades to optimise the operations in ports and on terminal. Over the years so-called Port Community Systems or Cargo Community Systems (CCS) were implemented to handle the exchange of information related to cargo and cargo transport, import and export. Port Community Systems provide services not only to the ports community but also to organisations with the logistics chain of all modes, sea, inland water, rail and road. These are services in the area of transport management and the pre-notification of terminal visits, both on the level of the modality and cargo. Based on the pre-notification, terminal planning can be optimised and the utilisation degree of the inland transport modes improved, as on-carriage operators have a clear view of the availability of the cargo and the respective government control and document status. The interaction between ports, terminals and IWT requires seamless digital interfaces and reliable information services.

**RIS enabled Corridor Management**

Given the fact that especially in Europe a multitude of fairway authorities is responsible for their specific fairway stretch within a much larger transport corridor, a much more structured approach for cooperation was defined in the CoRISMa project [2] and will lead to the corridor-based implementation of selected and harmonised RIS in the ongoing COMEX project [3]. Digitalisation is essential for a successful implementation and operation of Corridor Management.

**Ad 2 The technological developments**

There are many technological developments that will support the above-mentioned business developments and will be essential for the digitalisation in IWT and the Inland Waterway Network. **New Technologies** like Internet of Things (IoT), Artificial Intelligence (AI) and Big Data will be studied in order to define their benefits for the digital transition.

In the context of smart shipping the development and use of **smart sensing** will be essential, with the objective that vessels can respond automatically to their environment. Sensors that detect infrastructural information or hazards allow a ship to take action itself based on this information or generate a proposal to the crew for action.

Since the early stage of sailing, **Positioning Navigation and Timing (PNT)** information has been vital to ensure navigation safety of navigation. PNT is part of the critical infrastructure necessary for the safety and efficiency of vessel movements, especially in congested areas. Moreover, nowadays, PNT has become a key element of smart shipping. The study on smart sensing as well as on PNT services are of high importance for the digitalisation of IWT.

**IWT suitable technologies in the road, rail and maritime traffic and transport domains.** In the road, rail and maritime world stakeholders are more and more making use of information technology to improve the safety, security, reliability and efficiency of waterborne transport. As a specific example the maritime world is developing the concept of the Maritime Connectivity Platform [4]. This connectivity platform is a reliable basic communication framework able to act as a platform for information providers to present the available information and services and provide all the necessary information for interested and authorized users to retrieve the information. It is worth studying whether this platform concept can be beneficial to be used also in the IWT domain.
An essential precondition for efficient synchromodal data exchange is that there is a harmonised information model which is accepted by the stakeholders. This information model should be based on an information Service Directory. Having a harmonised information model and service directory would enhance safe, efficient, reliable inland navigation and its connection with other modes of transport and it would strengthen the position of IWT in the transport chain.

**Ad 3. The facilitators affecting the digitalisation of inland waterways.**

**Rules and regulations** will have an impact on the development of services and technologies as well as the related information and data collection, processing, storage, exchange and provision in the multimodal transport environment. The business development and technological development and consequently digitalisation of IWT might be hindered by rules and regulations. In the context of this project legal measures might be needed to facilitate the digitalisation process.

It is evident that standardisation of systems and data as well as a well-defined data-quality level for information and data are essential for the performance of information services in traffic and transport management.

**Cybersecurity and privacy.** The digital era is transforming shipping and bringing enhanced monitoring, communication and connection capabilities. At the same time, it creates new and profound (cyber-)risks to all aspects of inland navigation. Therefore, all feasible measures for mitigating these risks need to be implemented, monitored, and continuously improved. These measures must include contingency plans with procedures on how to manage situations where the integrity of IT systems has been compromised due to cyber-attacks.

For each of these developments a harmonised set of proposals will be created related to the digital transformation of inland waterways regarding service requirements, information and data requirements, technical solutions and facilitating measures to be taken.

Implementation of the proposals will be based on the roles and responsibilities of the participating fairway authorities and with a focus on the tasks of these authorities with respect to digitalisation of the inland waterways. A set of implementation scenarios will be developed in which the technical, organisational, financial and operational consequences will be defined. These implementation scenarios will be aligned with stakeholders in IWT and are expected to benefit from the current implementation of RIS and will build on the results of the recent RIS enabled Corridor Management projects CoRISMa and COMEX. As such it will create new possibilities for the deployment of RIS.

The **Masterplan Digitalisation Inland Waterways** will provide insight into the current inland waterway digitalisation readiness level and steps to be taken to reach desired levels in order to leverage IWT capabilities. It intends to provide concrete action perspectives for both participating and other fairway authorities.

The masterplan digitalisation inland waterways aims to provide a favourable starting position for IWT digitisation initiatives, not only within the IWT domain but also connecting to road transport and other modalities. This will directly and indirectly strengthen IWT as an essential and attractive transport mode in the transport chain by increasing the efficiency of inland navigation, thereby giving positive impulses to the IWT sector.

The Masterplan Digitalisation of Inland Waterways paves the way to a stronger, more reliable and sustainable IWT and as such directly and indirectly contributes to the EU 2020 strategy and the European transport policy.

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Full Paper:  

1. Background information  
The concept of River Information Services (RIS) was first initiated by the European Union initiated in 1998. Since the first European RIS initiatives, this concept on information exchange to support traffic and transport management in inland navigation has found its way throughout the world. River Information Services are in an implementation stage in North and South America, Europe, Asia and Africa. PIANC established a Working Group in 2002 that developed the Guidelines for River Information Services. These Guidelines are an important pillar in the implementation of River Information Services; the Guidelines have been updated in 2004, 2011 and 2018. In the 2004 update, further developments on services and standards as well as the technical and practical experience were included. In 2009 PIANC established the Permanent Working Group 125 with the task to keep the Guidelines for River Information Services up to date. In the 2011 update to the guidelines, WG125 focused on the world wide status of the implementation of River Information Services. The 2018 update to the guidelines focused on aligning RIS services with the maritime e-Navigation concept, including introducing the e-Nav concept of operational and technical services. Developments in the area of corridor management were incorporated, primarily affecting the existing RIS Traffic Management Information service. Finally, the 2018 guidelines were revised to move from a European-oriented perspective to guidelines optimized of use on a worldwide scale.  

2. The role of RIS within a multimodal network  
Inland Navigation and River Information Services is facing in the coming decade many new challenges from various perspectives. All different transport modes are making the shift towards digitalization. Inland navigation is also moving towards a digital world under impulse of different worldwide initiatives. This means data and information services will become more and more crucial and critical for transport and traffic management in inland navigation.
With the introduction of the concept of the Physical Internet, the different transport modes need to invest in services, feeding a multimodal network able to process a transport request or need in the future. To make the inland waterways a valuable and trustful link within a multimodal network different challenges need to be tackled:

- Geographical upscaling: River Information Services will need to interconnect different stakeholders of a waterway network on a continent by means of a (pan-) corridor management approach versus a national or regionally focussed approach like it is nowadays. This current narrow approach is hindering the growth of inland navigation.

- Multimodal/Synchro modal ready: Once these international waterway networks are able to offer operational and technical services, interconnection with other transport modes will be required. By exchange knowledge, experiences, ideas, technologies and lessons learned these different transport modes can converge to a similar approach and framework. This approach will finally result in a multimodal network. The big challenge will be the coordination of such an approach covering and steering the different transport modes to act to fulfil a common goal, which is the stage of synchro modality.

Synchro modality is the optimal flexible and sustainable allocation of cargo to different modes and routes in a network under the direction of a logistics service provider, so that the customer (shipper or forwarder) is offered an integrated solution for its (inland) transport (source of definition: TUDelft - Synchronmodal container transport).

- Future Proof: new technologies will allow new applications in the area of infrastructure and vessels, including increasing requirements towards data and information service. At the same time, these new technologies will challenge the existing technical and operational services to evolve. These services must be designed to be scalable, trustful, of high quality and flexible enough to resist future demands. In the specific case of autonomous vessels, this need to be addressed within the concept and framework of Smart Shipping. Within this framework not only the vessel is taken into account, but also the interaction with the shore infrastructure (bridges, locks, traffic centres, …). Therefore RIS developments must be closely in line with the concept of Smart Shipping.

One can conclude the role of RIS is still very important and focused on safety and efficiency, but faces the opportunities and challenges of new technologies and trends. RIS will be the facilitator for inland waterways to become a trustful link within a synchronmodal transport network.

3. The approach of PIANC WG 125 (2019-2022)

How is the PIANC WG 125 going to deal with these complex challenges? The final goal is a valuable contribution of Inland Navigation to a well performing synchronmodal transport network, therefore a good insight in other transport modes, together with a decent knowledge in different technology trends, is necessary.

Since River Information Services are covering a set of services on both transport and traffic management, RIS should be able to close the current gaps to reach the above mentioned goal.

Related to other transport modes investigations will be necessary and done in:
- Intelligent Transport Systems related to road traffic
- Telematics Applications within the EU rail system, mainly focused on Freight services (TAP)
- E-Navigation related to Maritime Navigation
These investigations in intelligent transport systems of other transport modes will allow the PIANC WG 125 to look for similarities and connections with inland navigation and thus defining new or updating existing River Information Services (both operational and technical) to support practical use cases. E.g. once Smart Shipping is able to take place in a safe way with maximum respect of harmonization and standardisation, one of the next phases can be focused on efficiency within traffic management.

Finally these new or updated services need to be harmonized in a worldwide way, so inland waterway networks across continents can be interconnected via Maritime Services (i.e. concept of e-Navigation) allowing industry to benefit from it in a cost effective way stimulating the use and benefits of Inland Navigation.

The final report of PIANC WG 125 will elaborate this research and formulate guidelines useful for e.g. implementing countries, possible directives and regulations, Research & Development projects, implementation projects, etc.
Interaction between RIS in inland navigation and ITS for roads. The bridge opening dilemma

The Netherlands came from water and still depends on water. Industry, transport, recreational time – all these sectors intensively use thousands of kilometres of waterways in and around the cities and throughout the provinces. So intensively that inland navigation and vessel traffic management will demand more and more attention from road traffic management during the upcoming years.

For both inland navigation as well as road traffic, the focus has been to optimize the use of the available civil infrastructure. Considering the organisation concerning vessel traffic as well as road traffic is mostly separated, the initiatives for optimizing the use of the fairways and roads are also often separated. And now, the autonomous developments in vessel and road traffic are increasingly demanding timeliness and predictability of travel time. This requires a multi-domain approach at the locations where vessel traffic and road traffic meet which is at movable bridges and freight transport terminals. First, the different developments will be discussed before going into more detail.

More emphasis on waterborne freight transport
The increase of freight transport in combination with the pressure on the road network keeps the initiatives alive to transport more freight by water. This refers to transport via inland waterways, when possible in combination with transport along the coastal waters, the so-called ‘Motorways of the Sea’. The increasing emphasis on low-emission manners of transport only enforces this trend. Waterborne transport is much more environmentally friendly than road transport. Moreover, the costs are lower and it leaves more space on the road. For example: one container ship can transport dozens or even hundreds of containers, while one truck can, at the most, handle two, depending on size. More than enough reasons for the government to stimulate inland waterway transport. But what does that mean in terms of inland navigation and vessel traffic management?

Currently, approximately one third of freight transport in the Netherlands is waterborne. If we want this number to increase, we will also need to transfer more and more high-end (= expensive) goods...
and goods with a limited shelf life from the road to water transport and vice versa. This leads to additional demands regarding the strictness and reliability of inland navigation.

The by Europe much desired concentration of freight flows on logistic routes along the *Motorways of the Sea*, goes hand-in-hand with an increasing interest in ‘synchronmodal’ transport; or in other words, transport along logistic routes on which it is possible to switch easily between the different modalities at any time, after each route segment. The implied promise of synchronmodal transport is that the number of empty journeys will drastically decrease. The position of a modality, including inland navigation, as link in the network of logistic chains enhances the need for strict and reliable travel times.

The increasing claim on strict and reliable travel times of inland commercial navigation result in the fact that inland navigation also urgently requires a smooth passage at locks and movable bridges.

**Two sides claim free passage**

International river arrangements, which were once initiated by the Vienna Convention and the Convection of Mannheim, still protect the free passage of sea-going vessels. In and around the seaport areas, this fact has a claim on the opening of movable bridges for maritime navigation in a timely manner.

However, not only commercial navigation requires a smooth passage on inland waterways. Recreational navigation, with its own economic importance and character, also has its own demands. The Netherlands has the unique situation of a so-called 'Staande Mast Route' (Mast-Up Route) which enables recreational navigation to travel with a fixed mast from east to west and north to south. Specifically, this means that the bridge also opens for recreational vessels with a fixed mast on fixed times. These times are often originally planned outside rush hour, but are in danger of increasingly overlapping with rush hour since the shoulders of rush hour are expanding more and more.

**Increasing need for timeliness for road traffic**

Road traffic experiences developments of its own. With the increasing importance of optimizing the use of the road and a low-emission mobility, timeliness has also a crucial role here. The importance of, for example, (high-end) public transport is also increasing, which requires a strict adherence to the time schedule (reliable travel time), even on routes that include movable bridges.

In addition, there are developments in our society that are penetrating the world of road traffic management. Think for example of centralization in health care: hospitals centralizing units, closing one location and thus losing any specialization offered locally. The new idea is that the quality of health care must come first and that people will thus have to travel a bit further. But this results in a new claim for ambulance services. Those ten to fifteen minutes of extra travel time to a hospital which has centralized all the important units and specialization should be doubled in terms of the ambulance that needs to cover the additional distance to said hospital. The ambulance also needs to return to its own region in order to ensure equal distribution and availability of ambulance services. Also, the additional ten to fifteen minutes of travel time requires (even) more strict and reliable travel times for ambulances in case of emergencies. Due to partially similar reasons, the police and fire department are also struggling with the required response times and they have claims of their own concerning the reliability of travel times. Claims that translate into a strong request to grant free passage at movable bridges to emergency services with blue flashing lights and to a (much) lesser extent to the same emergency services that are making their way back to their stations.

**Redirect road traffic in a timely manner**
From the road user's point of view, an optimized use of the road network comes down to choosing the right route and thus direction and being able to maintain the correct speed. If we want a driver to not only consider his/her own interest, but to, either consciously or not, also take the interests of the traffic manager to better distribute road traffic across the road network and corridors, and the interests of vessel traffic and the emergency services into account, we then have to provide both the drivers as well as the skippers with information. Information that allows the skippers and road users to better plan their journey and arrival with less hindrance and irritation and without any unnecessary use of fuel and emission of exhaust gases.

With the program Blauwe Golf Verbindend (BGV) of the Dutch Ministry of Transport, collaborating waterway & road managers devote themselves to improve the service regarding the users of waterways and roads through the implementation of innovative technology and smart collaboration. Together they created smart mobility solutions for reliable and current information about open bridges and available berths in ports. This successful collaboration is constantly expanding with more governmental partners.

Thanks to Blauwe Golf, there are over a hundred bridges that are self-communicating and there is easy insight into the available berths in the Ports of Rotterdam, Amsterdam and the Agency of Waterways and Public Works of the Ministry of Transport (Rijkswaterstaat) due to the BLIS system. Current data that is available for free through websites and apps which are being used by an increasing number of skippers and road users on a daily basis.
Data that provides insight for the governments themselves in a cross-regional manner into traffic flows in order to further optimize their own services.

Where fairways and roads meet...

In the Netherlands, this game of interests comes full circle at the movable bridges. Each target group – commercial navigation, recreational navigation, trucks, public transport, the emergency services – increasingly lay claim to the fact that they require a smooth passage. And for the time being, we are not taking trains into consideration, seeing as this mode of transport always has priority.

What is the impact of this game of interests in relation to vessel and road traffic management? The impact is twofold, namely (1) the coordination of the traffic organisation on the road and fairways and (2) the exact determination of the right moment of operating the bridge at times the claims of multiple modalities occur together.

Traffic organisation for an optimised traffic flow on both the fairways and roads

We start with traffic organisation. This is a term that originates from the domain of vessel traffic management; from inland vessel traffic services (Inland VTS) to be precise. It discusses information service, navigational service and traffic organisation. Traffic organisation literally means preventing the occurrence of dangerous situation on the waterway by collaborating with the skippers in order to distribute the movement of the vessels in the time available on the waterway, so a safe and efficient vessel traffic situation can be established. From the goal to optimize the use of the waterways, traffic organisations can be stretched to organizing vessel movements in such a way that, provided the conservation of the safety aspect on the waterways, strict and reliable travel times can be achieved.
In provinces and municipalities, this additional form of traffic organisation along waterways with lots of movable bridges results in a schedule for vessels: a so-called 'blue wave' for vessels which, when they have been registered in the schedule, will encounter bridges that open upon their arrival. In a similar manner, vessels can be offered a blue wave in vast port areas.
Figure 3. Coordination of the ridge openings to provide a ‘blue wave’ to skippers

On the road, traffic organisation is best captured in the timely activation of a traffic scenario that anticipates the operation of the bridge in favour of vessel traffic. A traffic scenario that alerts road traffic to an (upcoming) opening of a bridge in a timely manner and provides an alternative route. And, obviously, prepares the alternative route for a higher traffic demand; for example green traffic lights that last longer along the alternative route. Combined with or as part of activating the traffic scenario, real-time data about the bridge that is to be operated and eventually opened can be communicated to service providers. This combined results in information that allows the skippers and road users to better plan their journey and arrival with less hindrance and irritation and without any unnecessary use of fuel and emission of exhaust gases.

The right moment

We then find ourselves once again at the point of determining the right moment to operate the bridge; the so-called micromanagement. Around the bridge, the situational awareness of the bridge operators needs to be heightened by giving them a broader arrangement of information. This concerns information regarding the condition of the waterway itself from the notices to skippers / mariners, current positions and speeds of upcoming vessels, but also involves the emergency services with blue flashing lights and current positions of public transport buses in reference to their schedules. The bridge operator is thus able to construct a proper overview and to manage a situation around a bridge. The next step could be determining a priori based on this information and a set of decision-making guidelines of ‘who has priority for a bridge passage at what time’, generating automatic advice for the bridge operators. Advice that would indicate down to minutes what the best moment is to operate the bridge.
Figure 4. Overview for a bridge operator with the fairway stretch capturing his/her ‘own’ bridge (left), the log with the vessels passed so far (midst), an online advice for the next bridge opening (upper right) and an overview of the current punctuality of public transport busses right)

The interesting thing about decision-making guidelines is that it must include the disparate value of time for various modalities. For example: suppose a series of movable bridges opens once every half hour to allow vessels to pass. These vessels will adjust their speed to the opening times of the bridge, but have to wait several times during the length of the entire corridor. The cars on the road spend less time waiting, but here the numbers come into play: when a lot of cars have to wait for only a couple of minutes, the 'vehicle loss hours' quickly add up to several hours. A five minute wait is truly pressing when an ambulance on its way to an emergency encounters an open bridge or when a police car is heading to an accident site. And high-end public transport, such as an express bus or streetcars, cannot endure any waiting.

In summary: careful management of the game of interest regarding vessel and road traffic management explicitly requires a multi-domain approach from one integrated traffic centre or from separate but closely collaborating centres for road and vessel traffic.

In practice: solving the bridge opening dilemma in the province Noord-Holland

This concludes the backgrounds and conditions of a proper coordination of vessel and road traffic management. What has to be done in order for these two worlds to seamlessly overlap in reality?
Figure 5. Cruquius bridge in the province Noord-Holland

The province Noord-Holland has already made considerable headway with solving bridge opening dilemma. This province has almost three hundred movable bridge decks. In terms of *Blauwe Golf Verbindend*, they have taken the initiative to develop a system that supports the bridge and lock operators. This system was finished early 2018 and was named BMS 3.0, with BMS meaning ‘online decision support system for bridge operators’ (or literally: bridge management system). It shows, among other things, when vessels will be arriving at their object and provides insight in vessel traffic in the immediate vicinity. The system also shows request to keep the bridge closed for emergency services with blue flashing lights, like police cars, fire trucks and ambulances. When an emergency service on duty approaches the bridge, the system advises not to operate to bridge. The same goes for (high-end) public transport, such as the express bus to Schiphol Airport. The operator is advised not to operate the bridge when the express bus is approaching, most importantly when it is already behind schedule. This prevents travellers from missing their flight due to an open bridge. The road traffic centre can also influence the advice, for instance during a spike in traffic activity. And vice versa, a bridge opening can be announced by the traffic centre which allows for the road traffic to be dynamically redirected.

Bridge and lock operators register the passing of vessels and their direction in the system so this information is also visible for bridges and locks down the route. In addition, they record malfunctions and fill out the inspection reports. This way, it becomes immediately clear what happened during their shift. The bridge openings and malfunctions are made publicly available via the platform *BlauweGolfVerbindend.nl*, for instance in the National Data Warehouse for Traffic Information (NDW). In addition, the system also shows weather forecasts and notices to skippers / mariners.

Due to this system, road traffic can flow better. But how is it helping inland navigation? Operators anticipate the arrival of vessels and make sure that their waiting time is as minimal as possible. In addition, the province Noord-Holland is introducing waterway route planning (schedules for inland navigation) that can provide a blue wave for vessels. When vessels adhere to the advised speed, they can pass multiple bridges without waiting: the bridges will open as the vessels arrive at said bridges. Due to the connection with the *Blauwe Golf Verbindend*, skippers get
insight into the current waterway route planning and can 'register' themselves to be included in the planning. By keeping the vessels in convoy, the bridge will not have to be opened as often and there are thus less interruptions for road traffic.

First evaluation results ((source: “Evaluatie Blauwe Golf Vervolg – Eindrapportage”, Arcadis on behalf of the province of Noord-Holland, 28 September 2018) show that the process of operating bridges is properly facilitated and even simplified. Critical elements in using the BMS prove to be:

- The availability of the data. Trustworthy advices build upon data that is always available and of the right quality;
- the transparency is the rationale behind an on-line advice and the data this advice is built upon. Especially in those cases where the advice is counterintuitive for the bridge operator;
- the participation of all waterway & road operators along the considered fairway corridors. In the period after launching the BMS3.0 some of the waterway & road operators in the province Noord-Holland where still experimenting with the BMS3.0 to gain a better understanding and thus trust in the system.

The next step, anticipate in road traffic management on predicted bridge openings when maritime vessels come in place

The possibilities of vessel traffic organisation to provide ‘blue ways’ are limited in areas with maritime vessels. After all free passage of maritime vessels is still protected. This means that the bridge will be opened, regardless of the traffic situation on the road. The result is that visitors and residents of municipalities in a sea port area have to deal with a daily dilemma: what is the fastest route from my home to their destination and back? A good example is the situation in the port area of Rotterdam. Without congestion, the Botlek tunnel is the fastest route for most residents. Due to the limited capacity, this route is often congested and alternative routes via the Botlek bridge and Spijkenisser bridge are explored. But then vessel traffic comes into play. Both bridges open on average at least once during morning rush hour and once during evening rush hour. Such openings have a large impact on traffic: many drivers are surprised and the high traffic intensity during rush hour result in a considerable amount of congestion. After an opening, it can take quite some time for congestion to be resolved. These openings are not expected by the road users and they cannot anticipate quickly enough. This leads to an unexpected addition to their travel time. Soon, drivers learn to avoid the bridges which results in underutilization.

Guiding road users in situations with maritime vessels is the next step. A first version of this add-on functionality will be piloted late 2019 – beginning of 2020.
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RIS, Puerto, Sevilla, Guadalquivir, AIRIS

Title:
AIRIS-PS Project for the complete implementation of RIS (River Information Services), in the Port of Seville and in the Guadalquivir Waterway

Abstract:

Introduction
The AIRIS-PS project is a project financed by the European Commission within the funding instrument of the Connecting Europe Facility (CEF) for Transport under the priority of River Information Services. The objective of the priority is to implement River Information Services in the Port of Seville and in the Guadalquivir harmonised with the practices applied in the European Inland Waterway Network. River Information Services and Systems are designed to provide support to improve traffic and transport management and enhance operational procedures. RIS will contribute in an essential way to the improved competitiveness of waterborne transport in the supply chain. In this sense, the AIRIS-PS project is considered as a key project for the improvement of the accessibility and capacity of the river access to the Port of Seville. River Information Services will lead to the increase of transport to the port of Seville not only the number of ships calling for Seville will increase but also bigger vessels can visit the port of Seville.

River Information Services in a maritime environment
Unique in the AIRIS-PS project is that RIS related systems will be implemented in an inland river and inland port with maritime transport and as such the project is contributing to the strategic objective of safety and efficiency in the Guadalquivir and to the competitive transport through the Port of Seville by:

- Improved knowledge of the waterway: that is, precise bathymetry, accurate tidal model, precise measurement of the height of the surface of water and waves, etc.
• More information on traffic on the waterway and in the port: characteristics of the vessel - size and draft - characteristics of the cargo, etc.
• Better traffic management in the Guadalquivir Waterway: optimization of human resources (for example, navigational practices) and materials, of the anchoring areas, optimization of the convoys entering and leaving the road, etc.
• Better management in case of emergencies.
• Better coordination of port operations, etc.
• Better transport information in a multimodal environment: maritime transport.

The project will proof that River Information Services will be applicable in the maritime environment in Seville and the synergy of maritime and inland information services will be highly beneficial for multimodal transport information services.

The project execution
The AIRIS-PS project is structured in 2 phases:

• Phase 1: Implementation Studies which includes:
  o Execution of a state of the art study on River Information Services in Europe and the applicability in the port of Seville and the Guadalquivir.
  o Definition of the System Architecture of a RIS related system concept in the Seville domain.
  o Identification of the systems and services to be implemented in order to concretize the Scope of the Project.
  o Definition of Pilot Design Bases.
  o Plan for the implementation of the standard.

• Phase 2: development, implementation, testing and validation of Pilots including the development of the Plan for the complete implementation of RIS adapted to the Guadalquivir Waterway. Three pilots will be implemented based on different types of RIS services:
  o FIS - Fairway Information Services
  o TIS - Traffic Information Services
  o TMS - Traffic Management Services

The following figure represents the functional systems architecture as the basis for the AIRIS-PS implementation plan and implementation strategy:

![Figure 1. Preliminary architecture of the system with the implementation of the pilots](image)

The approach of the AIRIS-PS project is based on the application of the guidelines for the implementation of River Information Services as developed and published by PIANC.

Scope of RIS services Pilots

**Pilot 1. Navigable Channel Information Services (FIS)**
Pilot 1 focuses on providing different users with Waterway Information Services, including the acquisition, representation and publication of real-time information on the waterway and port infrastructures.
This information will also serve as a source of information for the rest of the pilots to implement new functionalities. Pilot 1 will consider the implementation of the following subsystems:

- Common database and adaptation of the FIWARE platform for the Information Management
- FIS Web Portal
- Sensorization of Hydrological and Meteorological conditions of the estuary
- “Intelligent" Maritime Signalling System
- Drafting and publication of a Port Information Guide.

![Figure 2 Pilot functional architecture FIS](image)

**Pilot 2. Traffic Information Services (TIS)**

Pilot 2 focuses on providing different users with Traffic Information Services, including the acquisition, representation and publication of real-time traffic information from vessels equipped with AIS. Pilot 2 will consider the implementation of the following subsystems:

- Port Monitoring System for monitoring traffic and navigation on the Guadalquivir and in the port of Seville
- Implementation and automated generation of bathymetric charts
- Portable Pilot Units to be used by the pilots to support safe and efficient navigation.
- Travel Planning Tracking Application for the visualisation of the voyage plans – as to be developed in pilot 3 – on board of the vessels carrying Portable Pilot Units and in the Port Monitoring System.

**Pilot 3. Traffic Management Services (TMS)**

Pilot 3 has the objective to increase the accessibility of the Port through the implementation of a tidal window voyage planning system. Developing a voyage planner as traffic management tool has the overall objective to increase in number and size vessels that will visit the port of Seville. Pilot 3 will consider the implementation of the following subsystems:

- Generation of the Digital Waterway Network (DWN) in accordance with the RIS index, for the characterization of the navigable waterway.
- Travel Planner. SW tool that allows to calculate the possible itineraries of the ships for a given date, generating a forecast of the navigation plan for that date taking in consideration the tidal preconditions.
Conclusion
The AIRIS-PS project is a big step into the digitalisation of the traffic and transport services of the Port of Seville and as such transforming the port into a Smart Port. The Port of Seville is an important hub in the transport network in the European core transport network, connecting the Motorways of the Sea, via an inland waterway with the Mediterranean Core Transport Corridor; the step towards digitalisation of the transport chain by the project AIRIS-PS is consequently of great added value for the whole transport chain. The Port of Seville is in preparation for the next step and will launch in 2019 the project “AIRIS-II Synchro”, a project that will be supported by the European Commission. The main objective of this follow up project is to demonstrate the feasibility of the development of innovative systems to increase the efficiency of Port of Seville by favouring Synchro-modality. The project will develop and implement systems intended to enhance synchro-modality of port operations.
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Keywords:
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Security, Waterways Management, Marine Planning

Title:
Enhancing Accessibility and Usability
of Automatic Identification System (AIS) Data
Paper:

The ability to identify watercraft and their intentions is essential for safe and secure navigation, situational awareness, and efficient movement of goods. Developed in the 1990s, Automatic Identification System (AIS) is a technology specifically designed to facilitate and provide this maritime capability. AIS data forms a key piece of maritime knowledge, which can be used to better inform operational and policy decisions and enhance entrepreneurial opportunity.

AIS information is collected and used by various entities around the world, including government agencies, the military, and commercial providers. This paper will examine the use of AIS data collected by government entities, focusing on the United States. It will examine the usefulness of this data, particularly when it is shared among government agencies. It will then highlight the challenges facing users of this data, suggest some ways to address these challenges, and provide specific examples and suggestions that have been implemented or are underway in the United States. While this paper is U.S. centric and not restricted to inland waterways, the issues addressed are universal and just as applicable to rivers as they are to coastal and deep-sea waters.

The Value of AIS Data

Vessel traffic information derived from AIS data provides great opportunities to maritime stakeholders to enhance marine transportation system safety, efficiency, and security.

To gauge the status of current use of historic, terrestrial AIS information and associated challenges within the U.S. Federal government, detailed requirements from agencies were collected to better understand what they are using the data for and to clearly define challenges they face in acquiring and using AIS information. Agency requirements were analyzed in terms of data accessibility and usability. Accessibility is primarily concerned with user capacity to access and ingest data; usability is concerned with user access to processes used to create information from the data, or the final products themselves. Access to data alone does not determine usability. Transforming data into actionable data, information, and knowledge products requires sustained value added by both users and producers.

Table 1 High-level overview of U.S. Federal agency responsibility and application of AIS information.

| Federal Agency | AIS Lifecycle Role | Application | | |
|----------------|--------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| BOEM | X | X | | | X | X | |
| BTS | X | | | | | | |
| EPA | X | | X | | | | X |
| FCC | X | X | | | | | |
| MARAD | | X | | | | X | |
| NAVY | X | X | | | X | X | |
| NOAA | X | X | | | X | X | X | |
| SLSDC | X | X | | | X | X | X | |
| USACE | X | X | X | | X | X | X | X | |
| USCG | X | X | X | | X | X | X | X | |

Certain Federal agencies have significant expertise and capabilities for using AIS data, largely related to mission specific responsibilities. Federal agencies both provide and use AIS data, with some generating AIS data and using AIS-derived products within the same agency. In many cases, different offices within a given agency utilize AIS information for differing purposes. Three agencies are providers of terrestrial AIS information: U.S. Coast Guard (USCG), U.S. Army Corps of Engineers (USACE), and the St. Lawrence Seaway Development Corporation (SLSDC). A handful of agencies disseminate Federal AIS data and derivative products to more easily facilitate AIS data accessibility and usability for partners and stakeholders.
The first AIS system implemented in the U.S. was in the St. Lawrence Seaway. The Saint Lawrence Seaway is a critical transportation link that connects the markets and manufacturing, mining, and agricultural producers of the upper Midwest and Canada to each other and to the Atlantic. The U.S. SLSDC and Canadian St. Lawrence Seaway Management Corporation have long employed a Vessel Traffic Service system to monitor the position, course, and speed of commercial maritime traffic to ensure safe and expeditious passages through the Seaway while minimizing shoreline erosion and protecting riparian interests.

USACE uses AIS to assist in lock operations, waterway monitoring, navigation planning studies, and communication of navigation safety information to vessels. USACE has also developed robust analytical capabilities for AIS data that provide insight into vessel operations related to USACE-maintained infrastructure such as dredged channels, breakwaters, and locks. These capabilities have been applied to examine topics such as vessel behavior in critical habitat areas, on-water incident investigations, and port resilience in the face of hurricanes.

The Value of Collaboration and AIS Data Sharing

Agencies with maritime missions can enhance the benefits derived from the use of AIS data by expanding coordination with other government partners and stakeholders. USCG, USACE, and SLSDC each manage independent AIS networks along the U.S. coasts, inland waterways, and Great Lakes, respectively. While each of the agencies have their own missions in these overlapping regions, they have worked together to produce and maintain a cohesive national AIS network that provides a consistent picture of vessel traffic across the U.S.

While the original intent for AIS was for vessel safety and waterways monitoring, stakeholders are increasingly recognizing the applicability of the data for a variety of purposes that have great value both within and outside the government. AIS data is used for risk assessments, marine planning, port management, fisheries enforcement, environmental compliance, marine mammal avoidance, and freight statistical analyses, among others. As illustrated in Table 1, the diversity of users and applications of AIS data illustrates how one dataset can serve many stakeholder needs for the benefit of a stronger, more efficient, marine transportation system.

Challenges to Accessibility and Usability of AIS Data

While there are clearly benefits in the use of AIS data itself, which are magnified by the ability to share it among stakeholders, consistent access to, management of, and analysis of AIS data is a challenge for these stakeholders. These challenges can be broadly divided into four categories pertaining to data:

1. Access,
2. Validity,
3. Management, and

Barriers include, but are not limited to, policy and technical barriers to interagency data sharing primarily related to cybersecurity and information assurance policies, inability to access data in a timely manner, inconsistent data format and quality, impractical access to long-term data storage, need to validate data with third party sources, and a need for standard analysis products or decisional tools for users with limited capacity or expertise in AIS.

AIS data is currently the best source of vessel track data, but it is just one example among the plethora of maritime data available to maritime stakeholders in this increasingly data rich operating environment. Within this paper, the analysis of the problem and division of data challenges into four categories following the data lifecycle (access, validity, management, and user support) can serve as a case study and structure for broader discussions on data accessibility and usability. Lessons learned from this process can hopefully inform other stakeholders working to address big data challenges, including balancing data sharing with cyber-, privacy-, and national security needs.
Addressing the Challenges

Based on the assessment of Federal usability and accessibility of historic, terrestrial AIS data and information, the following short-term recommendations are proposed:

1. Better define and articulate the value proposition of open and easy access to AIS data across the Federal Government and public stakeholders.
2. Expand options for user access to AIS data by leveraging existing data dissemination capabilities, such as the MarineCadastre.gov platform.
3. Increase awareness of existing AIS tools that enable AIS information accessibility and usability.
4. Improve the usability of AIS-derived information products by establishing links to external data sources.
5. Identify geographic and temporal coverage gaps in U.S. AIS data and develop plans to fill them.

These recommendations necessitate, and are contingent upon, continued interagency coordination to develop prioritized requirements and to identify and maintain resources and funding.

Specific Examples

Certain Federal agencies have invested substantial resources to develop capabilities to access and use AIS data. One such example is the Federally-managed MarineCadastre.gov (mentioned in recommendation #2). The National Oceanic and Atmospheric Administration and the Bureau of Ocean Energy Management jointly manage MarineCadastre.gov, a Geographic Information System (GIS)-based marine data viewer and repository that provides decision support tools for siting of offshore renewable energy, mineral extraction, aquaculture, and other activities. MarineCadastre.gov has operated as a distributor of AIS data, storing and providing access to coastal AIS information from 2009-2017. By expanding upon this established platform, rather than creating new systems, AIS stakeholders can leverage existing capabilities to more quickly meet identified requirements.

A key takeaway from this process is the value of identifying common requirements and developing recommendations tailored to them. These requirements were developed within a collaborative, interagency team. Collaboration fosters a common understanding and use of the data, enabling analyses to be conducted on data sets that are consistent across agencies.

Summary and Conclusions

We envision that ultimately AIS data will be easily accessible to all maritime stakeholders in a timely manner, and in a manner that is appropriate for their use and capabilities. This enhanced accessibility and usability will support decision making for safe, efficient, environmentally responsible use of the marine transportation system.
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Keywords:  
multimodal transport, information system, digitization, cooperation

Title:  
Rhine Ports Information System: a front running port community system in Europe

Full Paper:

RHINE PORTS INFORMATIONS SYSTEM: A FRONT RUNNING PORT COMMUNITY SYSTEM IN EUROPE

The cooperation of the 9 Inland Ports Basel, Weil, Mulhouse, Colmar, Strasbourg, Kehl, Karlsruhe, Mannheim and Ludwigshafen has been set up in 2012 as a front running initiative at the European level. Based on the awareness that shared interests of inland ports have become much more important than competition issues, these ports have put in place a project consortium in order to conceive a global and interconnected transport system in the trinational region. Even before the start of the EU corridor studies, this initiative has been one of the first infrastructure investigations from a corridor perspective in Europe.

2012-2014 - A large study program aiming at identifying priority actions to increase the corridor performance

From 2012 to 2014, the Upper Rhine ports have undertaken a large study program aiming at the elaboration of a common masterplan for investment priorities and cooperation opportunities. Within a market study, the ports investigated the traffic situation in 9 key branches and made a forecast of traffic development until 2025. A second study analyzed capacities and interconnection of their infrastructures: for the first time the 9 ports shared detailed information about infrastructures, bottlenecks and investment projects. Based on the results, the ports agreed on a list of priority projects necessary for maintaining transport capacity in spite of growing transport volume forecasts. In addition, the study points out the need of container capacity enhancement and provides a list of cooperation recommendations to increase modal shift initiatives.

2015-2018: Implementation of a common digital infrastructure, the first trinational port community system in Europe.

Since 2015, the Upper Rhine ports have engaged in a new CEF-action aiming at implementing an Upper Rhine traffic management platform which was the most promising recommendation for further cooperation in the study program mentioned above. In this initiative, the 9 ports intend to digitalize the communication
and planning processes in multimodal transport via a centralized and transparent Port Community System (PCS).

The implementation of this first PCS for inland ports is done in a step by step approach. Its first development is a barge planning tool and a Customs module for waterborne container traffic in the area of RheinPorts Basel-Mulhouse-Weil. This platform called RPIS (RhinePorts Information System) is operational and is currently progressively extended to all terminals on the Upper Rhine.

After two years of operation, the feedback of users about RPIS can be better explained by quoting one of them: Swissterminal AG. “Continuous delays in seaports and significant events such as e.g. the interruptions in Rastatt and Melzo make the planification of ship cargo handling difficult. Together with the misuse of reservations in form of so-called no-shows have in the past led to shortages in available time windows for trucks in the terminal in Basel. In its container terminals in Basel and Birsfelden, Swissterminal has therefore introduced an electronic barge call management system for the container transport. With the RPIS (Rhine Ports Information System), the company is now - thanks to Digitalization on the Rhine corridor – able to offer more efficient cargo handling processes. By using RPIS and accepting the commonly elaborated usage rules, inland vessels are for the first time considered in a performant in slot-booking system. Customers benefit from a unique booking system for inland vessels, data exchange concerning the real time localization of containers and electronic customs processing.” Source: GOOD NEWS, 02/2018

**Next steps from 2019 on**

New developments of the RhinePorts Information System are under way:
- Interfacing with e-RIS (river information system in the Upper Rhine) in order to have real time information;
- Extension on a functional level to bulk and cruise ship traffic;
- Creation of a legal entity (a German company) in order to manage the system as a common digital infrastructure.
Title:

**Smart reporting - Reducing reporting burdens along the Danube waterway**

*Introducing reporting only once with single entering of data for IWT*

Extended Abstract:

Administrative barriers in reporting of passenger and goods transport on the Danube waterway and its navigable tributaries are a major obstacle for the efficiency and competitiveness of the Danube as an important transport axis crossing 10 riparian states in the CEE area. As a result, border crossing transports along the Danube have to transmit the required data to respective competent national authorities several times using different paper forms. These long-winded administrative processes are both time consuming and inefficient and lead to a prolongation of the total idle time, which is subsequently reflected in a prolongation of the total travel time of vessels. Since the costs for vessel operation make up a significant share of transport costs, transportation costs consequently increase as well, threatening the already low profit margins.

To facilitate the reduction of administrative burdens was identified as priority area within the framework of the EU strategy for the Danube Region. Initiatives in the priority area P1a strongly recommended harmonizing forms for all authorities and countries along the entire Danube. Rarely changing technical details of vessels like certificates validity, name, width and depth should be accessible to all authorities, avoiding repeated requests of the same data.

In the age of digitalization, River Information Services (RIS) can contribute to overcome outdated official processes by technologies such as Electronic Reporting (ERI), Vessel Tracking and Tracing (VTT). These River Information Services have been created to enhance Inland Waterway Transport (IWT) in terms of safety and efficiency of transport by means of telematics, with the overall goal to improve its modal split. Nevertheless, actual cross-border interworking of River Information Services is still limited, in particular with regard to data exchange across borders, comparable quality of data and harmonised service levels fitting to user requirements. Therefore public authorities still cannot enjoy the full benefits of RIS for traffic management and the logistics users of RIS still have only a few benefits from RIS for transport management, most of them within the limits of national borders or of different quality in different countries. For RIS users this means that they have to enter the same data repeatedly via national RIS portals or on different but similar paper forms to fulfil their reporting obligations along their transport route.

In order to tackle the existing fragmentation of services, the concept of RIS enabled Corridor Management was established. Based on a mutual agreement between waterway authorities along specific transport corridors, it aims at harmonized services and functions for improved traffic management by authorities and more efficient transport management by the logistics sector.
A substantial step towards the reduction of reporting burdens is currently realized within the framework of the CEF funded multi-beneficiary project RIS Corridor Management Execution (RIS COMEX), through the specification and implementation of harmonized corridor RIS services. Main intention of the RIS COMEX project is to realise these Corridor RIS Services for authorities and logistics users within inland navigation and to transfer the Corridor Services into sustainable operation. The priorities to be achieved are the reduction of administrative barriers, specifically of reporting burdens (by means of cross-border electronic reporting), efficiency improvements in inland navigation (cross-border exchange of information for logistics stakeholders) as well as better planning reliability of waterway transports and the reduction of travelling times (cross-border travel planning).

The core objective of the presented RIS COMEX approach related to cross-border electronic reporting and exchange of information for logistics stakeholders is to create a single portal, supported by all competent RIS authorities and available for all types of transport such as dangerous goods transport, non-dangerous goods transport, container transport and passenger shipping. The entry of data is required only once, according to the reporting requirements along the respective transport route.

In the presented approach the derivation of respective reporting requirements for a define transport route is based on a comprehensive transnational survey aiming at identifying all national reporting obligations in the Danube corridor. The survey was conducted within the framework the RIS COMEX sub activity 3.4 and covered the thematic areas of port registration reports, arrival and departure reports, dangerous goods reports, police controls and statistics. As a result around 200 data fields were identified, that were subsequently consolidated and structured to a comprehensive data model for reporting in inland navigation. The data model is structured in data groups, containing information on safety related issue, voyage details, convoy details, consignment details, passenger and crew related data as well as waste information and customs related information.

Based on the voyage planner realized within RIS COMEX, skippers and shipping companies can easily determine their route including all relevant stops and handling procedures. By specifying the basic transport information such as route and transport category in the single reporting window all reporting obligations along this specified route including reporting rules can be displayed. This central access point is then further used to fill in the required data supported by a smart completion assistant. Due to the interconnection with nationally fed databases as the European Hull Database a significant percentage of data can be re-used, preventing multiple data entries. In addition to pre-filled static vessel hull data the system also supports the use of other reference data like a list of locations to easily select an origin and destination, a list of vessel types and cargo lists for easy selection of the transported cargo. Furthermore, an intelligent repository of previously reported data is provided where the submitted Electronic Reports are stored (with consent of the reporting party) so authorised users can access this repository and reuse existing reports. The re-use of already available data is closely intertwined with smart user management. This smart user management secures access authorization according to the consent agreement of reporting parties - consequently data can also be used by authorised third parties such as shippers, fleet managers and other logistics partners, expanding the circle of beneficiaries. The COMEX Electronic Reporting System enables the reporting parties to send existing voyage and cargo information directly to any related logistics users or third parties in order to increase efficiency and optimise planning.

With consent of the reporting party, the COMEX Electronic Reporting System creates appropriate reports using existing templates and sends them to the responsible authorities in the predefined format via the defined communication mean. Based on the performed mapping process of required data fields with data fields of (standardized) messages in electronic reporting such as ERINOT, ERIVOY, PAXLST, BERMAN and CUSCAR it is also possible to send data by customized Electronic Reports to authorities. The RIS users have the possibility to create new or update already submitted Electronic Reports efficiently to fulfil all reporting obligations for their transport and to receive confirmations from the related authorities.

This approach guaranties the availability of submitted Electronic Reports at the related competent authorities and further includes a confirmation of receipt as well as the possibility for authorities to send a feedback in case the provided information is incomplete. In contrast to decentralized reporting systems, where electronic reports are forwarded from one national RIS authority to the next national RIS authority in the neighbouring
country, the COMEX Electronic Reporting System forwards all messages directly to all concerned authorities via a centralized service, if commanded by the reporting party, so that the communication between authorities and the reporting party is simplified significantly and errors leading to messages that cannot be forwarded are minimized. As a result, both RIS-users and authorities benefit from a central communication system, which enables customer-friendly reporting processes and helps to overcome existing set-backs in data exchange between national RIS providers. Figure 1 provides an overview of basic functionalities provided by COMEX Electronic Reporting System to the reporting party.

Fig. 1. Basic Functionalities of the COMEX Electronic Reporting System for the Reporting Party

The RIS COMEX approach for (electronic) reporting only once with single entering of data also allows the interaction with external systems or users which act as data provider or data consumers. In principle various types of external data sources/consumers may be connected to the COMEX Electronic Reporting System, certainly under consideration of strict authentication and authorisation mechanisms.

The envisaged approach for information provision towards competent authorities enables authorities to increase the efficiency of vessel controls in order to potentially reduce waiting times for and the duration of vessel controls. The specification of the respective services will be finalized in June 2019. The implementation is expected for 2020.

This conference contribution will give an insight into existing reporting barriers for the Danube waterway transport and will provide an overview of legal reporting requirements in the Danube riparian countries. The presentation will mainly address the RIS COMEX approach for reporting only once with single entering of data and highlight the benefits for all stakeholders towards the reduction of reporting burdens along the Danube.
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Keywords:  
Electronic reporting, Inland AIS, implementation  

Implementing River Information Services (RIS)  
- Lessons learned from the Rhine – 

The Central Commission for the Navigation of the Rhine (CCNR) can look back on 20 years of support for the development of RIS and their implementation on the Rhine1. Because the CCNR is convinced that RIS have the capacity to enhance safety and competitiveness of inland navigation, it became an early adopter and the Rhine the forerunner for RIS. Being a forerunner provides for important learning, from which other implementers of RIS can profit.  

This important learning is most obvious in the implementation of Inland AIS and electronic reporting in Rhine navigation.  

CCNR’s RIS implementation process  

The CCNR, when implementing new RIS, follows a step-by-step process of planning, execution, verification and adjustment. The planning is based on the CCNR's Strategy for the Development and Implementation of RIS on the Rhine and its bi-annual work programme. Detailed planning takes place in the CCNR’s Working Group on RIS, together with the national RIS operators and – very importantly – the navigation sector. The CCNR acknowledges failures in past RIS projects, for example in the implementation of electronic reporting for container vessels and learns from these failures.  

The execution takes places on different levels. The regulatory level sees amendments of the Police Regulations for the Navigation of the Rhine (RPR), for example making electronic reporting for certain vessels mandatory or requiring the carriage and use of Inland AIS equipment. In some cases, the Rhine Vessel Inspection Regulations (RVIR) would be amended as well to provide for technical requirements for RIS equipment, like Inland AIS devices. The practical level sees first of all communication activities to inform skippers and ship-owners and convince them from the benefits of the RIS to be implemented. Other activities on the practical level include the provision of particular software to be used on the vessels, opening helpdesks for support to users or the installation of land infrastructure.

1 Further information on the CCNR’s RIS activities is available at http://www.ccr-zkr.org/13020700-en.html#09
The verification can take many forms. For electronic reporting, the monitoring consists mostly in counting the number of vessels having the required application onboard. For Inland AIS, two years after it became mandatory, the CCNR undertook an online-survey. As this survey was both very complete and very successful, it provides strong feedback to most aspects of Inland AIS.

The feedback from the Inland AIS survey led to a number of adjustments and follow-up activities on the regulatory and the practical level. The RPR has seen already some amendments. Currently, an ad hoc working group examines the need for changes in technical standards and the procedures for the installation of Inland AIS equipment onboard.

**Automatic Identification System – AIS**

The obligation of carriage and usage of Inland AIS and an electronic chart display system is not a river information service in itself but as a RIS technical service rather a prerequisite for several services like lock management, berth occupation etc. and therefore mentioned here. Most importantly, the equipment provides the skipper with additional information supporting his navigation tasks and thereby improving safety of Rhine navigation.

The latter aspect was the main motivation for the CCNR to introduce on 1 December 2014 the obligation to install and to use Inland AIS devices and Inland ECDIS devices or comparable electronic chart display devices. This obligation is defined in the RPR (art 4.07) and more information is available in the information document published by the CCNR. This obligation applies to all vessels navigating on the river Rhine with the exception of small craft and barges without their own propulsion system.

To best assess the difficulties and problems encountered by users and to enable those affected by these requirements to make proposals for improvements, the CCNR decided to conduct an online survey in order to collect information from the various stakeholders two years after the implementation of the obligation.

Over a two-month period in 2016, more than 1000 fully completed questionnaires and more than 400 partially completed but still usable questionnaires were obtained. More than 90% of these questionnaires were completed by the skippers. In addition, companies that install equipment on board vessels, waterway administrations and police services also participated in the survey. The survey’s findings were analysed and published in the document “Analysis of the online survey conducted in the context of evaluating the implementation of the mandatory installation”. This document contains the evaluation and summary of the survey findings and offers a wealth of information based on more than 100 questions and answers in three languages.

On the basis of the survey’s findings, the CCNR adopted in spring 2018 conclusions and recommendations in the context of evaluating the implementation of the mandatory installation Inland AIS devices and electronic chart display systems on the Rhine. These conclusions and recommendations will underpin the CCNR’s future activities, both as concerns RIS and beyond. At the same time, in a broader context, the CCNR is bringing these conclusions to the attention of other international organizations, the inland navigation sector, application developers and equipment manufacturers. Likewise, the CCNR would want RIS experts in Europe and beyond to profit from these conclusions and recommendations. The CCNR also hopes that the European Commission will benefit from using this document in its work on enhancing RIS – in the knowledge that those who took part in the survey represent a large proportion of the European inland navigation industry.

For its own purposes, the CCNR translated the some 60 recommendations into an action plan, specifying for each of them the relevant target group and the concrete measures to be considered as response to the specific recommendation.

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3 [https://ccr-zkr.org/files/documents/ris/enq_Ais_e.pdf](https://ccr-zkr.org/files/documents/ris/enq_Ais_e.pdf)
4 [https://ccr-zkr.org/files/documents/ris/conclus_Ais_en.pdf](https://ccr-zkr.org/files/documents/ris/conclus_Ais_en.pdf)
Electronic reporting

The RPR defines in Article 12.01 the reporting requirements for vessels navigating on the Rhine. Initially, only those vessels and convoys carrying 20 or more containers had to report electronically. With effect from 1 December 2015 it became mandatory for all vessels and convoys carrying containers to report electronically. This extension of the initial and more limited reporting requirements has reduced the administrative workload for skippers and improved safety of navigation by having critical data available at all times in a more accurate fashion.

For the first electronic reporting obligation the initial intention was it to come into force on 1 April 2008, but a number of difficulties surfaced and the CCNR had to postpone the entry into force of these requirements to 1 January 2010. Indeed, implementation on an international scale calls for substantial coordination. For example, it is essential that all the national databases involved in the data exchange use the same reference data. That may seem trivial, but if there is any change in the reference data, the change must be taken into account in all the countries at exactly the same time. Another problem with data exchange resulted from technical difficulties: although the message to be transmitted between two countries complied with the electronic reporting standard, there was still a margin for interpretation in the standard, which was not being understood in the same way by the neighbouring countries. Finally, it was necessary to adapt the dedicated national ICT systems, and that is never an easy task to achieve! However, the CCNR and the member states administrations, based on the extensive cooperation of their experts, could solve all challenges and make the electronic reporting a useful tool for ensuring safety while at the same time keeping the administrative burden at a minimum. Recognizing the initial implementation failures, a study was commissioned to examine what went wrong and to recommend processes, which in the future would help to avoid those failures.

As the first and later extended mandatory electronic reporting of vessels and convoys carrying containers proved to be very beneficial, the CCNR decided to extend the reporting requirements even further and to introduce electronic reporting requirements for all vessels with fixed cargo tanks on board on 1 December 2018.
Communication campaign on electronic reporting; traffic centre Bingen

Learning from earlier failures and successes and following the recommendations resulting from the experiences with electronic reporting, the CCNR and its member states, among others, put an enormous emphasis on public communication and cooperation with the inland navigation sector. For example, the CCNR set up a dedicated web page, dedicated “newspapers” were published and even information banners displayed along the Rhine. This extensive communication campaign contributed significantly to the successful implementation of the extension of the electronic reporting requirements on vessels with fixed cargo tanks. In light of this smooth extension, the CCNR intends to expand the electronic reporting even further and to demand that by the end of 2021 all vessels required to report will do so electronically.

Conclusions

These examples on Inland AIS and electronic ship reporting allow to draw the following conclusion:

- ICT systems for public safety are highly complex and highly sensitive anyway. If such a system is to be implemented in several countries, the complexity and sensitivity multiply. It requires a well functional international cooperation supported by highly engaged and cooperative experts to solve the challenges of the implementation of such a system.

- A holistic approach is necessary when successfully implementing a new technology or a new service. Holistic means to involve all the countries along the waterway, to work closely with the stakeholders and to go beyond technical and legal issues, putting a strong emphasis on communication.
Aids to Navigation (AtoN) have a major impact on safety of traffic on inland waterways. Traditional AtoNs like buoys or traffic signs are key to marking the navigable fairway and inform about dangers or relevant infrastructure (e.g. berths) in a harmonized way. However these traditional AtoNs sometimes have issues with reliability or visibility. Strong current, floods, ice or vessel allisions may cause buoys drifting from their intended position or make them sink. Situations like strong back light, fog, snow or heavy rainfall may cause problems in detecting and correctly interpreting buoys or landmarks. Lights atop AtoNs have improved the situation but require additional efforts in verifying the correct functioning of these electrified devices in a hostile environment.

The Automatic Identification System (AIS) includes a possibility to equip any type of AtoN with an AIS AtoN station. This station called “Physical AIS AtoN” monitors its position and regularly broadcasts its name, type and position to all other AIS stations in communication range. This works well in the maritime environment since buoys tend to be very big and can carry large batteries and solar panels necessary to power such AIS devices. In addition the so called “synthetic monitored AIS AtoNs” make use of alternative communication technologies such as GSM or satellite communication to send the status of the AtoN to an onshore system which processes the information and relays it to the AIS link using shore based AIS base stations. In both cases the AIS AtoN information will be displayed as a generic symbol in an Electronic Chart System (ECS).

On European inland waterways buoys are significantly smaller than in the maritime field and do not always provide the possibility to carry huge weights. Still administrations want to introduce electronic monitoring capabilities for AtoNs in order to make the maintenance procedures more efficient and more focussed. In addition the waterway marking on European inland waterways is done according to the European Code for Inland Waterways (CEVNI). CEVNI defines different/additional objects than IALA which doesn’t allow for a direct usage of the AIS AtoN report (AIS message 21) as defined in the global AIS standard. Given these circumstance the experts in Europe have been created a method to code the AtoNs as defined by CEVNI into the standard AIS AtoN report while ensuring full backwards compatibility with the maritime world. Further the European River Information Services (RIS) Expert Groups (EG) have defined a method for the smart display of Inland AIS AtoNs on Inland Electronic Chart Systems (IECS) in a way that reduces clutter and links the AIS AtoN object to the related static AtoN object coded into the traffic regulation layer of the Inland Electronic Navigational Chart (IENC).

The European RIS Expert Groups have in cooperation with projects funded under the “Connecting Europe Facilities” (CEF) like “FAIRway Danube” and “RIS COMEX” created a framework for chosing the right AIS AtoN technology depending on the needs and framework conditions. Key parameters are the availability.
of a shore based AIS network, the availability of commercial communication services (e.g. UMTS or LTE), desired level of autonomy of the floating devices, investment vs operational costs and many more. A draft example of the SWOT matrix is given in the following figure:

<table>
<thead>
<tr>
<th>Monetary Aspects</th>
<th>Real buoy without AIS</th>
<th>Real buoy with AIS &amp; AcN station</th>
<th>Real buoy with monitored Synthetic AIS AcN</th>
<th>Real buoy with predicted Synthetic AIS AcN</th>
<th>Virtual AIS Aids to Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment costs (buoy)</td>
<td>-</td>
<td>high</td>
<td>high</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maintenance costs (buoy)</td>
<td>-</td>
<td>high</td>
<td>high</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Repair costs (buoy)</td>
<td>-</td>
<td>high</td>
<td>high</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>One-time Investment costs (shore system)</td>
<td>-</td>
<td>low</td>
<td>high</td>
<td>med</td>
<td>med</td>
</tr>
<tr>
<td>Communication costs</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>med</td>
<td>no</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Safety Aspects</th>
<th>Real buoy without AIS</th>
<th>Real buoy with AIS &amp; AcN station</th>
<th>Real buoy with monitored Synthetic AIS AcN</th>
<th>Real buoy with predicted Synthetic AIS AcN</th>
<th>Virtual AIS Aids to Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility on fairway</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>no</td>
</tr>
<tr>
<td>Visibility on radar</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>no</td>
</tr>
<tr>
<td>Visibility on ECDIS</td>
<td>static</td>
<td>dynamic</td>
<td>dynamic</td>
<td>semi-dynamic</td>
<td>dynamic</td>
</tr>
<tr>
<td>Automatic off position recognition</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>n/a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Aspects</th>
<th>Real buoy without AIS</th>
<th>Real buoy with AIS &amp; AcN station</th>
<th>Real buoy with monitored Synthetic AIS AcN</th>
<th>Real buoy with predicted Synthetic AIS AcN</th>
<th>Virtual AIS Aids to Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional AIS VDL load</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Necessity for mobile internet connection</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Remote configuration</td>
<td>no</td>
<td>partially</td>
<td>yes</td>
<td>no</td>
<td>n/a</td>
</tr>
<tr>
<td>Adaptation of AIS management system</td>
<td>no</td>
<td>little</td>
<td>yes</td>
<td>yes</td>
<td>n/a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-requisites for safe on-board usage</th>
<th>Real buoy without AIS</th>
<th>Real buoy with AIS &amp; AcN station</th>
<th>Real buoy with monitored Synthetic AIS AcN</th>
<th>Real buoy with predicted Synthetic AIS AcN</th>
<th>Virtual AIS Aids to Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory ECDIS carriage</td>
<td>No</td>
<td>yes/no</td>
<td>yes/no</td>
<td>yes/no</td>
<td>yes</td>
</tr>
<tr>
<td>Vessel investment costs (ECDIS)</td>
<td>No</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Requires higher availability of AIS shore network</td>
<td>no</td>
<td>no*</td>
<td>no*</td>
<td>no*</td>
<td>yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional features</th>
<th>Real buoy without AIS</th>
<th>Real buoy with AIS &amp; AcN station</th>
<th>Real buoy with monitored Synthetic AIS AcN</th>
<th>Real buoy with predicted Synthetic AIS AcN</th>
<th>Virtual AIS Aids to Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional sensor data (temp., depth, water quality)</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>nonce</td>
<td>no</td>
</tr>
<tr>
<td>Online overview of physical buoyage system</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>n/a</td>
</tr>
</tbody>
</table>

In order to verify and fine-tune these parameters, trials have been executed to compare different AIS AtoN solutions under operational conditions, mainly a physical AIS AtoN Type 1 and a Synthetic AIS AtoN using satellite communication. Since the tests were still running while this extended abstract has been written, no final conclusion can be presented in the abstract. Still, they will be the focus of the oral presentation in October.

The following two figures provide insight to the different equipment used:

- Physical AIS AtoN Type 1
- Synthetic AIS AtoN
In parallel a research effort is being executed with the major European manufacturers of Inland ECDIS viewer applications to ensure safe and unambiguous display of dynamic AIS AtoN information on board without cluttering the screen. This shall be reached with replacing the static AtoN chat object with a dynamic one as long as the AtoN is in place and functioning well. The result of this research effort and examples from on-board trials will be included in the presentation.

Finally the impact and framework conditions for using dynamic AtoN information for waterway management will be tackled from the point of view of an infrastructure operator. Aspects like time-to-alarm, buoy-drift with changing water levels and impact of vessels colliding with the floating AtoNs are currently investigated.

Screenshot of the AtoN management application.
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Keywords:  
EU RIS COMEX, Aids to Navigation, Inland AIS, Inland ECDIS  

Title:  
RIS COMEX Elbe-Weser Corridor  
Providing Digital Aids to Navigation Information via AIS and ECDIS  

Full Paper:  

Improved traffic awareness on board is the well-known advantage of the combination of AIS and  
ECDIS in maritime and inland navigation. A mandatory carriage requirement for Inland AIS, often  
enhanced with a chart display system like Inland ECDIS, is on most European inland waterways in  
place. The most countries have also established an AIS shore infrastructure along the waterways  
to support their shore based river information services by the received AIS data from the ships, e.g.  
regarding VTS, ship reporting, or look management systems.  

However, the digital infrastructure of AIS and ECDIS has more to offer. Enabling digital data  
exchange from shore to ship in a standardized form via AIS and being able to display those data on-  
board on an ECDIS display allows also for the provision of safety related information which may  
directly affect to the navigation of the vessel.  

The RIS COMEX reference application in the Elbe-Weser-Corridor aims to elaborate and to test the  
provision of safety and navigation related information. The traffic and situation awareness on board  
should be improved by information services using the digital infrastructure of AIS and Inland  
ECDIS. The focus is on the transmission of temporary information, which is only of interest for a  
relatively short period of time, e.g. when a ferry is crossing the fairway, or when a bridge has  
restricted vertical clearance caused by current high water level. That information of temporary  
nature is usually not included in an Inland ECDIS chart and may not be at all or not in a timely  
manner part of the set of information broadcasted via Notices to Skippers/Mariners Service.  

The various information which are needed for navigation refers to navigational restrictions along  
the waterway which are categorized by the expression “digital Aids to Navigation information”.  
This includes temporary limitations of the fairway, or constraints at fairway related objects as well
as highlighting special physical Aids to Navigation, e.g. an important buoy and its actual position. This includes the possibility to broadcast an “off position indication” of the buoy when it is drifted away and might become a hazard to navigation. In this case we need a special equipped buoy which is able to detects its current position, to check whether it is still “on position” or not, and to transmit its’s status by an AIS message.

A reference implementation has been set up at the river Elbe in the Czech Republic and in Germany to gain experience and get feedback from the skippers/mariners regarding the usefulness and the practical application of this kind of digital Aids to Navigation information.

The existing AIS shore infrastructure along the river Elbe is expanded to be able to provide digital Aids to Navigation information. The existing notice mark data base for the management of the physical Aids to Navigation in the river is amended by the new AIS AtoN object types (real and virtual AtoNs) and further developed to create, maintain and provide the digital Aids to Navigation information for the project as well.

Buoys at some specific, important places in the waterways will be equipped with a special AIS AtoN station which transmits periodically an AIS AtoN message, containing the type of the buoy, its name, and its actual position. If the buoy is too far drifted away from the required position (“adrift”), an “off position indicator” is set. At the screen of the on board ECDIS the buoy will be displayed with its actual position on the chart and in case of adrift highlighted to indicate its faulty location. The transmissions of those buoys are called “real AIS AtoN Messages”, as they come from a physical buoy.

However, it is also possible to transmit AIS AtoN Messages for locations in the waterway where no buoy is placed. On the ECDIS chart the information of those messages will be displayed at the position contained in the message, even there is no real buoy in the water. This is called “virtual AIS AtoN Message”. Elaborating on this effect is one of the major aspects in the project.

For example, in cases of an accident of a vessel or when an obstacle in the waterway occurs after a flood period, or for a period of maintenance work, a “virtual AIS AtoN Message” may be used for immediate indicating the event. Even if it will take some time to deploy a physical buoy at the relevant position, the obstacle will already be visible on the ECDIS chart on board, using the symbol of the appropriate buoy.

Pursuing this idea further, the visualization of information on an Inland ECDIS chart may go beyond the traditional symbolization of buoys or other aids to navigation. Lines, areas, pictograms or text labels at the relevant position may be more explanatory about the situation to mark. In the project, several examples for using virtual AIS AtoN Messages, also in the broader sense, will be provided.

**Recommended track in the fairway (Elbe-Km 516 - 520)**

In some areas at the Elbe River there is a steady changing river bed. There is no constant marking of the navigable part of the river, but aids to navigation on shore indicate the change of the fairway from one side to the other in the river. As the river bed is changing constantly, the surveying of the river bed by echo sounding systems have to be carried out regularly.
Figure 1: Changing river bed at the lower Elbe and providing a recommended track

It is planned to construct a recommended track out of the sounding results and provide those to shipping by virtual AIS AtoN Messages, indicating the leading line on the ECDIS chart. The usefulness of such a leading line for the skippers navigating in that area should be evaluated.

**Water level dependent marking of low bridges**

Bridges across the waterway have a certain minimum air draft, which should be common for the whole waterway. However, some bridges are sometimes lower than the average air draft for that river. Depending on the water level of the river, those bridges can become a hazard in case of higher water level and the corresponding lack of air draft (vertical clearance). A virtual AtoN Message will be broadcasted in this case and highlight an area at the bridge. Additional the actual air draft value will be provided as text in the chart.

The whole process can be automated:

- Checking the current water level at the related gauge
- Calculating the current available vertical clearance
- Sending out the AIS messages when the available clearance is lower than the standard value
- The visualization at the Inland ECDIS on board when the message is received

Figure 2: Water level dependent marking at low bridges when the vertical clearance is lower than the standard value (7.00 m)
Indication – Ferry crossing
Several ferries operate at the river Elbe. Some are not motorized, but are attached to a chain at a fix point about hundred meters upstream. This cable ferries are using the current of the river to move from one side to the other. The German expression for that kind of ferry is “Gierseilfähre“.
The fairway is blocked due to the chain, depending on which side of the river the ferry is located. The chain is marked with buoys, and as such visible for the shipping.
Within the project it is planned to broadcast a virtual AtoN message from the ferry itself, to indicate that the ferry is crossing and blocking the fairway. This message will result in the visualization of an area surrounding the ferry on the ECDIS chart for the duration of the blockage.
Several ferries in the Czech Republic and in Germany will be equipped with this feature.

Figure 3: Indication – Ferry crossing

To provide digital AIS AtoN information to shipping needs both, the enabling of this function on shore as well as on board. This will be done by extending the ashore functionality, to be able to initiate and to transfer the needed data, and on board, by implementing these new functions in existing Inland ECDIS equipment. A retrofit of certain navigational equipment might be indispensable on the way to the digitization of shipping.
The project will be evaluated by using a questionnaire to the participating partners, to get feedback from shipping as well as service providers on shore. Also direct communication (interviews, on board visits) a foreseen.

Conclusion:
For the navigation at inland waterways the availability of reliable and complete information about the current navigational conditions and restrictions are essential.
This information need affects several aspects and aims:
- To improve the safety of navigation
- To ease voyage planning and to support traffic execution, e.g. to avoid waiting times at locks and harbours

The combination of the standardizes RIS Services, especially AIS and Inland ECDIS, provides the possibility to forward the information immediately to the vessels and to visualize it clear and in round terms at the Inland ECDIS system of the skipper.

In the frame of the RIS COMEX project are a lot of test applications planned, which use the new technical possibilities. Parallel will necessary the amendments the existing RIS standards be formulated, especially in cases where the tests show, that the applications are helpful, reliable and economic.
Introduction

In Germany automation and remote operation of locks goes back to the middle of the nineties. To support design and operation, standards were developed and introduced by the German Waterways Administration at the end of 2015. On the basis of these standards new lock operation centres (LOC) have to be planned and operated. Currently there are 26 LOC in operation and 8 centres in planning or construction phases.

A current project concerns the introduction of remote control and operation at the Saar River. The Saar River connects the industrial centres of the Saarland via the Moselle River with the European inland waterways network. The Vb classified developed 90 km river stretch from Saarbrücken to the Moselle River (figure 1) can be used by push tugs of 185 m length and 11.4 m width. The German Federal Waterways Administration started designing and building a Lock Operation Centre (LOC) at Mettlach weir. Depending on the actual traffic volume up to 3 operators will control the six Saar locks (10 chambers) simultaneously. The 6 weirs can also be controlled and operated. The Saar Lock operation centre will start operation at the end of 2019.

Standards for Remote Operation

The German Federal Waterways and Shipping Administration has developed several standards for automation and remote operation of locks and weirs that were summarized in a guideline that was introduced in 2015. On the basis of these standards new lock operation centres have to be planned and operated. The standards include optimised design proposal for operation centres, comprising the entire process system and also the elements of staffing,
design and arrangement of workstations and components, as well as the graphical user interface for operation and visualization. As an example, a standard operator desk was introduced that include all necessary devices for monitoring, communication and process operation. The desk enables ergonomic standing and sitting postures with optimum space within reach, fields of vision, viewing distances and motion sequences. The reduction of the number of devices to be installed in the desk was consistently implemented as recommended by an ergonomic study that was conducted with deep involvement of experienced operators. The concept of remote operation differentiates between fixed or dynamic allocated operating desks to a lock chamber. However, local operation on site is also possible in case of failures.

Remote Operation of the Saar Locks

The project aims to establish remote operation of Saar River locks and weirs from one centre located at Mettlach that will provide the following services

- Remote control and operation of 6 large lock chamber (190 m x 12 m) and 4 small chamber (40 m x 6,75 m) for pleasure crafts
- Remote monitoring of 6 weirs and remote operation in defined situations, e. g. failure at one hydro power plant (responsible for normal weir operation), mal function of the automatic weir control system, high water situations
- Contact point for emergency communication with shipping
- Remote control and operation of 6 pumping stations
- Collecting and disseminating data for traffic statistic applications

Beside planning and building the operation centre the conversion to remote control means a number of extensive measures. First, the drives and control technology at each lock have to be modernized by adding controllable process components such as new valves and position measuring systems to the hydraulic drives. State of the Art PLCs (programmable logic controllers), sensors and actuators connected by a safety bus ensure reliable operation. Before the implementation on site the PLC software has been tested under simulation environment to avoid logical failures. Remote operation is based on the transmission of sensor and other data to the operator desks at the LOC. The camera system forms an important sensor. Before the modernization of the large lock chambers 3 cameras were in use, now 7 to 10 modern type approved IP cameras have been installed to monitor safety critical areas during the lock process. A high available communication between operator and ship is also an important factor to ensure a safe lockage. At the operator desk one communication touch screen combines voice communication with a ship via VHF radio communication and loudspeakers installed at the lock chambers. The operator desk also includes an additional touch screen for statistic applications (electronic log book) and future traffic management functions. It is planned to incorporate lock management functions to reduce delay times for ships in near future. To ensure transmission of the mentioned data, the provision of a high available communication infrastructure is required. The communication infrastructure is based on a German wide broad band network with fibre optic cables and SDH multiplexer (a standard technology for synchronous data transmission) operated by the German Federal Waterways and Shipping Administration.

All functions and services can be switched and connected to the selected lock by one mouse click from the main screen of the PCS (process control system). The PCS software is based on distributed processes and high redundant systems with hot stand by functions and was customized developed for this project. Additional features were built into the PCS, e.g. supervising all network components, the uninterruptible power supply (UPS) unit, connections to the PLC’s etc.

In summary, the project includes the following major steps

- Design and building of the LOC
- Renewal of the electrical installations, modernization of drives and control technology at the locks
- Implementing a new video camera system to monitor lock chambers and waiting areas
- Renewal of radio communication, loudspeaker and intercom systems
- Implementing a process control system (PCS) including standard process visualization (figure 2)
- Connection to the communication infrastructure of the German Federal Waterways Administration

It was required that shipping should be affected as little as possible. As far as it was possible a lot of renewal work was carried out during the annual 10 days shipping ban period, e.g. installing and commissioning of the process control system and the modification of the hydraulic of the large locks ready for remote operation.

The LOC has got a control room with 6 standard operator desks for lock operation and 2 small standard desks for the weir control, whereby the lock chambers and weirs can be freely assigned to the operator desks, figure 3. This is usually done by the operator at the beginning of his shift and then remains unchanged during service. The barrier-free building contains also the office for the chief operator, social rooms and a technical room. To accommodate the control cabinets, a space requirement of 60 cubic meters is provided. The air conditioning of the control cabinets is via a raised floor. High available power supply with redundant UPS ensures reliable operation. Maintenance and repair is carried out both with personnel of the Waterways Administration on the basis of maintenance contracts. Remote maintenance is part of the second level support taking also into account aspects of cyber security.

**Status of the project**

The conversion to remote operation of the locks and weirs is completed. The LOC building is completed and equipped with the necessary technology. It is intended to start remote operation with successive connection of three locks until the end to 2019. The remaining locks will be connected to LOC in the beginning 2020. With regard to safety one month trials for one lock each is planned with parallel operation from LOC and also manned operator desks on site. It is anticipated that due to the involvement of the personnel in all project phases, the acceptance of conversion to remote operation is high. Remote control and operation of the Saar lock will ensure high quality levels of services to shipping.
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Title:  
InCom Workgroup 192: Developments in the Automation and Remote  
Operation of Locks and Bridges

Introduction

This paper highlights the information found in the new report produced by InCom Workgroup 192. InCom WG 192 deals with Developments in the automation and remote operation of locks and bridges. The main objective of WG192 was to update to 2008 Report on Developments in the automation and remote operation of locks and bridges to reflect technological advances and new considerations related to remote operation in the last 10 years. Members of the working group included participants from Belgium, Canada, France, Germany, The Netherlands, The United Kingdom, and The United States. Included in the report are sections dealing with:

- Business Case Development for Remote Operation and Automation  
- Organizational Implementation  
- Operational Implementation  
- Technical Implementation  
- Safety  
- Security  
- Traffic Management  
- Information Management

Business Case Development for Remote Operation and Automation

This section sets out the framework for establishing a business case for remote operation. According to the business case, which covers the reason for initiating a remote operation project, the costs, benefits, risks and opportunities should be evaluated.
For countries considering the implementation of remote operation of movable bridges and locks, the experience of other countries can be very useful in the development of their own business case. Therefore, the business case may provide parties who currently operate and maintain bridges and locks locally, with a brief, high-level understanding of key factors that should be evaluated when considering a change to remote operation as well as practical examples of remotely operated facilities or those under consideration.

The following topics or key factors are included in the business case. Moreover, it comprises the questions that need to be addressed and a first possible answer to these questions:

- **Agency Motivation:**
  Why agencies decide to implement remote bridge or lock operation?

- **Customer Service and Support:**
  How have shipping companies and other users reacted to the change?

- **Design, Construction, Operation and Maintenance:**
  What are the key factors that should be considered during the design, construction, operations and maintenance phases?

- **Workforce Change and Development:**
  What is the initial and current reaction of the workforce to the change and the major focus of workforce development necessary to implement the change?

- **Risk and Benefit Assessment:**
  What are the greatest risks and benefits associated with remote bridge and lock operation? Are the benefits a one-time occurrence or are they reoccurring?

- **Approximate Cost of the Project:**
  What are the approximate costs linked to the remote operation project? Are the costs a one-time occurrence or are they reoccurring?

- **Future Outlook:**
  What are the trends in traffic, both in volume and nature? Will it potentially change the balance between cost and benefit?

**Organizational Implementation**

When implementing automation and remote operation, it is necessary not to limit yourself to the technical implementation but to take into account the organizational implementation.

Concerning the organizational design for remote control and automation, several aspects need to be taken into consideration. It is necessary to analyse the current organizational structure and carefully consider if and what changes are needed in light of the implementation of remote control. In case a change is required, the new organizational structure needs to be translated into organization charts and relationship hierarchies, with the appropriate spans of control and management layers.

The work related to remote control requires a different skill set than the one required for local operators. There is more emphasis on collaboration, the tasks are less physical and might be more difficult to manage (for example in terms of performing several tasks at the same time). Finally, implementing remote control means that the headcount, workload, and associated FTE requirements can be optimized.
It is crucial to have clear roles, responsibilities and accountability within an organization. After implementing remote control, operators in a remote control centre will have to work together and must depend on each other.

In general, the governance structure to be applied to the remote control organization will be centralized, because automation inevitably leads to the transition from a decentralized to a more central model.

In the light of the changes described above, it is clear these changes must be well managed to avoid or overcome natural resistance. The importance of a thorough change management cannot be emphasized enough.

**Operational Implementation**

Several procedures and processes need to be redefined or new ones need to be implemented whilst transferring from local operating modes to remote control.

Processes and procedures not only consolidate standard operation, but it is equally important to have well-defined guidelines for the maintenance team during breakdowns, malfunctions or faults. Therefore, a distinction must be made between standard remote operation and maintenance operation.

Several procedures must be developed for each operating mode and each step in the remote operation process. For the definition of new or redefined procedures, close attention must be paid to following aspects:

- Training of operators: competence profiles must be redefined and a training plan has to be prepared to match these profiles.
- Traffic management: corridor management according to the blue wave, lock planning, etc.
- Communication procedures between skipper and remote operator: registration of ships per corridor.
- Mooring protocols.
- Access control.
- Registration of ships, incidents, malfunctions, etc.
- Procedures and protocols need to be flexible to allow the operator to accommodate local issues (i.e. poor visibility, locality to schools and hospitals).

The responsibilities of the operators in a remote operation centre extend far beyond the responsibilities required for local bridge and lock operation. Complex traffic situations entail an increased mental load: operators now must imagine the overall situation. Maintaining the correct situational awareness might prove more demanding in a remote operation centre.

Workload should be reasonably distributed throughout the day. A workload that is too high can increase the risk of human errors due to stress. A workload that is too low on the other hand can have an equal result originating from loss of concentration.
When determining the amount of operators needed and the optimal workload in a control centre, several factors need to be taken into account. The number of structures being controlled is only one factor and should not be the only factor to be taken into consideration. Other influencing factors could be for example, the number of movements of each structure, complexity of the structure, type of traffic etc. The amount of people working simultaneously in a control centre is best when kept between 4 to 8 personnel. This allows for an efficient intercommunication.

The transition from local operation to remote control operation implies a distinct skill set. The switch to remote control comes with additional training requirements for remote operators. The regular training requirements for local operators should be retained but supplemented with additional training requirements. The systems used in a control system are IT-related, so basic IT-skills should be present or acquired by the operators. Building a 3D mental image based on a 2D camera images is a skill that should be present, combined with working as a team.

With the implementation of remote control and automation, an operator cannot carry out local repairs or perform small maintenance tasks. Moreover, since the operator is no longer the eyes and ears on the ground, additional attention must be paid to object inspection. For the definition of new or redefined procedures for maintenance operation, close attention must be paid to following aspects.

- Object inspection (raising the frequency of inspections, adding inspection tasks to periodic maintenance, introduction of remote condition monitoring techniques, …).
- Fault detection: automatic alarms, detection by operator, preventive maintenance...
- Use of SCADA for monitoring, fault detection and diagnosis by the remote operator, or making the SCADA status / fault information available in real time to (mobile) maintenance teams.
- Training of maintenance operators.
- Communication between maintenance operator at the local structure and the remote operator after a fault detection and during maintenance operation.
- Access control.
- Lockout-Tagout: A proper “lockout-tagout” procedure is recommended to monitor the engine room.
- Installation of uninterruptable power supply.
- Response time of maintenance operators.
- Registration and analysis of malfunctions.
- Procedures for remote operation failure and/or more extensive maintenance or repairs.

**Technical Implementation**

Standardization is the first step towards effective automation as highly standardized procedures and procedures pave the way for successful automation. Standardization is also a necessity when it comes to technical implementation. Due to the variety, number and age of the infrastructures, standardization is extremely difficult. Apart from the fact that there is often no real standard for all objects, the management is often fragmented over various contractors. Bridges, locks and water retaining constructions are mostly
designed and deployed by third parties under governance of civil contractors which prevents standardization and uniformity. It is therefore of great importance to invest in the development of a broad standard.

There is not one perfect way to manage the system architecture but not all are equally effective. Managing the system architecture means managing complexity. The transition to remote control increases the overall system complexity rapidly. If not well managed, complex systems are vulnerable systems that are hard to maintain and expensive to modify.

Complexity is built in, in the use of automation-related components, because first of all, dynamics increase. Secondly, because without proper standardisation, variety becomes very high as well, even for components with almost identical functions and purpose. With automation components, component lifecycles are much shorter. Time from design, to implementation, maintenance, modification and finally disposal can range between 2 to 10 years.

In a remote control system, several components are interlinked with components that are located outside the physical boundary of the object. Therefore, to analyse the overall system, a purely geographical and physically bounded breakdown is impossible and a system perspective is more suited. This is the approach found in the field of system engineering.

To reduce complexity and to manage these (sub)systems on an organizational level, organizational structure should be at least partially aligned with a division into (technical) subsystems. This reduces the need to transfer knowledge and reduces variety.

The main (sub)systems of remote control are the following; sensors and actuators, control system (PLC), data-communication, Supervisory Control and Data Acquisition-system (SCADA), Video-Management System (VMS) and Radio-communications.

Most of these systems now follow the developments from the IT-world. These developments include, IP-based communication, client-server architecture, cloud-computing, miniaturizing, object-oriented design, IoT, … which all allow for a simpler implementation of and new possibilities in remote control.

Examples of such new possibilities which are currently researched, developed and even implemented are;

- interlinked and interchangeable controle centres
- full-automation of water management based on a sophisticated decision-support system can take into account a large number of parameters from different sources and can present a number of predictions based on different inputs and hypotheses.
- Optimized remote control based on traffic management
- Full-automated operation of bridges
- Automated self-service operation of locks and bridges
- Hands-free mooring
- Simulation technology, both for training purposes as well as prototyping and testing
Safety

This section will describe some considerations on the practical implementation of safety measures. The requirements are described for operational safety and technical safety. Movable bridges and locks are subject to compliance with machinery safety regulations.

Within the European Union, CE-marking became mandatory from 1st January 1993. There are two approaches concerning the CE marking. In the first one, the waterway authority is itself responsible due to the fact that they are the nominated machine manufacturer. In the second approach, the waterway authority passes on the responsibility for CE marking to the contractor or machine manufacturer. The last one is generally more appropriate if a complete new lock or bridge is being constructed. However, when an existing lock or bridge is significantly modified, this last option is less favoured by the machine manufacturer.

Risk reduction measures must be implemented according to the hierarchy of risk reduction which is applied in the following sequence:

- Step 1: Inherently safe design measures
- Step 2: Safeguarding and/or complementary protective measures
- Step 3: Information for use

The aim of functional safety is to bring down risk to a tolerable level and reduce its negative impact. To ensure the same safety level as local operation when operating remotely, a risk assessment is necessary by following the hierarchy of risk reduction and defining the safety functions.

Operation of a lock or a bridge in an incorrect sequence can lead to unacceptable hazards. To overcome this, hard-wired or software interlocks are implemented to ensure that mal-operation of equipment cannot occur.

There are different types of interlocks which broadly fall into two categories, being safety interlocks and asset protection interlocks. At the onset of the design it is desirable to assume that safety interlocks should not be overridden.

The requirements for system interlocks are derived from the risk assessment of the object. A quantified risk assessment defines the level of risk which may result in the need to assign the interlocks as ‘safety functions’ in which case a suitable standard would be selected and followed (i.e. EN ISO 13849-1 or EN IEC 62061).

In general, the use of a safety-PLC is becoming more common when implementing safety interlocks and achieving the desired safety-level. The remote emergency stops must be certified, including the safe transmission of emergency stops from the remote operation centre to the local structures.

When defining the interlock requirements, consideration needs to be given to the required object availability and the responsibility allocated to the operator. It may be considered acceptable for the operator to override certain low consequence interlocks under certain conditions. It is recommended that the interlocks are implemented close to the object under control (i.e. the object site PLC panel).

Finally, once technical and functional safety measures are implemented, one must not forget operational safety. When operators only operate remotely, they might lose the knowledge of the object in situ and surroundings. They must be able to maintain situational awareness. This can be achieved by periodical trainings and a well performed operational implementation.
Security

When implementing remote operation, additional security items need to be addressed. There is no longer the presence of a local operator to monitor access control so remote monitoring becomes vital. When there is no longer a local operator present, it is more likely that buildings and equipment are more prone to external threats like vandalism or burglary. If necessary, a fence and access control should be installed. This is especially applicable on larger locks, infrastructure near a school, public areas or in city centres. In some cases, fences and access control is used to keep people in in addition to out of certain areas. In all cases, enough cameras should be installed, and the images should be recorded and kept for a sufficient amount of time (for example 30 days).

By introducing a more complex remote control network, cybersecurity vigilance becomes even more important than normal. It is certainly one of the largest risk factors – loss of connectivity between the control centre and the facility could be, at the very least, inefficient and expensive and, at most, catastrophic. The implementation of security services is only possible when the impact on primary business processes, especially those that affect public safety, is known and understood. The necessary security measures should therefore always be determined by a formal risk assessment. As industrial automation specialists are often new to these type of assessments, it is essential to get all stakeholders involved, including engineering, operations, and IT groups.

Information Management

In general, information management is not the first motivation of introducing remote control. However, remote control systems and centres are using a lot of data that might be valuable for other purposes. Since remote control systems already require large investments in information technology and data transmission capabilities, it is usually only a small extra effort to use this same infrastructure to collect, analyse, and store the data collected. Data that used to be entered manually for reporting purposes can now often be collected automatically.

By capturing and combining data from different sources, new kinds of information and insights can be created and presented. It is important, however, when designing remote control systems and the overall architecture to think about the way in which the data will be made available. If not properly thought through, the risk arises that the data will be contained within separate systems without proper means to transfer and share between systems.

Varying data importance leads to different requirements about the speed, resolution and accuracy of the data. For example, lock operation requires real time water level values each second, whereas for historical water level trend analysis, one value each 15 minutes may suffice. A well thought out strategy concerning this can largely reduce the needed performance and capacity of the technical systems and data transmission capabilities and, as such, the system costs.

Some providence is advised towards the nature and usage of the collected data since operators might have some reservations about data being used to monitor their personal actions and performance. While this may be justified in some cases, clear communication about the reasons and goals of data-collection to affected personnel is recommended.
1. Project background

The Haut-de-France great size network, operated by the Nord-Pas-de-Calais territorial direction of Voies Navigables de France (VNF), fills a strategic position in the French fluvial network: It connects, via the Canal du Nord, the Parisian area, on one hand to the French harbours of Dunkerque and Calais, and, on the other hand, to the Belgium and Dutch networks, up to the harbours of Anvers and Rotterdam. In that respect, this network constitutes one of the major waterways in France in terms of tonnage and merchandise transportation.

This Haut-de-France network is constituted by 16 locks located along 240km and 4 different waterways. It is also equipped with dams, pumping stations and other facilities for the global network hydraulic management. The VNF staff ensures the operation of these facilities in order to allow the navigation 14 hours per day.

In the frame of the Regional roadmap for the planning of the Waterway, and also taking into account the implementation of the coming Canal Seine Nord Europe (CSNE), VNF foresees a high traffic increase, with, for some sections, a tonnage multiplied by 2.5 in the next 20 years and up to 100 boats per day in some locks. In that context, VNF intends to improve the service provided to users, by extending the navigation period to 24h/24, 360 days per year, while keeping the current navigation levels of safety and availability.

In order to fulfil this objective, VNF and the Nord-Pas-de-Calais territorial direction (DT Nord) have launched the project for the Nord-Pas-de-Calais lock remote operation. This project should enable the remote control of locks from one or several “control centres” or “remote operation centres”. The objective target for this project completion is 2023. To complete that objective, VNF committed early 2018 a joint venture including SETEC ITS, CNR and IPAX (architect) for the Design and the implementation of this project.
2. **Main constraints and issues**

The realisation of such a remote-control system, which can meet the expectations of the VNF, seems to be particularly ambitious. It needs to address various challenges, which go beyond engineering.

2.1. **Human and organisational challenges**

The remote-control locks involve many changes in terms of human resources and operation, that goes along with a new approach: the lock keeper becomes an operator.

Indeed, considering his new position, the operator changes his relationship with the users, since he is no longer present on the lock: New ways of communication must be implemented, accessible for both professionals and amateur sailors who may not be as well equipped.

Remote control locks changes also the relation between the operator and the facility itself: Up to now, lock keepers were always assigned to a unique lock. While with remote-control system, every operator should be able to take over any facility in remote control scope, whatever their characteristics and specificities are. The mastery of all the facilities, in safe conditions, will require a specific training process.

Beyond the lock keepers, the project will also impact the maintenance staff, either in the facilities:

- To take over the local maintenance previously carried out by the lock keepers
- To take over the maintenance of the new local devices provided by the remote-control systems
- To ensure a local operation in case the remote-control system is failing,

or in the “control centres” to ensure the maintenance of the new equipment.

2.2. **Technical challenges**

In order to meet the expectations of the VNF in terms of safety and availability, in addition to all the organisational issues developed just before, many technical challenges will have to be addressed, such as:

- The definition and implementation of interfaces adapted for the operators, in order to give them communication means and the information access they might need, also in order to guarantee a mastery of their environment similar to a local operation. To solve the issue, a workgroup was created with operation staffs (lock keepers), the Contracting authority and the Designer. The workgroup allowed improving the ergonomy and the general use of the operator’s control panels, as well as the operation modes and process that they will implement daily.

- The definition of new of operation modes for the remote-control of locks, which have to be able to manage traffic variations, for example during the night. The system will have to be able to work with a variable number of operators and therefore allow a dynamic allocation of locks. Thus, one lock can be linked indifferently to an operator station or another. This absence of permanent link between an operator station and a lock implies many technical issues, in terms of redirection of data (video, VHF calls, …) but also in terms of safety.

- The safety provided to users in remote control operation has been designed using the so-called "GALE" methodology (Globally At Least Equivalent), which ensures that the level of safety in remote control operation is higher (or equivalent) than the one existing today. The remote-control operator, like current lock keeper, will be the first responder in case of a danger. He will have, from his remote panel, safety tools, implemented on the basis of specific standards (NFC 13489-1, IEC 61508,...) allowing him to stop the lock cycle, to block the doors and stop water movements in the lock (main hazard considered), while maintaining the communication with the user.

- The future remote-control system will also have to integrate the operation of the facilities of the future Seine Canal Nord Europe, from the control centre operator panels, common to those used for the facilities of the Nord-Pas-de-Calais network. Beyond the sizing of the equipment, the compatibility of operating modes between very different structures, including the future Somme Canal Bridge, should be considered. This challenge will be met thanks to a methodological analysis of the interfaces, the flexibility of the chosen architecture and an early configuration, so the specificities of facilities can be considered.
3. Design principles
In order to address all the issues identified within the framework of this project, including those described above, the teams of the project management joint-venture designed the remote control system by applying the following principles:

- **Upgrading the equipment of the locks**: PLCs, cameras, site security, etc. These installations must guarantee an optimal level of safety as well as the provision of the necessary information to the operators. These operations must be carried out with a minimum of traffic disruption, in particular navigation stops.

- **Construction of two control centers**, located respectively in Waziers and Valenciennes (59). These two centers are designed in such a way that each of them can take over the operation of all the network facilities, in total back-up to each other. It should be noted that the Waziers centre, designated as the main one, will also host a development and training area for the remote control system.

- **Creation of a 180km communication network**, connecting all the facilities to the two control centres. In order to optimise the overall cost of the operation, the use of existing infrastructure will be favoured as much as possible.

4. The prospects for the future
This project, estimated at 23M€, is a real challenge for the VNF and the Project Manager teams of the SETEC ITS - CNR - 1PAX joint venture. The aim is to design the **first multi-centre remote control system for large gauge locks in France**.

It is part of an overall context of optimising transport infrastructure and a wish to develop inland waterway transport services, as demonstrated by the completion of the Seine Canal North Europe project. As such, this operation should make it possible to define standards in terms of operating and organisational methods applicable to all future VNF telecontrol projects.
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Approaches to Automatic Entering of Locks

Shifting transportation of goods from road and rail to inland waterways is a promising solution for the reduction of the environmental footprint of freight traffic. As a result, in December 2013, the German Federal Ministry of Transport pointed out that inland navigation should be strengthened as an important mode of transport. In order to remain internationally competitive and to adapt the technology standard of the transport mode waterway to the common modes of transport, not only modernly
equipped waterways are necessary, but also innovative techniques on board of an inland vessel.

The aim of the project SCIPPER is the development of an assistance system used for automatically entering/exiting a lock. Passing a lock is one of the most common but also most critical maneuvers in inland navigation. In Germany typically, a ship of 11.40 m width enters a lock chamber, which is 12 m wide, thus, there are 30 cm of space on each side.

Moreover, entering a lock is a very demanding task within inland navigation. The view of the bow of the vessel is limited, since the skipper is about 100 m away, and often cargo such as containers block the direct line of sight. The maneuvers require very high concentration of the skipper and good knowledge about the ship’s behavior. Typically, all propulsion and steering units of the vessel, as main engine, rudder and bow thruster are operated in parallel. Consequently, one lockage takes about 30 minutes and ships may pass up to 15 locks a day. Thus, the amount of time needed to enter and leave a lock takes a considerable part of the total travel time.

Automation of navigation during entering a lock, maneuvering inside and leaving will increase safety, on the one hand. On the other hand it may accelerate the whole passage, or make its duration at least predictable. Therefore, both economy for the individual skipper and capacity of the waterway can be improved.

One technology basis for the new automation function is the provision of reliable and highly accurate information of the position, orientation and velocity of the inland vessel.

To reach this goal several tasks are addressed:

- Advanced satellite-based positioning techniques are used to provide accurate and integrity monitored information about the ships position and heading. GNSS processing will be based on PPP technology (precise point positioning). Transmission of PPP correction data requires significantly less capacity than RTK corrections. Thus a PPP data stream can be more easily combined with other information on a carrier with limited bandwidth.

- The transmission capabilities of the new VDE system (VDES) will be used to transmit GNSS corrections. One part of the new VDE system is a high speed data channel with up to 100 kHz bandwidth in the VHF frequency band. This data channel will be used to broadcast PPP correction data. Combining the high speed data channel with the reduced bandwidth requirements of PPP compared to may generate a precise navigation service that has the potential to enhance significantly accuracy of navigation on inland waterways.

- VDES offers bi-directional communication between ships, between ships and land stations, and between ships and satellites. The VDE high speed data channel with its new transmission capacities opens up new perspectives for inland waterway transport. Additional information about the actual state of the lock will be provided to the assistance system on the vessel. Since there are worldwide no products available as transmitting and receiving units, this project offers the opportunity to develop innovative technologies for future products that base on this specific pilot application.

- Close range sensors will provide information about relative position of the vessel when approaching and entering the lock chambers. The reception of GNSS signals may be interrupted when entering a lock due to a bridge or due to the gate itself, depending on the construction of the lock. Furthermore, inside a lock chamber reception of GNSS signals may be degraded since sky is only partly visible at the antenna’s position. Thus, redundant information about
position and orientation of the vessel in the lock chamber is required. Close range sensors like LIDAR (laser scanner) or automotive radar provide this information which will be fused with the GNSS results.

- Advanced control algorithms will regulate all propulsion and steering devices of the vessel. Due to the slow movement of the vessel, the control algorithms have to be able to handle actuators with discrete states. For example the main engine has to be coupled and uncoupled to generate a short impulse on the ships movement.
- Measurements and the actual state of the vessel and its actuators will be presented to the skipper in a nautical display. In the nautical display this information is combined with classical navigation information like Inland-ECDIS chart, Inland-AIS and navigation radar of the vessel.
- Entering a lock chamber will be tested in detailed simulations before full scale trials are carried out.

In the presentation the setup of the overall system will be explained. The system will be separated in three parts, a land-based segment with the acquisition and preparation of the data, the transmission segment including the required hardware and the ship segment. In the ship segment, real time processing of the sensor data as well as the control of the vessel is performed.

Furthermore, requirements identified in the first stage of the project will be presented. The locking process will be segmented in 5 parts: approach to lock chamber, entering lock chamber, navigation inside lock chamber, leaving lock chamber and navigation towards waterway. For each segment of the locking process, requirements regarding accuracy, update frequency and time to alarm have been identified from the control systems point of view.

Also first results from GNSS processing and tests of close range sensors will be presented.

The results provided by the project SCIPPER will be the basis for control and regulating technology used in a variety of other situations by an inland vessel, that navigates autonomously. They are altogether an important step towards a future automation of inland navigation.
Command and Control of Vessel Trains in Inland and Short-sea Shipping

Abstract:

Within the European research project NOVIMAR vessel trains for inland and short-sea shipping are being developed. A vessel train is made up of a leading vessel and several other vessels that follow the leading vessel automatically at a pre-defined distance. This idea is known as platooning within road transportation. In the various sub-tasks of the NOVIMAR project many different aspects regarding the vessel train are being investigated. They cover such diverse topics as business models, technical developments and legal implications, amongst others.

This contribution presents intermediate results on the technical developments within NOVIMAR. Specifically, the command and control module of the vessel train is introduced and examined. The command and control module is comprised of an automatic controller for each individual vessel, a human-machine-interface for the vessel train operator as well as a ship-to-ship communication system. This contribution focuses on the general approaches employed to realize such a vessel train command and control module. The following aspects are covered:

- Automatic control of an individual vessel: The lateral deviation to a pre-defined reference track as well as the distance to the vessel in front is being controlled.
- Vessel train formation: Concepts for enabling vessels to join or leave a vessel train are presented.
- Vessel train navigation: Concepts for navigating the vessel train as a whole by the operator on the leading vessel are discussed.
- Ship-to-ship communication: Information exchange between the vessels within the vessel train as well as information exchange with other traffic participants is highlighted.

Practical results from automatically sailing inland vessels on major European waterways using an automatic track-keeping system are presented. This track-keeping system forms the basis for the vessel train control system developed within NOVIMAR. Results from simulations carried out on a state-of-the-art ship handling simulator give a first glance of the vessel train system as a whole. Also an outlook on the next steps within the NOVIMAR project is given. Legal issues arising from vessel trains, the human factor, cyber
security as well as ways to deal with emergencies are also addresses within NOVIMAR but are not within the scope of this paper.

**Automatic control of an individual vessel**
Automatic control of the individual vessels of a vessel train consists of two independent controllers. Track control is acting on the rudder to keep the lateral distance to a given reference track (also called guiding line) at a desired value (see Figure 1). The reference track consists of a series of geodetic positions that are used to compute a smooth set of reference values for the feedforward and feedback part of the track control loop.

![Figure 1: Track control (lateral distance control loop), grey: reference position and orientation (setpoint), black: current position and orientation, blue: guiding line](image1)

The distance control loop acts on the engine throttle to regulate the speed and the longitudinal distance to the ship directly in front. The distance to the ship in front is defined as the length of the reference track between the two ships to take the bends of the river into account (see Figure 2).

![Figure 2: Longitudinal distance control, green: distance along guiding line](image2)

**Vessel train formation**
In the vessel train procedures radio voice communication between the crew on the leader of the vessel train and the crews on the follower vessels plays a fundamental role. Changes in the vessel train configuration are prepared through voice communication up to a level where the automated system takes over control of the follower vessel. The actual formation of a vessel train is executed by ECDIS chart systems with vessel train capabilities. The operator on a potential follower vessel selects a potential leader vessel or a vessel in an already active vessel train. An AIS request message is sent to the ECDIS system of the leader vessel asking the operator to accept the follower. If the operator on the leader vessel chooses to accept the follower, an AIS reply message is sent to the follower and track and distance control is activated on the follower vessel. From this moment on, the operator on the leader vessel takes over responsibility for the navigation of the follower vessel. The operator on the follower vessel is not involved in navigation any more but must be available in case of emergencies. When coupling to an already existing train, the operator on the new follower vessel is able to choose the position in the train by selecting the ship directly in front instead of the leader. Decoupling from a vessel train is also initiated by the operator on the follower vessel and includes similar request and acknowledge messages.

![Figure 3: Flow diagram of the formation of a vessel train while travelling](image3)

![Figure 4: ECDIS display of vessel train with 2 ships (leader and follower) seen from the leader vessel, during request from new ship AALST 101 to join the train](image4)
**Vessel train navigation**

The operator of the leader vessel faces two tasks when navigating the vessel train along the river:

- Avoiding stationary objects
- Reacting to encountering traffic or passing slower ships

The main goal of the vessel train control system is to help the operator to perform these tasks safely and easily without monitoring or controlling every single ship. Thus, the operator is given no control over single follower ships but navigates the vessel train as a single unit. Two different modes have been developed to navigate a vessel train.

**Assisted guidance:** To navigate the vessel train around stationary objects on an arbitrary track, the operator steers the leader vessel manually. The follower vessels will automatically track the path of the leader vessel using a guiding line generated from AIS position reports (see Figure 5). To ensure that all following vessels are able to stay on the desired track, the operator must sail the leader vessel as if it was the vessel with the slowest dynamics in the train.

**Automatic guidance:** The whole vessel train follows a common reference track with the leader vessel navigating automatically, too. This mode assists the operator when the vessel train is encountering traffic or passing slower ships. In order to adjust the vessel train's position relative to traffic, the operator is able to adjust the lateral offset to the guiding line (see Figure 6). This offset is applied to all followers immediately. To ensure that all vessels stay inside the fairway and don’t collide with any obstacles, the vessel train control system includes a set of predefined fairway boundaries that define the navigable area excluding obstacles such as bridge pillars and shallow waters. If the operator on the lead vessel sets a lateral offset, the value is checked by the control system on each follower and adjusted according to the fairway boundaries (Figure 6).

The operator on the leader vessel is able to adjust the speed of the vessel train by changing the speed of the leader vessel. The follower vessels will automatically adjust their speed in order to keep the desired distance to the ship directly in front. The distance between the vessels of the vessel train can also be adjusted by the operator on the leader vessel if necessary.

**Ship-to-ship communication**

Communication between the ships of a vessel train is divided into three parts (see Figure 7). One part is radio voice communication. This is used to prepare all procedures concerning the vessel train. Another part uses the AIS (Automatic Identification System) VHF transponder system that is commonly used on all sea-going and inland vessels. AIS is compulsory on the major inland waterways in Europe. An application specific AIS message has been defined to enable coupling and decoupling with a vessel train. This message can be received by the surrounding traffic. It is used to announce the presence of a vessel train to surrounding traffic and shore infrastructure because the operators on other ships need to be aware of the reduced maneuverability and great size of the vessel train.

Since the bandwidth of AIS communication is limited and needed for other purposes, the third part of the ship-to-ship communication uses a TCP/IP-based network such as GSM or wireless LAN. A set of custom NMEA ASCII messages has been defined to exchange all relevant information between the leader and the follower vessels. The following values are transmitted from the leader vessel to the followers:
- **Vessel train mode**: Assisted guidance or automatic guidance
- **Desired lateral distance** to the reference track (Automatic guidance only)
- **Desired longitudinal distance** between the vessels of the vessel train (one common value for all ships)

In reverse direction, from the follower ships to the leader, there is only one custom NMEA message containing various alarms. If more information about the track or distance control on a follower vessel is required, the operator on the lead vessel is able to access the web interface of the control system of each follower.

**Practical results with trackpilot**
Since the presentation of argoTrackPilot by argonic in December 2017, 45 units have been sold and have navigated automatically for tens of thousands of hours. The track control system has been improved continuously based on the experience gained from collected data and feedback from skippers. The goal was to increase the time travelled with active automatic track control without switching off. Thus, a lot of effort has been put into GPS error detection and dead-reckoning to be able to pass beneath bridges without having to switch off track control due to bad GPS signal reception. Table 1 shows some exemplary routes and the time travelled with automatic track control being active.
Within the project NOVIMAR, first real-time experiments using two bridge simulators were carried out at MARIN research institute in the Netherlands. Two experienced skippers were given a short introduction how the vessel train control module and the simulator is used. After the introduction each skipper navigated the vessel train from the leader vessel simulator in different scenarios:

- Familiarization: Sailing upstream with only one oncoming ship.
- Sailing upstream: Traffic with two oncoming ships and two slow ships going upstream
- Sailing downstream: Traffic with three oncoming ships and two slow ships going downstream

The experiments showed that navigation of a vessel train with two ships works well using the command and control module described in this paper. But to navigate safely with a vessel train, the operators need a good understanding of the way the follower vessels will react depending on the selected mode of the vessel train. Furthermore, it became clear that passing slower ships with a vessel train is a difficult task because the operator on the leader vessel must take into account the position of all follower ships with respect to the slower ship.

Conclusions and outlook

The concept of the vessel train command and control module was successfully tested during the simulator demonstrations carried out at MARIN. Additional simulation tests with several experienced skippers will be used to further refine the employed command and control methods. Practical full-scale tests on board of inland and short-sea ships will be carried out within the fourth quarter of the NOVIMAR project.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 723009.

### Simulation results with vessel train

<table>
<thead>
<tr>
<th>Route</th>
<th>Duration</th>
<th>Track control</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duisburg-Dordrecht</td>
<td>11 hours 50 minutes</td>
<td>86 %</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Amsterdam-Rotterdam</td>
<td>8 hours 20 minutes</td>
<td>91 %</td>
<td>Canal 1.2 m</td>
</tr>
<tr>
<td>Düsseldorf-Antwerp</td>
<td>22 hours 51 minutes</td>
<td>81 %</td>
<td>River 2.6 m</td>
</tr>
<tr>
<td>Strasbourg-Antwerp</td>
<td>46 hours 15 minutes</td>
<td>84 %</td>
<td>2.5 m</td>
</tr>
</tbody>
</table>

*Table 1: Routes travelled with active track control*
Smart Rivers 2019 Conference  
/ September 30 - October 3, 2019  
Cité Internationale / Centre de Congrès  
Lyon FRANCE /

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Keywords:  
Innovation, automation, regulation

Title:  
Automation in inland navigation:  
current projects and future regulatory challenges (AB_26_6)

Full paper:  
Automation takes place in all means of transport, be it by air, sea, road or rail. Basically, automating tasks substitutes machines for human actions. Automation nourish important expectations in terms of economic benefits with the reduction of operational costs and the creation of new business models, but also creates challenges for maintaining the current safety levels.

In 2018, the competent ministers of the Kingdom of Belgium, the Federal Republic of Germany, the French Republic, the Netherlands and the Swiss Confederation called on the Central Commission for the Navigation of the Rhine (CCNR) to press ahead with development of digitalisation, automation and other modern technologies, thereby contributing to the competitiveness, safety and sustainability of inland navigation\(^1\). The same year, the CCNR adopted a first international definition of levels of automation in inland navigation and then enables assessment of the need for regulatory measures.

This presentation provides insight in the development of innovating automation projects in Europe, using the international definition of level of automation developed by the CCNR. After summarising expectations and concerns with automation, it presents the ongoing regulatory work for the navigation of the river Rhine as well as future challenges for the implementation of automation.

Specific context for inland navigation

While automation is also being promoted in maritime navigation, the characteristics of inland navigation, which are very different from those of maritime navigation, should be taken into account. Inland navigation vessels operate in confined surroundings. The operating conditions are fixed by the waterway dimensions, the transiting of locks and their dimensions, the water levels and the bridge clearances. These restrictions appear clearly in the classification of European waterways\(^2\) or in the technical

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\(^1\) Mannheim Declaration “150 years of the Mannheim Act – the driving force behind dynamic Rhine and inland navigation”, Central Commission for the Navigation of the Rhine, 2018

\(^2\) See PIANC, WG179 activities to update CEMT classification
regulations regarding vessel manoeuvrability. These restrictions receive specific attention in several pilot projects (for example crossing narrowed arch bridges or assistance for entrance in the locks).

Contrary to maritime shipping, the traffic on inland waterways remains often very dense outside the port areas, especially on international waterways, such as the river Rhine. Passing and overtaking of inland navigation vessels is quite common, but thanks to skilled boatmasters, rules compliance and good communication, the number of collisions remains limited. For example, just 30 collisions between vessels have been observed in 2013 and no lives were lost on the German Rhine, one of the busiest inland waterways worldwide.

Serious accidents on waterways are rare. Within the past 50 years there have only been half a dozen incidents that have interrupted navigation of the Rhine for more than 48 hours. However, accidents such as the one involving the motor tanker “Waldhof” in 2011 are reminders of the risks of polluting the environment as well as the risks for people living close to the waterway. These risks are substantial, as with a loading capacity of 3 million tonnes in 2016, tanker shipping on the Rhine has taken on sizeable part of the transport of dangerous goods in Europe. Therefore, maintaining the high level of safety of inland navigation is one of the major challenges for the development of the new technology and the corresponding regulatory framework.

Knowing the specific characteristics, constraints and risks, automation in inland navigation must be treated as a distinct subject from maritime navigation, or rather a challenge, be it for R&D, economic appraisal or regulatory needs.

**International definition**

During its plenary meeting in December 2018, the CCNR adopted the first international definition of levels of automation in navigation. This definition allows a clear understanding of all levels of automated navigation, subsequently enabling an assessment of the need to take regulatory measures, based on a common understanding. The experience gained with the various research and development projects should stimulate more in-depth discussions on levels of automation and would enable the definition to be amended by 2020 if so required.

![Definition of levels of automation in inland navigation](source: CCNR, Resolution 2018-II-16)

**Inventory of pilot project**

Many national and international research and pilot projects are pursuing innovation by developing higher level automation applications for inland navigation. Gaining experience with such applications is critical for

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3 European standard laying down technical requirements for inland navigation vessels (ES-TRIN), chapter 5
4 CCNR, Market observation, 2018, Chapter 8
5 CCNR, Resolution 2011-II-8
6 CCNR, Market observation, 2017, Chapter 5
evaluation of technical possibilities and expected advantages. Based on the international definition adopted by the CCNR, this presentation gives an updated insight in the development of exciting automation projects in Europe (see Annex 1).

Expectations and concerns

These projects nourish important expectations in terms of economic benefits. The main benefits are claimed to be the reduction of operational costs - crew costs and fuel costs (smart steaming) – and the increase of the payload (better use of the space on board with no accommodation, wheelhouse…). Experience gained in the air and maritime sectors shows that automation is also a driver for better use of the existing resources – for example increase of annual trips (no resting time and faster mooring) or increase of efficiency in port operations. Some pilot projects also aim to initiate new business models, such as commercially viable navigation on smaller inland waterways that today are not sufficiently used. A first attempt to identify and quantify cost and benefits of a fully automated and unmanned inland navigation vessel (supported by an onshore remote control centre) shows a positive business case. Further examination is necessary to compare the savings (including possible benefits for the society) with the investment in new technologies (onboard and onshore) and costs for society.

To date, underpinning all regulatory provisions is the responsibility of the boatmaster. However, responsibilities on board are likely to change considerably as a result of automated navigation. For example, a legitimate question arises as to the current and de facto legal basis for applying responsibility when a vessel that is operating largely automatically causes damage to a third party. Pursuant the international or national police regulations, inland vessel crews are obliged to minimise negative impacts on, and damage to, the environment in the event of accidents and to collaborate with the relevant authorities and emergency services. They are also obliged to render assistance in emergencies. There needs to be consideration of how automated solutions can ensure that inland vessels remain able to discharge these obligations even with reduced crewing, or no crew at all. Ultimately, the repercussions of automated navigation lead us to anticipate a redistribution of responsibilities between the vessel owner, the boat master and the manufacturer. In addition to the impact on the labour market and employability, automated navigation also prompts fears such as the dehumanisation of social relationships and also the the disappearance of the boatmasters' skills.

Cybersecurity and data protection issues will also need to be addressed. Automated systems are fundamentally more prone to cyber-attacks than other inland vessel shipboard systems. Furthermore, automated systems continuously collect and analyse data some of which can legally be deemed personal data.

Although the need for regulatory measures for automated navigation arises from technical developments, because of automated navigation’s far-reaching consequences, a holistic perspective taking account of economical, environmental, social, legal and ethical considerations is called for.

Regulatory work within CCNR

With the active contribution of the Belgian delegation, CCNR has started an analysis of its regulatory framework and discussion on questions of principles for amendments necessary to allow a proper implementation of automation. These questions of principle are not easily answered, but the answers are needed as the basis for consensus between countries and for writing new or amending existing regulation. This regulatory work concerns most of all the rules for navigation and operation of the vessels. The CCNR would welcome an exchange on such decisions of principle taken by regulators in other parts of the world and faced with the challenge of developing a framework for implementing automation in inland navigation.

Challenges and conclusions

The development of automation in inland navigation requires taking into account the characteristics of inland navigation and associated risks, especially for the transport of dangerous goods. Maintaining the existing

7 INN-IN, Edwin Verheght, 2019.
high level of safety of inland navigation is one of the major challenges for the development of the new technology.

Based on the international definition adopted by the CCNR, an inventory of pilot and research projects was carried out. Gaining experience with such applications is critical for evaluation of technical possibilities and expected advantages.

CCNR has started the regulatory work in order to allow a proper implementation of automation in the light of safety and sustainability. High automation should only be implemented if it supports sustainability of inland navigation (economic, social and environment) and at the same time places the human factor in the center.

Globally, PIANC has taken on an important role with the setting up of the InCom Working Group 210 on “Smart shipping on inland waterways” which will further automation with the specific perspective of infrastructure providers and traffic managers.

Annex 1 - Inventory of pilot and research projects (as at March 2019) (Source: CCNR)

<table>
<thead>
<tr>
<th>Ref. no.</th>
<th>Pilot project name</th>
<th>Project sponsors</th>
<th>Work duration</th>
<th>Country</th>
<th>Degree of automation</th>
<th>Brief description</th>
<th>Links</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LAESSI “Guidance and assistance system for increasing the safety of navigation on inland waterways”</td>
<td>Consortium comprising four public and private organisations: - in-innovative navigation GmbH - WSV - DLR - Alberding GmbH</td>
<td>2015-2018</td>
<td>DE</td>
<td>1</td>
<td>Advanced assistance system with 4 features: 1) bridge collision warning system provides timely warning to the vessel’s master in the event of a problem when passing beneath a bridge; 2) berthing assistant displays distance measurements and calculations relative to the quayside or other vessels, thereby assisting the boatmaster during a difficult berthing manoeuvre; 3) track control assistant assists the boatmaster by maintaining the vessel on a predetermined track when travelling through a sector; 4) control screen permanently displays all the vessel’s movements, the rudder position and speed of the propeller.</td>
<td><a href="https://www.innovative-navigation.de/allgemein/erfolgreiche-abschlussdemonstration-des-verbundprojekts-laessi/">https://www.innovative-navigation.de/allgemein/erfolgreiche-abschlussdemonstration-des-verbundprojekts-laessi/</a></td>
</tr>
<tr>
<td>2</td>
<td>Shipping Technology</td>
<td>Shipping Technology</td>
<td>2016 - ...</td>
<td>NL</td>
<td>3 - 4n</td>
<td>Use of (existing) nautical equipment for collecting on-board data and building a predictive model to enable automated navigation based on artificial intelligence (AI).</td>
<td><a href="https://shippingtechnology.com/">https://shippingtechnology.com/</a></td>
</tr>
<tr>
<td>4</td>
<td>NOVIMAR</td>
<td>Consortium (22 bodies) with Netherlands Maritime Technology NMT as coordinator</td>
<td>2017 - ...</td>
<td>EU</td>
<td>3</td>
<td>Reorganisation of navigation with ship trains (platooning): 1 lead vessel + accompanying vessels (remotely controlled and with a reduced crew).</td>
<td><a href="https://novimar.eu/">https://novimar.eu/</a></td>
</tr>
<tr>
<td>5</td>
<td>Seafar</td>
<td>Seafar NV</td>
<td>2018 - ...</td>
<td>BE</td>
<td>3</td>
<td>Existing vessel equipped with sensors for automated navigation on a predetermined course, taking account of the environment (but with remote control) Test on the Albert Canal in December 2018</td>
<td><a href="https://www.seafar.eu/news/">https://www.seafar.eu/news/</a></td>
</tr>
<tr>
<td>Ref. no.</td>
<td>Pilot project name</td>
<td>Project sponsors</td>
<td>Work duration</td>
<td>Country</td>
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<td>Brief description</td>
<td>Links</td>
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<tr>
<td>9</td>
<td>Hull-to-hull (H2H)</td>
<td>Kongsberg, KU Leuven, Mampaey, SINTEF</td>
<td>2017-2020</td>
<td>EU</td>
<td>3</td>
<td>The aim is to develop a concept for hull-to-hull and hull-to-keel positioning. Positioning accuracy is a key element in developing automated vessels. H2H is intended as an open concept with standardised data exchange to enable different suppliers’ vessels, infrastructure and solutions to work together. Demonstrations are planned between now and 2020: Norway, Netherlands and Belgium (specific to the navigable waterways).</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>AutonomSOW</td>
<td>Andering GmbH, LUTTRA Hafen Königs-Wusterhausen, DLR Neustrelitz Bundesverband Öffentlicher Binnenhäfen</td>
<td>2019 - ...</td>
<td>DE</td>
<td>-</td>
<td>2019 Feasibility study for an automated and autonomous inland navigation trials area on the Spree-Oder waterway. 2010 Setting up of the trials area 202X Operating trials on the Spree-Oder waterway</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Autonome Schifffahrt auf der Kiel Förde (CAPTiN – Clean Autonomous Public Transport)</td>
<td>Christian-Albrechts-Universität zu Kiel</td>
<td>2018-…</td>
<td>DE</td>
<td>3-5</td>
<td>Together with partners, the University is studying systems and components for autonomous public transport traffic and for autonomous navigation (combination of passenger transport by bus and by ferry).</td>
<td><a href="http://www.uni-kiel.de">www.uni-kiel.de</a></td>
</tr>
<tr>
<td>15</td>
<td>Captain AI</td>
<td>Captain AI, Havenbedrijf Rotterdam, Watertaxi Rotterdam</td>
<td>2018-</td>
<td>NL</td>
<td>3-4</td>
<td>An initiative aboard the Rotterdam Port authority vessel RPA-3, similar to the Shipping Technology approach and using sensor readings to feed into IA.</td>
<td><a href="https://www.captainai.com/">https://www.captainai.com/</a></td>
</tr>
<tr>
<td>Ref. no.</td>
<td>Pilot project name</td>
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<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>16</td>
<td>ASM Roboats</td>
<td>Massachusetts Institute of Technology (MIT), Delft University of Technology (TU Delft), Wageningen University and Research (WUR).</td>
<td>2016-2020</td>
<td>NL</td>
<td>...</td>
<td>In the third research year activities will focus, among others, on: - Upscaling navigation and autonomy to a 1:2 scale Roboat. Due to their size, these vessels have different dynamics and navigation behavior. - Further developing the latching mechanism for 1:2 scale prototypes to latch individual vessels or dock them to the quays. - Designing and refining the propulsion technology, the energy system and the electric charging technology for 1:2 scale prototypes. - Further developing the water sensor technology in collaboration with Waterjet.</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Remote Control Tug</td>
<td>Kotug, Alphatron, KPN, M2M Blue, Veth</td>
<td>2018</td>
<td>NL</td>
<td>3</td>
<td>Kotug can remotely control the RT Borkum. Studies the possibility of unmanned towing. <a href="https://www.kotug.com/newsmedia/kotug-demonstrates-remote-controlled-tugboat-sailing-over-long-distance">https://www.kotug.com/newsmedia/kotug-demonstrates-remote-controlled-tugboat-sailing-over-long-distance</a></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Sensing</td>
<td>Marinminds</td>
<td>2018-</td>
<td>NL</td>
<td>4</td>
<td>A broad range of new and existing technologies need to be integrated into one system. Project Sensing focuses on developing a prototype of an on-board sensor- and data acquisition system. With testing automotive grade sensors and object recognition software, gain insight in the required alterations and development of the algorithms for later use in autonomous systems <a href="https://www.marinminds.com/">https://www.marinminds.com/</a></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>AURIS (AUtonomous Remotely monitored Innovative Ship)</td>
<td>MARIN</td>
<td>2018-…</td>
<td>NL</td>
<td>3-5</td>
<td>The objective of this project is to research which sensors and analysis methods are required to achieve optimal situational awareness of the marine environment from a ship, and to interface an (autonomous) vessel with a Shore Control Centre. This will be done by developing and testing a modular intelligent situational awareness module (ISAM) on a 6m rigid-hulled inflatable boat.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>modular Autonomous Underwater Vehicle (mAUV)</td>
<td>MARIN</td>
<td>2018-</td>
<td>NL</td>
<td>3-5</td>
<td>The objective of the mAUV v1.0 project is the development of a modular underwater vehicle (mAUV) hardware &amp; software, including all a first approach for 6D control and allocation. It will be used for basin model tests at 6D control and allocation. In the coming years the model will serve as one of MARIN's underwater test platform for AUV research.</td>
<td></td>
</tr>
</tbody>
</table>
Title:
Towards Smart Shipping in the Netherlands

Autonomous shipping on inland waterways has the full attention of the shipping sector. Applications and systems that are needed for autonomous navigation are maturing. Although the inland waterway fleet is considered to be at the end of level 1 on the automation scale of the CCNR\(^1\), development that could make it possible to navigate a ship remote or autonomously is moving fast. If and how this will eventually lead to autonomous ships, is still uncertain.

Despite these uncertainties, the development raises questions about how autonomous transport over water can be implemented in a societal responsible way and in what way waterway managers should react. This short paper addresses the strategy of Rijkswaterstaat related to Smart Shipping\(^2\) developments in the Netherlands.

The importance of innovation in the shipping sector
6000 Dutch inland ships annually transport 365 million tons of cargo from harbors on the North sea to the hinterland. This represents one third of the total volume transported via the inland waterways in Europe. Inland shipping is a vital modality to ensure a functional transport system. Without this modality, ports like Rotterdam would not be able to transport all their goods.

Besides the economic potential, Smart Shipping is one of the methods to achieve the policy goals set by the Ministry of Infrastructure and Water Management (IenW)\(^3\). An example of such a goal is ensuring accessibility of the Netherlands through safe and sustainable transport by water. Besides that, smart solutions are promising in lowering emissions, thereby potentially increasing the sustainability of the sector and also in the long run increasing safely. Also, due to climate change, the weather is changing, which makes rivers and water levels less predictable. Systems used to make ships more autonomous, could help navigate changing rivers in a safe and efficient way.

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1. CCNR, 2018, "Geautomatiseerd varen, Ontwerpbesluit inzake de definitie van de automatiseringsniveaus in de binnenvaart"
2. Developments regarding autonomous ships in the Netherlands are defined with the term Smart Shipping. The definition of Smart Shipping is as follows: all innovations with regard to accommodating far-reaching automated sailing at sea and inland waterways.
3. Rijkswaterstaat is part of the Dutch Ministry of Infrastructure and Water Management. As the executive agency of the Ministry, Rijkswaterstaat is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands.
Current Smart Shipping developments
Driving forces behind smart shipping developments are the improvement of sensors, advanced artificial intelligence, connectivity and data aggregation. It is believed that innovations in the shipping sector have the potential to disrupt the current market. It is shown that this disruption often starts in a niche of the market. A niche being: a protected and bordered environment. One of those niches that is mentioned quite often is the transportation of goods on small inland waterways. Waterways that nowadays aren’t used anymore because of the ever increasing economies of scale. Autonomous ships could lead to new shipping concept, which could make it possible to economically exploit these small rivers and canals again. Those canals and rivers are less busy, have less complex infrastructure and could therefore be an interesting place where autonomous ships could be implemented.

A closer look at the current Smart Shipping developments show that most developments focus on applications and systems that make the navigational tasks more autonomous. The captain is assisted in making navigational decisions. These systems could eventually contribute to autonomous navigation. Although technical developments are fast moving, scenario studies conducted in the Netherlands show that, as a result of socio-economic development, the complex interaction with infrastructure (bridges and locks) and the busy, narrow waterways, a fully autonomous transport system over water looks not feasible within the upcoming 20 years. More likely, a hybrid situation with mixed traffic where (autonomous) ships will be operated by some form of human supervision, either on the ship or from shore, will exist.

The Rijkswaterstaat strategy on Smart Shipping
Looking at the developments of Smart Shipping, it was clear for Rijkswaterstaat and IenW that governmental bodies have a role to play. This role consists on bringing government, knowledge institutes and commercial parties together, for example by initiating a national forum. As a legislator, or in an international context as a co-legislator, IenW has the tasks to realize legislation that makes Smart Shipping possible. Already in 2018 the Ministry decided that the Dutch waterways under the management of Rijkswaterstaat would be available for testing of autonomous systems. To make this possible, a policy rule was written making it possible to test under strict conditions. Those preconditions are that nautical safety and sustainability must not suffer from Smart Shipping. Already early in the process international cooperation was established for example with Flanders. The Vlaamse Waterweg nv (DVW) also believes that smart shipping will initiate changes in the inland waterway sector and will have an impact on the operation of the organization. The inland waterways are a transport mode with a lot of potential and that is why DVW’s core activities is to support innovation in the sector to reach that potential.

DVW also wants to facilitate innovative experiments and therefore DVW opened up a test area for unmanned ships, which exists of all inland waterways under its authority. In Q2 of 2019 space was made in the Flemish law to enable tests with ships without crew on board. Before testing, applicants have to make a thorough safety analysis of their project.

Besides looking into legislation, preparing the physical environment on possible changing use is an important factor in the strategy. Infrastructure is subject to path dependency. It is therefore of big importance to recognize changing needs in an early stage. An autonomous ship cannot simply pass through a lock or through an area with Vessel Traffic Service. This requires coordination in the provision of services, whereby it is not excluded that new activities that must take place also necessitate a new division between public and private. Will governments facilitate automatic mooring in ports and locks, for example, and how will we do that? Can we leave this to be a market activity? And what about an international context?

Also, impact is expected on information management, traffic management and management & maintenance of the waterway. Some first exportations of these topics show that Smart Shipping asks for more accurate and higher availability of fairway information. Operation of locks and bridges most likely will change for this reason. Separation of traffic flows may be needed and traffic management becomes more complex in a hybrid situation. In a hybrid situation, it is expected that the need for (digital) infrastructure will increase.
Analyzing the impact of Smart Shipping

To get more grip on the questions above, a PIANC working group was started. In 2019 the PIANC WG 210 Smart Shipping was established with the goal to get insight in what the impact of the usage of smart ships can be on the existing inland waterway infrastructure worldwide. Parties from more than 15 countries joined the work group, covering Europe, North America and Asia. The members have a broad range of expertise as they represent all sides of the triple helix (governmental parties, knowledge institutes and commercial parties).

The first task of the working group will be to analyze the different smart shipping projects that are currently ongoing in all regions and to identify the current gaps in research. To do this, a template was made covering all relevant aspects of the different projects so this information can be combined for analyses. The information that is collected is extensive. For example, information is collected on: the key technologies used in the project, the impact on existing legislation and on the possible needs for adjustments on the existing infrastructure.

After the inventory, use cases are described. Analyzing the use cases should help to identify the impact and role of the waterway provider. The use case approach is based on the operational design approach. By defining a situation in the geographic domain, combined with a traffic and situational environment, a use case is made with different complexities. Used cases are for example: navigating a busy river or navigating through a lock. By analyzing a use case, an inside is given in what is needed in different situations. The analysis does not only focus on the ships capabilities in that situation, but also what is needed from the infrastructure or traffic management. This approach could give a first general inside in possible requirements and the role that the fairway authorities can and want to play. The results will be used to define functional needs and proposals for research for the future.

Conclusion

Although it is uncertain in which way the current developments of Smart Shipping will move, waterway managers should realize that the current development could have a disruptive impact on the shipping sector. This could lead to a changing demand for infrastructure. Because waterway infrastructure is subject to path decency, change could take time. By recognizing the developments early and waterway managers have enough time to make clear decisions. The approach of PIANC WG 210 could help by giving inside in the challenges and changes that lay ahead, because the general believe is that Smart Shipping could contribute to social economic challenges.
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Keywords:
Vessel design, Inland waterway transport, India, National-Waterway-1

Title:
Design of Standardized Vessels for the National Waterway 1 in India

Abstract:
The Inland Waterways Authority of India (IWAI) is improving the inland waterways sector through strategic development to ensure efficient and effective movement of goods within the country and for in-bound and out-bound destinations. National Waterway 1 (NW-1) is the most important Indian waterway and runs from Haldia (Sagar) to Allahabad across the Ganges, Bhagirathi and Hooghly river systems. It is 1,620 km (1,010 mi) long and is of prime importance amongst all the national waterways considering its locational advantages.

A key element for development of inland waterway transport (IWT) on NW-1 is the design of specific vessels that are well adopted to the navigation on this waterway. DST was contracted for the design of suitable IWT ship types, in different dimensions and for different types of cargo. These vessels should offer the best results in terms of high transport volumes, low transport cost, high safety level and low environmental footprint.

In order to work out standardized vessel concepts, vessel types had to be defined. In first line, the prevailing and/or expected operation conditions on NW-1 had to be considered, but also the experience of vessel design and operation on other international inland waterway networks. It appeared soon that the European scheme for ship dimension could not be applied.

The first step was to define a pattern of main dimensions based on the dimension of the infrastructure and the properties of the waterway. Using the DST database that contains the performance data of inland waterway vessels, the payload and operation cost of the vessels was assessed for the navigation on the waterway NW 1. This assessment considered, among others, the seasonal changes in fairway depth of the waterway. With the results, different business cases for vessel operation could be calculated.
For vessel design, the available water depth is a key parameter and, in the case of NW 1, these are quite low and also subject to large seasonal changes. It appeared also that the lowest part of the waterway can be almost considered as open sea, with specific requirements on strength and freeboard of the vessels. As next step, the hull forms for these vessels were elaborated, using the same setup of the propulsion system for all vessels. Following the requirements of standardized vessel design, other common features for equipment, accommodation and construction were defined. The design concepts were finally worked out for the different vessels and published as data sheets that compiled the most relevant data and features of the vessels.

In a CFD study, the stern tunnel shape was systematically varied by modifying the transom wedge angle in the stern region along the longitudinal plane within stern tunnel. A set of five variants of the stern tunnel geometry was developed from the base model. Numerical investigations were carried out in Star CCM+ for minimum viscous pressure drag at full load draft and complete water entrainment in the tunnel at ballast draft for design speed.

A comprehensive model test project carried out at DST was the next step. For three different hull types, performance in shallow water navigation was determined, including manoeuvring tests. Three basic designs of standardized inland waterway vessels for NW-1 in different main dimensions have been tested in order to assess their manoeuvring properties.
Design of Standardized Vessels for the National Waterway 1 in India

Operating conditions

From the navigation point of view, NW-1 consists of 7 operation zones, each with different properties, resumed in Table 1.

*Table 1: Description of main operation zones*

<table>
<thead>
<tr>
<th>Sector</th>
<th>Length</th>
<th>LAD</th>
<th>Sharp bends</th>
<th>Wave influence</th>
<th>Navigation zone according to IR Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haldia to Diamond Harbour</td>
<td>&gt; 3.0</td>
<td>none</td>
<td>Yes, up to 2 m</td>
<td>Zone 1</td>
<td></td>
</tr>
<tr>
<td>Diamond Harbour to Tribeni</td>
<td>&gt; 3.0</td>
<td>none</td>
<td>Yes, tidal bore</td>
<td>Zone 3</td>
<td></td>
</tr>
<tr>
<td>Tribeni to Farakka</td>
<td>351 km</td>
<td>3.0</td>
<td>Yes, with $R=300$ m</td>
<td>none</td>
<td>Zone 3</td>
</tr>
<tr>
<td>Farakka to Barh</td>
<td>347 km</td>
<td>3.0</td>
<td>none</td>
<td>none</td>
<td>Zone 3</td>
</tr>
<tr>
<td>Barh to Ghazipur</td>
<td>287 km</td>
<td>2.5</td>
<td>none</td>
<td>none</td>
<td>Zone 3</td>
</tr>
<tr>
<td>Ghazipur to Varanasi</td>
<td>133 km</td>
<td>2.2</td>
<td>none</td>
<td>none</td>
<td>Zone 3</td>
</tr>
<tr>
<td>Upstream of Varanasi</td>
<td>236 km</td>
<td>Natural depth</td>
<td>Yes, with $R=700$ m</td>
<td>none</td>
<td>Zone 3</td>
</tr>
</tbody>
</table>

The available water depth on NW-1 has to be considered in the vessel concepts. As a guideline, the following least available water depth (LAD) is considered:

The optimised “Option 2 Navigation Channel” has the following LAD:\(^1\):

\begin{enumerate}
  \item 3.0 m LAD from Haldia to Barh;
  \item 2.5 m LAD from Barh to Ghazipur, and;
  \item 2.2 m LAD from Ghazipur to Varanasi.
  \item Natural depths would be available upstream of Varanasi.
\end{enumerate}

As the draught of a river vessel has to be considerably smaller than the available water depth, we assume the following draught parameters in function of the operation range:

\begin{itemize}
  \item The under keel clearance (UKC) of a river vessel should be at the least 0.40 m, in order to maintain navigation at an acceptable speed and safety level. Without sufficient UKC, the risk of grounding is high and only low speed over ground is possible in upstream condition.
  \item Design draught ($T_d$): Average operation conditions, hull form and propulsion designed for optimum performance at this draught.
  \item Maximum draught ($T_{max}$): With sufficient water depth, the vessel is operated with maximum payload; still safety regulations are fully met.
  \item Minimum draught ($T_{min}$): At low water depth, the vessel remains in operation with reduced payload.
\end{itemize}

At present time, strong seasonal variations of the water depth have to be considered, see Figure 1. It is evident that vessels will be facing in many seasons water depth below the indicated LAD, and this in all reaches upstream of the Farakka lock. For this reason, the minimum draught ($T_{min}$) of the vessels has to be considerably lower than for, as example, a vessel designed for the River Rhine.

\(^1\) HOWE, page 28
Figure 1: Waterdepth data for different sectors of NW-1

In waterways with limited water depth, only the increase in length and breadth of the vessel will improve the payload. Considering the requirement of low freight rates, the vessel main dimensions are therefore always selected close to the maximum allowable limit dimensions.

On order to define advantageous main dimensions, several limiting side conditions have to be assessed:

- Influence of limited fairway breadth
- Increased propulsion power demand
- Size limitations of infrastructure, in this case the Farakka lock
- Draught and freeboard of the hull
- Hull strength requirements

Figure 2: Sketch of different navigation sectors

What is the appropriate strategy to define vessel types, considering the navigation conditions and shallow water depth? Different alternatives can be discussed:
• For different navigation zones, specific vessels with different properties are used, each optimised for the specific navigation conditions.
• Vessel should be able to operate in all zones of NW-1.
• Vessels should be able to operate in all zones of NW-1, but with modified operation schemes for the service in Zone 1 (Haldia to Diamond Harbour) and the last zone upstream of Varanasi.

Option a) has the advantage that each of the vessels will be optimised for the specific navigation zone. Shortcut is the necessity of frequent cargo transfer from one vessel to another during the voyage, and transport cost will be too much affected by the cost and delay of these transshipments.

For option b), there are conflicting technical requirements that are difficult to meet. Deep water and wave influence at Haldia would require hulls with high freeboard and heavy construction, whilst the shallow water conditions in the upper reaches of NW-1 call for light construction and low freeboard. A part of the vessel designs will be suitable for navigation in all zones.

For the other designs, the option c) will be considered. This means that in seasons with foul weather and high waves in the coastal waters of the Haldia range, the NW-1 vessels will have transhipments at Diamond Harbour and/or Tribeni.

Also, in seasons with low LAD in the reaches upstream of Farakka, the vessels will use additional dump barges to reduce draught and maintain the high payload.

The main dimensions of these vessels will follow the pattern discussed in the preceding chapter. For the service in the shallow water reaches, all vessels have to remain operational at a minimum draught of 1.30 m.

**Standardized vessel design**

The standardization of the vessels should be at a high level, including hull form, steel structure and propulsion devices, but also manoeuvring devices, crew accommodation and deck equipment. Standardization will help to obtain low production and maintenance cost for the vessels and facilitate the training of the crews. This design strategy will make it possible to have many parts in common for the vessels, but to make also sure that the each vessel meets best the particular operation conditions on NW-1.

Aiming at standardized vessel design, only one propulsion layout will be used for all vessels: Ducted propeller, diameter 1.45 m. on horizontal shaft in combination with a reversible gearbox and a combustion engine of 500 kW in rating A (heavy, uninterrupted duty). The propeller nozzle and the rudders are covered by a plate. This propulsion layout can be used in vessels having a minimum draught of Tmin = 1.30 m. All NW-1 vessels will have twin propulsion.

Excellent manoeuvring properties are a key asset for navigation on NW-1. State-of-the-art devices have to be employed, as they are largely in utilisation on other waterways and have proved to be efficient and fail-safe.

On the different types of NW-1 vessels, these will be:

• Double rudders behind each propeller
• Bow thrusters, driven by combustion engines of 150 to 200 kW, to be used in ports and during manoeuvres with the stationary vessel.
Vessel types

Referring to the terms of the contract attributed to DST, concepts for the following vessel types have been worked out:

<table>
<thead>
<tr>
<th></th>
<th>Cargo type</th>
<th>Short Name</th>
<th>L</th>
<th>B</th>
<th>D</th>
<th>Tmax</th>
<th>Payload at Tmax</th>
<th>Navigation Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Dry Bulk</td>
<td>B1</td>
<td>80.0</td>
<td>12.0</td>
<td>3.7</td>
<td>2.5</td>
<td>1579 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>1b</td>
<td>Dry Bulk</td>
<td>B2</td>
<td>110.0</td>
<td>12.0</td>
<td>4.3</td>
<td>2.8</td>
<td>2515 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>1c</td>
<td>Dry Bulk</td>
<td>B3</td>
<td>92.0</td>
<td>12.0</td>
<td>3.7</td>
<td>2.8</td>
<td>2105 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>2a</td>
<td>Tanker</td>
<td>T1</td>
<td>110.0</td>
<td>12.0</td>
<td>3.7</td>
<td>2.8</td>
<td>2434 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>2b</td>
<td>Tanker</td>
<td>T2</td>
<td>80.0</td>
<td>12.0</td>
<td>3.4</td>
<td>2.5</td>
<td>1524 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>3</td>
<td>RoRo</td>
<td>RoRo</td>
<td>70.0</td>
<td>14.5</td>
<td>2.8</td>
<td>1.7</td>
<td>757 t</td>
<td>Zone 3</td>
</tr>
<tr>
<td>4a</td>
<td>Container</td>
<td>CO1</td>
<td>80.0</td>
<td>12.0</td>
<td>3.4</td>
<td>2.5</td>
<td>1590 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>4b</td>
<td>Container</td>
<td>CO2</td>
<td>110.0</td>
<td>12.0</td>
<td>4.3</td>
<td>2.6</td>
<td>2140 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>5a</td>
<td>LNG Barge</td>
<td>LNG1</td>
<td>90.0</td>
<td>14.5</td>
<td>4.2</td>
<td>2.3</td>
<td>1037 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>5b</td>
<td>LNG Barge</td>
<td>LNG2</td>
<td>92.0</td>
<td>12.0</td>
<td>3.7</td>
<td>2.1</td>
<td>618 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>6a</td>
<td>Push Boat</td>
<td>PB</td>
<td>26.0</td>
<td>12.0</td>
<td>2.4</td>
<td>1.8</td>
<td>64 t</td>
<td>Zone 3</td>
</tr>
<tr>
<td>6b</td>
<td>Dumb Barge</td>
<td>DB</td>
<td>42.0</td>
<td>8.0</td>
<td>2.8</td>
<td>2.5</td>
<td>585 t</td>
<td>Zone 3</td>
</tr>
<tr>
<td>7</td>
<td>Car Carrier</td>
<td>CC</td>
<td>90.0</td>
<td>14.5</td>
<td>3.1</td>
<td>1.8</td>
<td>847 t</td>
<td>Zone 1</td>
</tr>
<tr>
<td>8</td>
<td>Dry Bulk</td>
<td>B_LNG</td>
<td>110.0</td>
<td>12.0</td>
<td>4.3</td>
<td>2.8</td>
<td>2452 t</td>
<td>Zone 1</td>
</tr>
</tbody>
</table>

CFD Study

The standardized vessels designed for NW1 are to ply in full load condition and ballast condition during its upstream voyage and downstream depending upon cargo availability. Therefore, the study of full propeller immersion in the tunnel at ballast loading condition is crucial. A transom wedge to the stern tunnel is a solution to overcome air entrainment in the stern tunnel. An investigation is carried out at IIT Kharagpur for the performance of different stern tunnel configurations with the base hull form. The stern tunnel allows for propeller of large diameter with water entrainment capabilities inside the tunnel when stern tunnel and propeller are partially immersed during ballast voyage. Figs. 1(a) and (b) show the 3D perspective view of the stern tunnel configuration with the ducted propeller and line diagram of the stern wedge angle for the variants, respectively.
The aim of this investigation is to minimise viscous pressure in full load condition and avoid air entrapment during ballast arrival condition, thereby improve propeller efficiency and decrease fuel consumption. Different stern configurations, as shown in Fig. 1(b), are investigated with the help of numerical simulation carried out in Star CCM+. Hull form variants, without the ducted propeller, are investigated to understand the stern tunnel's water entrainment capability as a function of its geometry. A total of five variants are studied by systematically varying the aft transom wedge angle along the propeller shaft centerline as shown in Fig 1(b).

All the variants are investigated for viscous resistance in the fully loaded condition at 9 knots speed using simple double body analysis, neglecting wave-making resistance due to low Froude number. It is observed that the variation of frictional resistance component is nominal for all variants, whereas viscous pressure resistance decreases from base hull to a minimum for variant V4. The transom wedge angle has an influence on viscous pressure resistance component.

Subsequently, all the variants are further investigated for water entrainment into the stern tunnel in ballast condition using Volume of Fluids method (VOF) to track the air-water interface. The influence of stern wedge shape on resistance in ballast condition is negligible. Therefore, in ballast condition water entrainment capability in the tunnel is the governing criteria for the stern variants. In deep water, base hull form and V2 shows good water entrainment capability in the tunnel, V3 has the partial water entrainment capability and V4 is completely incapable of drawing water into the tunnel. The water entrainment capability of stern tunnel variants in shallow waters is better compared to deep water due to the increase in local water velocity past hull. Except for V4, all the other variants perform better in shallow waters in terms of water entrainment in the tunnel a requirement for propeller operation.

**Model tests at DST**

A comprehensive model test project carried out at DST was the next step. For three different hull types, performance in shallow water navigation was determined, including manoeuvring tests. Three basic designs of standardized inland waterway vessels for NW-1 in different main dimensions have been tested in order to assess their manoeuvring properties. The following conclusions have been obtained:

- Model tests with captive models have shown sufficient stopping ability of the vessels.
- For stopping in downstream direction and backward speed, the vessels should use the bow thruster during the manoeuvre in order to maintain the vessel on a straight course backwards.
- Turning circle tests have shown the capacity of the convoy to navigate at moderate speed the sharp bends of NW-1 in downstream direction.
- The access to the Farakka is by far the sharpest bend on the waterway NW-1. This turn will be handled by all types of the new designs of the NW-1 vessels, at least as slow manoeuvre with little or zero advance speed of the vessel, probably assisted by the bow thruster.
- Hydrodynamic manoeuvring coefficients for the different vessel types in their largest dimension have been obtained with captive manoeuvring tests.
- Bow rudder test have shown strong manoeuvring forces with the vessel navigating at moderate speed in shallow water.
- All test results are valid for navigation in shallow water with water depth ranging between \( h = 3.0 \text{ m} \) and \( h = 5.0 \text{ m} \).

**Conclusion**

As IWAI is making much progress with the aim to promote the inland waterway transport on NW 1, the construction of some of the vessels is planned for the next years.
Optimal vessel class for container transport from hinterland to seaport, costs comparison between Class IV and Class Va.

Abstract:
Cost indicators for inland vessels indicate that larger container vessels sail at lower cost per TEU. The CEMT/ECMT recommends designing new inland waterways along the standards for CEMT Class Vb and to apply at least Class Va standards where a Class IV waterway needs to be modernised. However, in specific situations, a strong belief in “large is cheaper” results in higher costs compared to transport by smaller vessels.

A case study has been performed for a specific transport of containers between an inland port in the northern part of the Netherlands and the Port of Rotterdam. The conclusion was that, for this specific transport, the transport with class Va is not more economic than with Class IV vessels. On the other hand, the side branch to the terminal is only a Class IV waterway and would need huge investment to bring it up to standards for Class Va.

Introduction
This paper presents a cost comparison between various vessel classes, with the focus on Class IV and Class Va vessels for the transport of containers between the hinterland in the Netherlands and the Port of Rotterdam.

Waterway infrastructure
The main waterways in The Netherlands are modernized for Class V vessels. However, quite a few of the side branches that give access to the various container terminals are for Class IV or allow a limited draft and/or limited air-draft due to low bridges (RWS, 2019). The EU (ECMT, 1992) recommends that where a regional or Class IV waterway is to be modernised, the parameters should be adopted to at least Class Va.

The investment to provide larger vessels full access to inland terminals is huge. The works might include extension of the terminal, the enlarging (widening and deepening) of bends and straight sections of the canal, but also bridges and even locks. The cost for the civil works (excavation plus sheet pile for one bank) for upgrading a Class IV waterway to Class V are estimated at about 3 M€/km. However, actual cost might be much higher, depending on the available space and the additional work on bridges, locks and the terminal. Considering an investment in the waterway infrastructure that aims at a reduction of total costs, one should also investigate alternatives with smaller vessels.
Container vessels

Inland vessels have capacity varying from 24 TEU\(^1\) for the smallest to 480 TEU for the largest vessels. The full TEU capacity can only be used under certain conditions of container weight, vessel draft and air draft.

<table>
<thead>
<tr>
<th>Vessel Class (CEMT &amp; RWS)</th>
<th>Class II/M2</th>
<th>Class III/M3</th>
<th>Class IV/M6</th>
<th>Class IV/M7</th>
<th>Class Va/M8</th>
<th>Class Va/M9</th>
<th>Class VIa/M11</th>
<th>Class VIa/M12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length / TEU per row</td>
<td>m TEU</td>
<td>m TEU</td>
<td>m TEU</td>
<td>m TEU</td>
<td>m TEU</td>
<td>m TEU</td>
<td>m TEU</td>
<td>m TEU</td>
</tr>
<tr>
<td>Beam/rows</td>
<td>6.6</td>
<td>7.2</td>
<td>9.5</td>
<td>9.5</td>
<td>11.4</td>
<td>11.4</td>
<td>14.2</td>
<td>17.6</td>
</tr>
<tr>
<td>Draft/layers</td>
<td>2.6</td>
<td>2.7</td>
<td>3.0</td>
<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Airdraft (m)</td>
<td>5.25</td>
<td>5.25</td>
<td>7.0</td>
<td>7.0</td>
<td>9.1</td>
<td>9.1</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Vessels capacity Cap (Tons and TEU)</td>
<td>Tons</td>
<td>Tons TEU</td>
<td>Tons TEU</td>
<td>Tons TEU</td>
<td>Tons TEU</td>
<td>Tons TEU</td>
<td>Tons TEU</td>
<td>Tons TEU</td>
</tr>
<tr>
<td></td>
<td>540</td>
<td>24</td>
<td>750</td>
<td>28</td>
<td>1560</td>
<td>90</td>
<td>2020</td>
<td>108</td>
</tr>
<tr>
<td>Cost per hour</td>
<td>€ / hour</td>
<td>€ / hour</td>
<td>€ / hour</td>
<td>€ / hour</td>
<td>€ / hour</td>
<td>€ / hour</td>
<td>€ / hour</td>
<td>€ / hour</td>
</tr>
<tr>
<td>Sailing (Loaded)</td>
<td>€53.25</td>
<td>€60.26</td>
<td>€92.47</td>
<td>€120.55</td>
<td>€150.13</td>
<td>€177.26</td>
<td>€215.39</td>
<td>€227.61</td>
</tr>
<tr>
<td>Wailing (lock,bridge,port)</td>
<td>€39.23</td>
<td>€42.45</td>
<td>€65.37</td>
<td>€86.67</td>
<td>€101.25</td>
<td>€118.08</td>
<td>€136.90</td>
<td>€151.05</td>
</tr>
</tbody>
</table>

Table with dimension, capacity and costs\(^2\) (RWS,2018) of various vessels classes for container transport

Cost of sailing container vessels per TEU

The cost for sailing over a large distance (cycle of 2 * 500 km) have been calculated for the 8 vessels presented in the table above and divided by the capacity. The costs per TEU and per Ton have been plotted in graphs for two situations: for free air draft and for 7 m air draft that allows a maximum of 3 layers of containers.

The graph clearly indicates that in situation with free air draft, the sailing cost per unit decrease with increasing vessel size and that the largest vessel (Class VIa/M12) is the most economic.

For comparison the right figure indicates the effect of a limitation of the air draft to 3 layers. This maximum strongly limits the capacity in TEU for the largest vessels (Class Va and larger), where the sailing cost per TEU for vessel up to Class IV are unchanged. The sailing costs for the middle sized (Class Va) vessel, however, increase with 33% and for the largest (Class Va) vessel even with 67%. This illustrated that air draft limitations have a very significant effect on the sailing costs per TEU. Other factors that affect the sailing cost per TEU are the maximum allowed draft and the average weight of the container per TEU.

Total cost of container transport.

The total costs for container transport include not only the cost for sailing but also the time for container handling and waiting (e.g. for bridge to open, for a navigation lock or near the terminal). In a real case, the trends can therefore differ from those set out for the cycle above, putting larger vessels at a disadvantage. For example, for the large vessels not only is the cost per hour high, but the handling time at the terminal is also high due the larger number of TEU per vessel.

The total cost per TEU have been calculated based on the total transport cycle, considering the number of TEU per vessel being the maximum number in view of the limitations of the transport route.

One transport cycle from the hinterland to the Port of Rotterdam and vice versa comprises:

1. container handing (unloading and loading containers) at the terminal in the hinterland;
2. sailing with sea-bound containers to the Port of Rotterdam;
3. container handing (unloading and loading containers) at various terminals in PoR; and
4. sailing back with land-bound containers to the terminal in the hinterland.

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1. TEU: Twenty-foot Equivalent Unit (standard container with a length of 20 feet or 6,2 m)
2. Total of Fixed and Variable Costs for sailing and waiting, that includes cost for labour, fuel, and all other costs.

File: SR2019_Paper-PA_10_7_ClassIV-Va-20190906-HV.docx
The container handling time at the terminals has been applied according to sailing schedules from container vessels in operation (e.g. from AIS). The sailing time to the PoR has been calculated with the “The Blue Road Map” (BVB,2019) a tool developed by the inland navigation branch organisations made available through internet. For two specific cases the cost per TEU have been presented below:

1. Friesland (e.g. Heerenveen, Leeuwarden, or Drachten): maximum draft 2.75 m, 24 Ton/TEU (agriculture products), sailing distance approximately 260 km.
2. Alphen: maximum draft 2.8 m; sailing distance approximately 70 km.

Costs per TEU are plotted in the graphs (left 260 km to Friesland, right 70 km to Alphen).

Surprisingly, the vessel costs for the transport with Class Va vessels are equal or even higher than with the 85 m long Class IV/M6 vessels. The main reasons are that for large vessels the draft limitation is larger and the time at the terminal is significant longer than for smaller vessels. Especially for transport over short distances, the vessel costs for the terminal handling are significant part for the total transport cost: e.g. for Class Va vessel transporting over 70 km, 60% to 70% of transport costs is related to the time at the terminals.

**Conclusion**

The conclusion of the study is that the selection of vessel class should not be based on the cost indicators only, but include the total transport cycle, because the costs per cycle are strongly influenced by:

- Transport distance and sailing time.
- The costs for the (sea) terminal handling, especially for transport over short distances.
- The effect of air draft limitation on the TEU loading capacity of the container vessel.
- Draft limitation for the TEU capacity of the container vessel; and
- Weight per TEU.

Measures in the infrastructure to improve cost efficiency include:

- Increase maximum the free air draft on the container routes, allowing at least 4 layers of containers (including high-cubes); and
- Increase the maximum beam and draft on the container routes.

Measures from container operators to improve cost efficiency include:

- Reducing the time at the terminals, especially by increasing the speed of container-handling at the PoR.
- Increase the call-sizes per sea terminal (or reduce the number of terminal calls per transport cycle).
- Collect the containers for one sea terminals with one vessel from more than one inland terminal, instead of distributing the containers from one inland terminal over a number of sea terminals in the PoR.

Additional remarks:
- Smaller vessels require more departing vessels per week and offer thus more flexibility.
- Largest inland terminal in the Netherlands (Alphen: 175,000 TEU/yr) is Class IV waterway (BVB,2015)
- Up to a vessel length of 86 m (Class IV/M6), only 2 nautical staff are required.

**References:**

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RWS, 2019; Inland waterways in the Netherlands (ViN); Rijkswaterstaat, Centrale Informatievoorziening (CIV); July 2019.
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Mots clés:
Emissions de polluants de moteur diesel, technologies de traitement de fumées, particules fines, oxydes d’azote, hydrocarbures imbrulés, dépoussiérage, lavage électrostatique

Titre:
Nouvelles perspectives de réduction des émissions de moteurs fluviaux

Résumé:

1. Nouvelle norme EMNR pour le secteur fluvial: constat général

Les moteurs des bateaux de navigation intérieure font partie des EMNR(Engins Mobles Non Routiers) soumis à la nouvelle norme sur leurs émissions à compter du 1er janvier 2019. Cette norme qui concerne tant les moteurs de propulsion que les moteurs auxiliaires des bateaux de plus de 20m représente un saut technologique couteux pour la profession fluviale lui imposant le passage direct d’une norme CCNR2 (équivalent Euro II routier) à une norme Stage 5 (équivalent Euro V /VI routier) sans transition ni préparation de la profession.

Le durcissement de la réglementation européenne sur les émissions atmosphériques des moteurs fluviaux est perceptible dans l’évolution des VLE (Valeur Limites d’Emission) entre 2009 et 2019 :

- diminution notable de ces limites, de l’ordre de 30% pour le CO (monoxyde de carbone), et de plus de 25% pour la limite globale (HC+NOx) associées aux oxydes d’azote et aux hydrocarbures imbrulés
- remplacement de la limite globale par deux seuils séparés HC et NOx, dont la somme est inférieure d’au moins 50% aux VLE(s) globales de 2009
- diminution de la VLE « PM » (Particulate Matter) des matières particulières, d’un facteur 10 pour la valeur la plus contraignante, et surtout mise en place d’une VLE « PN » (Particulate Number) en nombre de particules.

L’émergence de la limite « PN » résulte d’un impératif de santé publique.

On distingue, dans le spectre granulométrique des particules :

- les « grosses », de taille supérieure à 10 microns
- les particules de taille inférieure à 10 microns (DPM10)
- les fines, de taille inférieure à 2,5 microns (DPM2,5)
- les ultrafines, de diamètre inférieur au sixième de micron
- les nanoparticules, de diamètre inférieur à 50 nm

La taille des particules détermine leur temps de séjour dans l’atmosphère. Si la sédimentation évacue les DPM10 en quelques heures, les DPM2,5 peuvent persister dans l’ambiance plusieurs jours voire plusieurs semaines.
Les particules les plus fines, engendrées par nucléation des suies sont les plus nombreuses, mais constituent une faible fraction de la masse totale. Les particules formées par agglomération sous forme de chaînes sont minoritaires mais constituent l’essentiel de la masse. Les particules de diamètre inférieur au dixième de micron sont respirables et pénètrent dans les poumons, où elles peuvent être entraînées dans le sang, et même atteindre le cerveau. Elles peuvent aussi s’accumuler dans les poumons et gêner l’oxygénation du sang. Une masse donnée de particules ultrafines aura un impact sur une surface de poumons beaucoup plus élevée qu’une même masse de particules de diamètre supérieur. Ces considérations ainsi que des études de toxicité et d’épidémiologie ont conduit à mettre en place la VLE PN, beaucoup plus exigeante en performances de captation que la VLE PM.

2. Exemple de marinisation d’un système de filtration classique pour le secteur fluvial

En 2018, VNF Lyon lance la construction d’un ponton de travail motorisé apte à remplir différentes missions d’entretien des voies navigables sur la Saône à grand gabarit de St Jean de Losne à Lyon et le Rhône à grand gabarit (notamment dans la traversée de Lyon). Au regard de la date d’entrée en vigueur de mise en application des textes réglementaires de la norme EMNR et de l’absence d’offres techniques des motoristes éprouvées pour le secteur fluvial, VNF prend rapidement la décision de dépolluer les deux moteurs du ponton multifonction.

Grâce aux résultats de l’étude réalisée en 2018 sur les possibilités de mariniser et d’installer des moteurs terrestres sur la flotte fluviale, VNF a ainsi obtenu du motoriste John Deere des éléments techniques permettant de mener cette expérimentation. D’un point de vue technique, la dépollution des moteurs du ponton impliquera d’y adjoindre des systèmes de post-traitements des fumées développés spécifiquement pour la profession fluviale. L’approche généralement considérée pour réduire les émissions des moteurs diesel du secteur fluvial combine :

- un réacteur catalytique d’oxydation (DOC = « Diesel Oxidation Catalyst »),
- un filtre à particules (DPF = « Diesel Particulate Filter »),
- un réacteur catalytique (SCR = « Selective Catalytic Reduction ») de réduction des oxydes d’azote.

Dans le DOC, les espèces CO et HC, sont adsorbées à la surface catalysée, et oxydées par l’oxygène des fumées (efficacités respectives de 90% et 85% à 350°C). Il en va de même pour les organiques volatils contenus dans les suies (≈20 à 40% de leur masse). On peut aussi catalyser l’oxydation de NO en NO₂ (jusque ≈50% de conversion).

Dans le DPF, les fumées traversent la surface poreuse des canaux d’entrée, qui y piège les particules. Pour réguler la perte de charge, on assure la régénération du filtre (oxydation des particules). Elle peut être active et cyclique (déclenchée par apport de chaleur sur seuil de pression) ou passive (en présence de catalyseur). Elle peut être facilitée par l’oxydation du carbone par NO₂, si l’oxydation de NO est catalysée en DOC, ce qui permet alors une régénération continue. L’efficacité d’abattement PM peut atteindre 95%, l’efficacité PN 90%.

Dans le « SCR », les oxydes d’azote sont adsorbés à la surface du catalyseur où ils réagissent avec l’ammoniac, injecté en amont. L’efficacité d’abattement atteint facilement 90%.

Sur le plan des motorisations industrielles adoptées pour les tracteurs, groupes électrogènes etc..., le stade expérimental des technologies DOC+FAP+SCR est bien avancé. En revanche l’intégration d’un moteur industriel marinisé dans un bateau échappe aux études générales au regard des investissements requis, du marché restreint et des multiples contraintes rencontrées sur un bateau par rapport aux autres environnements d’utilisation terrestre.

L’innovation principale du projet est donc de nature technique et consiste en l’étude des différentes contraintes spécifiques de la marinisation et à la mise au point d’un moteur et d’un système de filtration de nouvelle génération conforme à la nouvelle norme. Parmi les défis à relever pour y parvenir, on peut citer :

- Adaptation de la salle des machines à l’encombrement de l’ensemble constitué par le moteur et le dispositif de post-traitement ;
- Calorifugeage de l’ensemble permettant l’atteinte de températures élevées pour le bon fonctionnement du post-traitement sans élever la température dans le bateau ;
- Contrôle simultané des températures de fonctionnement du moteur, du turbo et de la vanne EGR au moyen d’échangeurs de température expérimentaux (Keel-cooling) ;
• Prise d’air le plus dense possible, donc froid, néessitant des échangeurs thermiques eau-air expérimentaux ;
• Intégration de cuves d’urée (AdBlue) dimensionnées pour la consommation du ponton et système de contrôle de température dans les 2 sens (réchauffage, prévention de l’évaporation) ;
• Stratégie de calculateur pour le fonctionnement au ralenti du filtre à particule

En outre, au-delà de ces modifications techniques, il importe de réaliser une instrumentation des performances permettant de mesurer et de vérifier les gains obtenus en termes d’émissions et de consommation en fonctionnement réel afin de pouvoir analyser les résultats et le cas échéant, effectuer les ajustements nécessaires. L’analyse des impacts environnementaux, menée en partenariat avec l’IFSTTAR (Institut Français des Sciences et Technologies des Transports, de l’Aménagement et des Réseaux) et l’implication de la DIGTM (Direction Générale des Infrastructures, des Transports et de la Mer) dans le processus permettront enfin de progresser de concert sur cette thématique qui deviendra rapidement critique, en l’absence de solution pérenne disponible.

3. Alternatives de dépollution des bateaux fluviaux

La solution DOC+DPF+SCR requiert des investissements importants (80 à 130 €/kW installé, compte tenu des métaux précieux des catalyseurs), des espaces d’implantation significatifs (plusieurs volumes de moteur), et induit une perte de charge importante (jusqu’à 0,1 bar). Elle nécessite une consommation d’ammoniaque ou d’urée (~4 €/kWh).

Ce constat incite, pour identifier d’éventuelles alternatives peut-être moins encombrantes et moins couteuses, à une revue des principales techniques disponibles, pour chacune des fonctions élémentaires d’abattement (CO, HC, PM&PN, NOx).

Pour l’oxydation des imbrûlés, existe une alternative par réduction à la source, consistant à injecter de l’hydrogène, en mélange avec l’air d’admission du moteur. La société Flexfuel, par exemple, commercialise un kit d’électrolyse d’eau distillée, permettant d’injecter le mélange gazeux produit (H₂+1/2O₂) dans l’air d’admission. Des essais ont montré des efficacités de 30% pour CO, et 50% pour HC, qui, bien qu’intéressantes, restent inférieures à celles d’un DOC.

Pour l’abattement des particules, les techniques connues, autres que DPF, sont la centrifugation, l’électrofiltration, l’absorption en laveur, et la réduction à la source par mélange du carburant avec un additif (efficacité limitée à 37% en masse). Dans un cyclone, la force centrifuge devient négligeable lorsque la taille des particules devient typiquement inférieure au micron. Elle est donc, d’après les caractéristiques granulométriques des particules « diesel », incapable d’abattement. Dans un laveur, au voisinage d’une goutte en mouvement, les particules grossières peuvent être absorbées par impact inertiel, et les fines par diffusion. L’efficacité qui en résulte, en fonction du diamètre, est caractérisée par un seuil de coupure, en deçà duquel elle décroît rapidement vers zéro lorsque le diamètre décroit. Un laveur « classique » possède un seuil proche du micron, et ne peut, d’après la granulométrie, capter qu’une faible partie de la masse partielle. Les meilleurs laveurs venturi nécessitent une perte de charge élevée pour augmenter l’inertie des particules, et ont un seuil de coupure de l’ordre du 1/10 de micron. Ils seraient donc capables d’une efficacité en masse, mais pas en nombre. Dans un électrofiltre, les particules électrisées de taille inférieure au libre parcours moyen (0,2 microns à 300°C) sont soumises à des collisions aléatoires avec les molécules, leur vitesse de migration vers l’électrode collectionne augmente lorsque le diamètre diminue, ainsi que l’efficacité de collecte. Pour les autres particules, l’équilibre entre force électrique et traînée détermine une vitesse de migration proportionnelle à la taille de particules, et l’efficacité de collecte tend vers 100% lorsqu’elle augmente. L’électrofiltration apparait donc la seule alternative envisageable connue, pour la captation en masse et en nombre. Mais un phénomène complexe de réenvol des particules collectées pourrait compromettre l’atteinte d’une efficacité suffisante en nombre. Une équipe de chercheurs a développé la technologie dite du laveur électrostatique (WES), qui évite ce phénomène. Elle consiste à électriser, en amont d’un laveur, les particules et les gouttelettes d’eau à des charges opposées, ce qui conduit à la migration des particules vers les gouttelettes (jouant le rôle d’electrodes collectrices, mobiles), et à leur absorption, cette fois irréversible. Les efficacités d’abattement PM&PN sont voisines de celles du DPF.
Pour la réduction des NOx, les techniques autres que SCR sont la réduction non catalytique (SNCR), les modifications d’alimentation du moteur destinées à réduire à la source, et l’absorption en laveur.

L’application de la technique SNCR sur un moteur diesel apparaît extrêmement délicate, et à performances limitées. La réduction à la source par modification des conditions d’alimentation des moteurs inclut l’injection directe d’eau dans le moteur (DWI), la vanne de recirculation des fumées dans l’admission d’air (EGR), et l’humidification de l’air d’admission (HAM). Les techniques DWI et EGR nécessitent des modifications significatives du moteur, leur mise en œuvre requiert l’intervention du motoriste. Leur efficacité atteindrait respectivement 65% et entre 50 et 60%. La technique HAM consiste à saturer d’humidité l’air d’admission, et son efficacité, importante (70 à 84%) a été prouvée à l’échelle industrielle en application marine. Elle ne requiert pas d’autres utilités que l’électricité de pompage et l’eau d’humidification (OPEX négligeable devant celui d’un SCR). L’absorption des NOx en laveur est délicate. L’espèce NO étant quasiment insoluble, l’emploi d’un laveur pourrait requérir la technique DOC en amont, pour oxyder NO. La société Marine Exhaust Solution a cependant qualifié l’application marine d’un laveur, avec efficacités d’abattement de 75% pour NOx, et 90% pour PM.

La revue des solutions d’abattement de chaque polluant met donc en évidence le potentiel des technologies WES en dépoussiérage et HAM en déNOx. Au moins deux combinaisons utilisant ces technologies pourraient avoir un intérêt : (DOC + WES), et (HAM+DOC+DPF).

La solution WES utilise, par rapport aux laveurs marins, des ratios liquide/gaz réduits, et une plus faible perte de charge. Un prototype industriel destiné à l’application marine a été réalisé par la société VTS, dont les essais confirment des performances PM&PN voisines de celles du DPF. L’enjeu est de grande importance, compte tenu de la possibilité éventuelle d’adapter les systèmes déSOx marins (« scrubbers ») pour traiter, enfin, un problème majeur d’environnement et de santé publique, par captation des particules fines et ultrafines. Une solution DOC+WES, dans le secteur fluvial, pourrait combiner absorption des NOx et des particules sur le laveur, stockage de l’effluent liquide à bord pour traitement ultérieur dans un système mutualisé mis en place dans les ports. Des efforts de recherche et de développement sont encore nécessaires pour confirmer l’intérêt de l’alternative identifiée, à l’échelle des moteurs fluviaux : faisabilité d’absorption NOx, estimation du volume d’implantation requis, montant d’investissement et coût d’exploitation.
Keywords:

Title:
On-board Energy Storage and Hybridation

Mots clés:
EMS, Energy Management System, Energie renouvelable, Sockage d’énergie à bord

Title:
Gestion de l’énergie à bord et hybridation de sources d'énergie

Résumé:
A partir de ces hypothèses la démarche poursuivie analyse les évolutions potentielles des modes de propulsion, suivant leur maturité décroissante :
• une propulsion hybride de type diesel – électrique
• une propulsion tout électrique
• une propulsion hybride “hydrogène – électrique” à plus long terme, c’est à dire par rapport à la propulsion actuelle que le moteur diesel est remplacé par une pile à combustible d’une part et par un (ou plusieurs) moteur(s) électrique(s) d’autre part.
Dans tous les cas ces systèmes de propulsion incluent un stockage d’énergie électrique sur batteries, ce qui pose la question de la stratégie d’optimisation de l’utilisation de ce stockage. Par ailleurs concernant la production d’électricité pour les besoins du bord, on considère en parallèle de la production directe issue de la chaîne de propulsion, des systèmes de production d’électricité par panneaux photovoltaïques déployés sur le pont du navire ou tout autre mode de production d’électricité de manière décarbonnée par exemple une pile à combustible auxiliaire alimentée par de l’hydrogène.
La problématique de l’EMS se pose alors en termes suivants :
• Quel arbitrage, pour l’électricité produite, entre autoconsommation et stockage ?
• Quel arbitrage en fonction de la demande en puissance entre les modes de fonctionnement de la chaîne de propulsion (régime du moteur thermique, plaque de fonctionnement de la pile à combustible...) et les autres modes de production de l’électricité ?
Les paramètres de ces arbitrages se déclinent entre :
• Profil de navigation, incluant les périodes de navigation effective, les escales et les servitudes en énergie associées, les phases d’arrêt permettant notamment la recharge des batteries par les panneaux photovoltaïques.
• Contraintes réglementaires sur les émissions atmosphériques dans certaines zones de navigation (par exemple lors de la traversée de zones à forte densité de population)
• Anticipation de la période de navigation et des besoins en puissance associés aussi bien pour la propulsion que pour les servitudes du bord.

On montre comment la prise en compte de ces besoins permet de définir les fonctions du système et les performances attendues pour répondre aux attentes de l’utilisateur :
• Les besoins en puissances (courbes de charge) qui se déclinent de manière générale entre :
  o Les besoins en énergie du bord : “hôtellerie”, besoins spécifiques liés au type de chargement, par exemple : réfrigération, contrôle de pression, etc.
  o Les besoins du système de propulsion en complément de la motorisation principale
  o Les auxiliaires pour les manœuvres (accostage, écluses...)
  o Le cas échéant les besoins pour les opérations de manutention
• Les capacités de production d’ENR qui peuvent être de deux types :
  o Sur les navires : celles-ci sont essentiellement liées au déploiement de panneaux photovoltaïques sur les surfaces horizontales disponibles à bord : ponts et toitures
  o À terre : en exploitant les possibilités de raccordement à quai avec des capacités de production d’électricité au voisinage des ports, par exemple : panneaux photovoltaïques sur les toitures des hangars, éoliennes, ou plus généralement utilisation d’électricité du réseau de distribution d’origine renouvelable
• Les performances du système de stockage (réserve d’autonomie, réserve de puissance)
• Les conditions d’utilisation du stockage (temps de réaction, durée d’utilisation…)
• Les interactions avec le mode de pilotage du moteur principal et le cas échéant avec les autres systèmes embarqués

Sur la base de ces éléments deux exemples sont proposés pour illustrer les choix technologiques et leurs possibilités d’implantation, dont les principales caractéristiques sont :
• La capacité et le type de stockage(s)
• La stratégie de pilotage et la définition fonctionnelle du système de pilotage
• L’architecture système générale
• La définition technique de chaque sous-ensemble et leurs caractéristiques impactant leur implantation sur le navire (encombrement, masse, interfaces…)

Au-delà des problématiques d’optimisation de l’utilisation de l’énergie électrique à bord (EMS proprement dit) l’intégration des technologies de stockage d’électricité et des composants électroniques seront abordées au travers d’une revue de la situation actuelle des technologies en les mettant en perspective sur plusieurs “dimensions” :
• la masse et le volume pour analyser leur intégrabilité à bord
• leur maturité, exprimée en TRL (Technology Readiness Level) et les mérites des technologies considérées en termes de gain sur les émissions atmosphériques, sustenabilité (c’est-à-dire l’impact environnemental global de ces technologies) et bien entendu leur coût.

L’approche proposée pour le dimensionnement du stockage d’électricité à bord est la suivante :
• on se place dans l’hypothèse majorante du point de vue du stockage :
  o d’une motorisation « tout électrique »
  o d’un rechargement en électricité systématique lors des escales, soit via le réseau national, soit via des stations de rechargement développées de manière spécifique autorisant l’utilisation directe d’énergie renouvelable
• d’un profil type d’utilisation d’un bateau automoteur

Le dimensionnement de la motorisation « tout électrique » s’appuie sur le cas de l’automoteur POSEIDON qui a fait l’objet d’études dans le cadre du projet PROMOVAN mené par l’IFSTTAR, dont les conclusions ont été publiées en 2015.
Nous avons repris les phases de navigation de cet automoteur (cf. rapport d’étude PROMOVAN) pour évaluer la masse de batteries nécessaires à une propulsion tout électrique. Pour mémoire sur cet automoteur la puissance crête de propulsion est de l’ordre de 1 MW et la puissance des auxiliaires de l’ordre de 15 kW. Le dimensionnement du système de stockage et de gestion de l’électricité, s’appuie sur les caractéristiques intrinsèques des cellules élémentaires puis de leur arrangement en modules puis en rack et enfin de leur intégration dans les volumes disponibles du bord. Le schéma ci-dessous présente cette organisation du stockage :

Nous avons considéré des batteries Li-ion qui sont les plus utilisées actuellement et qui présentent les caractéristiques intrinsèques suivantes au niveau des cellules élémentaires :
- densité volumique d’énergie : ~ 300 Wh/litre
- densité spécifique : ~300 Wh/kg

L’arrangement des cellules en « modules », c’est-à-dire en un ensemble de cellules connectées, pilotées par une électronique dite BMS (Battery Management System) et assemblées dans un boîtier, conduit aux densités suivantes :
- densité volumique d’énergie : ~ 200 Wh/litre
- densité spécifique : ~250 Wh/kg

L’arrangement des modules en « racks » qui constituent le motif volumique à prendre en compte dans l’architecture de l’embarcation conduit aux densités suivantes :
- densité volumique d’énergie : ~ 150 Wh/litre
- densité spécifique : ~220 Wh/kg

La dernière étape de l’intégration du stockage à bord consiste à prendre en compte les éléments supplémentaires suivants :
- un système de refroidissement des rack
- les convertisseurs et inverseurs
- l’EMS (Energ Management System) global

Dans le cas de solutions containerisées, qui sont utilisées pour le stockage stationnaire de l’électricité, les volumes requis et la masse des éléments supplémentaires conduisent à abaisser les densités d’un facteur environ 5 sur la densité volumique et 3 sur la densité spécifique. Des études d’intégration à bord de navires nous conduisent à préconiser un arrangement ad-hoc (i.e. non containerisé, par exemple dans les fonds et autres espaces disponibles) permettant de maintenir des densités plus élevées, typiquement :
- densité volumique d’énergie : ~ 100 Wh/litre
- densité spécifique : ~200 Wh/kg
Ainsi la simulation du fonctionnement de l’automoteur aboutit à une capacité de batteries de 9 MWh, ce qui
conduit à :

- une masse de 45 t
- un volume de 90 m³

Ces résultats montrent que l’hypothèse de tout électrique avec recharge quotidienne à quai et donc sans
production d’électricité à bord n’est pas compatible avec les gabarits des petits automoteurs. C’est pourquoi
nous analysons brièvement la production d’électricité à bord à partir de pile à combustible dont l’intégration
à bord des navires fait l’objet d’études approfondies notamment à l’échelle européenne.
Le gain en masse de batteries et en masse des auxiliaires associés est en première approximation
proportionnelle au ratio entre l’énergie produite à bord par une pile à combustible et celle stockée dans les
batteries, mais bien entendu l’introduction d’une pile à combustible et surtout d’un réservoir d’hydrogène à
bord représente des masses du même ordre de grandeur que la configuration stockage électrique seul.
Typiquement avec une répartition 50% stockage / 50% production d’électricité à bord, la masse du stockage
par batteries passerait à 24t, mais la PAC serait de 4t et le réservoir d’hydrogène de 22t. En revanche il y a un
gain en compacité globale du système de propulsion de l’ordre de 30%.

En conclusion la propulsion tout électrique qu’elle soit intégralement avec stockage d’électricité à bord ou
hybride entre production d’électricité par PAC et stockage n’a pas encore atteint des performances de masse
et de compacité compatible avec les plus petits gabarits d’automoteurs. Au-delà du gabarit Un des facteurs
déterminant sera le programme de navigation considéré. Par ailleurs ces technologies devraient bénéficier
des développements en cours pour le transport terrestre et les applications stationnaires liées au déploiement
des énergies renouvelables (ENR) qui ouvriront des opportunités au-delà des premières applications
existentes pour des navettes fluviales ou portuaires.
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Keywords:  
Climate neutral, strategy, transformation  

Title:  
A European strategy for a climate neutral EU by 2050 implying a deep transformation for the entire economy  
- impacts, opportunities and the need for the entire inland navigation sector to engage -
In November 2018, the European Commission (EC) presented a European strategy to reach a climate neutral EU by 2050\(^1\) entitled "A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy".

This strategy confirms the importance of strengthening climate ambitions at European and national levels to comply with the Paris Agreement and outlines the economic and societal transformations required to achieve the transition to net-zero greenhouse gas emissions by 2050.

To become climate neutral, all sectors of the economy will need to undergo a deep transformation, including transport and inland navigation (IN). IN will have to apply new technologies, transform its infrastructure, embrace social, economic as well as possible fiscal changes and most importantly develop new markets.

In light of climate change-related challenges and the Paris agreement commitments, all countries and international organisations will need to develop visions and strategies regarding which measures must be taken to steer and realise such a transformation. The EC strategic vision could be seen as a useful example from which the IN sector all over the world could learn on what to expect.

The CCNR also sees the need for a deep transformation of the IN sector and adopted a vision of zero emissions from inland navigation vessels by 2050\(^2\). Moreover, the Ministerial Declaration signed in Mannheim by inland navigation ministers of CCNR Member States\(^3\), tasks the CCNR with developing a roadmap in order to largely eliminate greenhouse gases and air pollutants by 2050. In this context, the CCNR analysed the EC strategic vision and intends to support both the EC, in developing it further, and the EU, in accompanying the transformation process of IN.

**Should the IN actors engage in upcoming debates about this strategy? How will this inevitable transformation impact IN? Could IN take advantage of new opportunities?**

While this strategy does not set binding climate targets for IN, implementing the EC’s vision towards net-zero GHG by 2050 will imply a profound change, requiring the IN sector to apply new technologies, transform its infrastructure, embrace social, economic as well as possible fiscal changes and most importantly develop new markets.

In accordance with the Paris Agreement, the European Commission is required to submit a detailed climate strategy for Europe to the UNFCC by early 2020. It is key for the EC to better understand the challenges of IN to be able to draw conclusions for its strategic vision.

The authors are therefore convinced that all IN stakeholders, and in particular PIANC, need to become involved in the further development and implementation of the strategy in order for IN to master the deep transformation and possibly even take advantage of it.

Those elements of the EC strategy which could have the strongest impact on IN, are outlined below:

<table>
<thead>
<tr>
<th>EC’s strategy</th>
<th>Possible impact on the IN sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central role of energy efficiency measures.</td>
<td>IN would need to become more energy efficient not only to remain competitive, but also to become climate neutral.</td>
</tr>
<tr>
<td>By 2050, more than 80% of electricity will be coming from renewable energy sources increasingly located off-shore.</td>
<td>In light of the expected need to more than double electricity production by 2050 and to do so in a climate neutral manner, it cannot be excluded that additional hydropower stations may be built on European waterways.</td>
</tr>
<tr>
<td>Primary energy supply will largely come from renewable energy sources.</td>
<td>If renewable energy sources are increasingly located off-shore, access to renewable energy</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>The share of electricity in final energy demand will at least double, bringing it up to 53%.</th>
<th>Electricity production will increase substantially to achieve net-zero greenhouse gas emissions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No “one-size-fits-all” solution to decarbonise all modes but rather a portfolio of solutions needed (electrification, alternative fuels hydrogen-based technologies, LNG etc…).</td>
<td>This applies also for IN. However, the greater the number of solutions, the less likely it will be to reach an economy of scale for IN propulsion systems.</td>
</tr>
<tr>
<td>Internalisation of external costs and taxation seen as a prerequisite for an effective transition and the most efficient tools for environment policy.</td>
<td>This could impact the price competitiveness of IN. It will also require transparent and accurate methodology for calculation of external costs.</td>
</tr>
<tr>
<td>Urban areas and smart cities considered as the first centres of innovation in mobility</td>
<td>An opportunity for substantial deployment of e-ferrys and IWT urban logistics.</td>
</tr>
<tr>
<td>Behavioural changes by individuals and companies as underpinning factors.</td>
<td>These changes require engagement from senior management to crew. Awareness building as well as dedicated training will be needed.</td>
</tr>
<tr>
<td>Stronger cooperation needed at global, regional and cross-border levels.</td>
<td>Opportunity for key IN partners to take part in the debate at all levels and to share its work on ecological sustainability.</td>
</tr>
<tr>
<td>Optimal interconnection and sectoral integration across Europe are necessary</td>
<td>Sufficient infrastructure must also be available to support regional development.</td>
</tr>
<tr>
<td>An EU economy that will need to become even more resource-efficient and circular.</td>
<td>Such evolutions could on the one hand lead to the disappearance of some IWT market segments (e.g. material used in the most energy-intensive industries, coal, crude oil and traditional petroleum products) and, on the other hand, create new market opportunities and support the development of existing ones (e.g. biomass, bio-based products, e-fuels, (recycled) waste etc…).</td>
</tr>
<tr>
<td>Reaping the full benefits of bio-economy and creating essential carbon sinks.</td>
<td>Carbon catching and storage (CCS) will require transport tasks which may represent a new market opportunity for IWT.</td>
</tr>
<tr>
<td>Tackling remaining CO2 emissions with carbon capture and storage.</td>
<td>Stress laid on completion of TEN-T and climate change driven funding/financing could lead to new or reinforced funding opportunities for transport infrastructure, including IWT infrastructures and alternative fuel infrastructure, and sustainable transport projects (including into new propulsion systems, digitalisation projects etc…).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Completion of the Trans-European transport network (TEN-T), core (by 2030) and comprehensive (by 2050) required.</th>
<th>More climate driven funding and financing programmes envisaged, also for research and innovation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>More climate driven funding and financing programmes envisaged, also for research and innovation.</td>
<td>For instance, the EC is proposing that: - 60% of the post-2020 CEF II programme envelope would need to be dedicated to projects contributing to the EU climate objectives. - 35% of the 100 billion euros Horizon Europe envelope should be dedicated to the</td>
</tr>
</tbody>
</table>
development of zero-carbon innovative and economically efficient solutions.

Need for the EU industry to become even more resource-efficient and circular.
Need to tackle remaining CO₂ emissions with carbon capture and storage (CCS).

Those evolutions could lead to the creation of new market opportunities or the development of existing ones. For example, biomass, bio-based products, e-fuels, (recycled) waste or even CCS, which will require new transport tasks.

There is no doubt that challenges related to zero-emission transport and climate change will drive policy measures in relation to transport and inland navigation in the short, medium and long term. Identifying and reflecting on the best ways to ensure the transition of IN towards a zero-emission sector already today is therefore key for the future of the sector. Indeed, to remain competitive, performant and attractive, inland navigation has no choice but to be ever more ecological. In order to achieve this successful transition, the status quo is not enough, and an appropriate mix of different measures must be found.

To give a more concrete example, investments currently made in vessels and infrastructure are already starting to shape the transition of the IN sector and how it will look like in 2050. Indeed, new vessels entering the market in 2019 will very probably still be in operation 2050. Such new vessels should therefore be future proof, by being for instance equipped with electric motors. Today, the electric energy needed would come from a generator driven by a diesel engine using fossil fuels. In a decade or two, this diesel genset would be replaced by a fuel cell using hydrogen or batteries, both using renewable energy.

Collecting data on innovative inland navigation vessels and the related challenges (for instance in relation to the safety concerns it may generates) is also a necessary step towards a successful transition.

Improvement of ship design to maximize energy efficiency as well as increasing availability and access to shore-side electricity can also be among this mix of measures required for a successful transition.

Similarly, the existence of financial incentives is key. This could for instance be materialised by:

- an easier access to funding and financing for “green” inland navigation projects, including pilots or,
- a flexible energy taxation framework allowing Member States to exempt from tax shore-side electricity supply for inland navigation vessels at berth and all fuel/propulsion systems (even future) for inland navigation and which allow to improve its sustainability.

The definition of long-term binding targets for the reduction of air pollutant and greenhouse gas emissions for inland navigation, addressing both existing and new vessels and engines, could also play a role.

The authors are looking forward to discussing the strategy’s implication with the conference participants and are interested to know about the current engagement of PIANC regarding climate change. They encourage the engagement of PIANC and other IN stakeholders in the ensuing process. To support an efficient transition of the IN sector towards zero-emission, PIANC and its national members could engage further with international organisations and national governments when developing visions, strategies and/or action plans for the necessary transformation processes.
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Keywords:  
hydrogen, mobility, innovation

Title:  
Are we ready for full deployment of hydrogen power?

Paper:

Climate and air quality issues accelerate the transition in transport  
In Auvergne Rhône-Alpes, transport is responsible for 33% of greenhouse gases and contributes significantly  
to air pollution; while in 2017 more than 2 million inhabitants were exposed to air pollution standards being  
exceeded, the Auvergne-Rhône-Alpes Region sets ambitious objectives in the Regional Scheme for  
Sustainable Development and Regional Balance Planning (SRADDET) for the transformation of mobility  
systems towards less carbon-intensive and less polluting systems, with a particular focus on hydrogen.

To decarbonise the energy mix, it sets a target of 36% renewable energy in regional energy consumption by  
2030, an increase of more than 50% compared to 2015, which will still require the use of hydrogen  
technologies to enable their integration into the system. More broadly for transport, SRADDET encourages  
innovation, not only in motorisation technologies but also in organisational methods, uses and public-private  
partnerships.

ZEV: the Auvergne-Rhône-Alpes Region launches the hydrogen mobility market  
In the Regional Economic Development Scheme, here again the hydrogen sector is identified as strategic. In  
response to this dual economic and environmental challenge, the Region is implementing the "Zero Emission  
Valley" project, which aims to launch the hydrogen mobility market by supporting a professional fleet of  
1000 light vehicles and creating the Hympushion company with its partners Engie and Michelin to deploy a  
network of 20 charging stations in major regional cities. This project is supported by the European  
Commission with €10 million under the Connecting Europe Facility funding instrument. An additional step  
would be the development of heavy vehicles, such as buses, dumpsters... or river boats?
The Region is also interested in hydrogen as the regional transport authority and is preparing the procedures for testing hydrogen trains, in line with the recommendations of a national parliamentary report on the greening of SNCF's train fleet.

**Hydrogen at the crossroads of CNR's activities: renewable energy production, storage, distribution... and territorial development**

For 80 years, renewable energies have been the core business of CNR, concessionaire of the Rhône and France's leading producer of 100% green electricity. Operator of hydroelectric power plants on the river and developer of wind and solar farms, CNR is both a regional developer and an integrated energy company specialising in the development of intermittent meteorological renewable energies.

Hydrogen, thanks to its electricity storage capacity, is therefore a major challenge for CNR. Indeed, obtained by electrolysis of water, the mass storage of hydrogen in the gas transmission network will enable CNR to optimise the use of renewable energies managed on its own account and on behalf of third parties, particularly in periods of abundance of the latter, during which electricity demand will be insufficient.

Investment in industrial-scale production units to achieve this objective also opens the way to new uses:

- A commercial supply of green hydrogen to industrial hydrogen users, in the Rhône Valley in particular, or elsewhere in the country via the guarantees of origin mechanism.
- The refuelling of recharging stations at a competitive hydrogen price for a rapid development of electric-hydrogen mobility on land, thus contributing to meeting the environmental challenges of the territories.
- Finally, inland waterway transport, which will also benefit from this energy to reduce its emissions, in particular for the crossing of metropolitan areas in zero emission mode.

This is why CNR is now involved in many demonstrators such as :

- JUPITER 1000 in Marseille, demonstrator of Power-to-gas, i.e. the production of hydrogen and methane from renewable electricity,
- The Quai des Energies, 2nd phase of the Hyway project in Lyon, with a hydrogen station for refuelling cars, buses and a river pusher,
- And the Pierre-Bénite hydrogen plant project, a 20 MW industrial demonstrator, which will supply the Hymulsion network stations in the Lyon metropolitan area, supply industrialists in the Chemistry Valley and inject hydrogen into the GRT Gaz network.

**VNF: the greening of the fleet**

Ecological because of its lower energy consumption, economic because of its massification capacity, reliable because of the safety of its transport, the waterway offers solutions adapted to transport requirements. With a lifespan of about 40 years by boat, the inland waterway fleet is not much renewed. The tightening of European emission regulations for non-road engines, as well as the development of low-emission areas and, more broadly, atmospheric protection plans, make it necessary to consider new models of river engines that consume less fossil energy.

In this context, in 2009 VNF initiated an R&D project to promote innovation in the propulsion and motorization of inland waterway vessels (hybrid diesel and electric propulsion with hydrogen complement to replace part of the current fossil energy sources): PROMOVAN.

The first stages of the Promovan program have shown that there are real opportunities for fuel consumption savings (between 10 and 15% reduction) and a reduction in associated pollutant emissions. To physically demonstrate that a river loading vessel can operate in all-electric, zero-emission mode in cities and use efficient diesel systems for long-distance navigation, several innovative powertrain projects have been launched on different river units:

- the construction of a multifunctional pontoon (equipped with 2 engines integrating diesel filtration systems with a particulate filter, an oxidation catalyst and a catalyst for selective catalytic reduction),
- and the design of a hydrogen pusher for urban use only (river waste collection and container barge pushing activities within the Port of Lyon, CFT).
Promovan partners: VNF, CFT, CEA, ENAG, IFSTTAR and Bureau MAURIC.

FLAGSHIPS: CFT in the race for a 100% H2 project
The FLAGSHIPS project (2019-2021) consists of building two boats powered by hydrogen fuel cells, with very different uses: a pusher for Lyon (operated by the Compagnie fluviale de Transport CFT, Sogestran group) and a public transport ferry in Norway. Both boats will run on green hydrogen, produced on site using electrolysers powered by renewable electricity. To ensure the supply of hydrogen to the Lyon pusher, CFT will rely on the infrastructure developed by CNR with the Quai des énergies and by the Auvergne Rhône-Alpes Region with the Zero Emission Valley programme.

The project is therefore based on the development of a 100% green and sustainable navigation offer. It aims to demonstrate that hydrogen propulsion is adapted to the needs of the river and maritime fleet and that it is a key factor in the fight against climate change. It must also make it possible to initiate regulatory developments related to this type of propulsion.

This project is finally a collective victory: CFT, which has been involved for a long time in the study of innovative propulsion systems, has been able to make it a reality thanks to the support of the State, VNF, CNR and the Rhône-Alpes Auvergne Region. The ecosystem is being set up and industrial and technological tools are being built to contribute to the development of a hydrogen sector.
For all these reasons, Flagship is supported by the European Commission to the tune of €5 million as part of the Horizon 2020 programme.

Project partners: CFT, Ballard, ABB, VTT, PersEE, Norled, LMG Marin and MCT.

This 100% H2 experiment could continue with the development of a fleet of several hydrogen units. CFT is already seeking to initiate a new consortium to industrialize and capitalize on this concept for other shipowners.
However, the migration of a significant proportion of the fleet to this emission-free inland navigation is conditional on the deployment of a hydrogen recharging infrastructure network enabling fuel to be replenished along the river.

The expert's view: the river sector, one of the markets where hydrogen is the most efficient
Indeed, due to the high energy consumption, the battery is set aside and competitors such as CNG (compressed natural gas) or GTL (synthetic fuel) cannot claim the same environmental performance as hydrogen.
Thus, the lines are moving fast and several demonstrators are being built in the Netherlands, Norway and the United States. France, which already has two hydrogen boats (Nantes and La Rochelle), has seen its Pays de la Loire and Sud-PACA regions strongly articulate their regional hydrogen strategy around this theme.

Beyond a promising market, it is an entire ecosystem that can revolve around a hydrogen boat. Indeed, it is because a boat consumes at least the equivalent of 15 cars (25kg/day) that an electrolyser can find its economic model by pooling land and river consumption. For example, an electrolyzer installed on a vehicle station can export its hydrogen to a boat (with dockside charging) within an 80km radius thanks to a truck logistics with a pressurized cylinder. This model makes sense because it combines the two main expenditure items, the electrolyser and the compressor. Thanks to the ZEV project, the Auvergne-Rhône-Alpes Region has given itself the means to invest in this costly hydrogen infrastructure. It is therefore by building on this future infrastructure and imagining complete hydrogen ecosystems (all applications combined) around these stations that the profitability of hydrogen will be achieved. On the other hand, it is by remaining in a classic and siloed scheme that delays will be taken.

We must therefore compartmentalize our thinking in order to allow hydrogen to express its full potential in terms of volume energy through strong and innovative partnerships.
Finally, when the first hydrogen boats are built on the Rhône, the banks will be able to accommodate solar hydrogen production. This allows an energy resilience of the river sector and therefore, in the long term, a strengthened competitiveness.
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Title:  
Innovative solar energy with the flow

Abstract:

The PPE, the multiannual energy program for France, plans for 2023 a significant acceleration of the development of renewable energies, positioning France in capacity to achieve the objectives of the Energy Transition Act for 2030. In particular, the objectives of the EPP will allow increase by more than 70% the installed capacity of electric renewable energies compared to 2014, the photovoltaic capacity thus having to reach 20.4 GW by 2023.

This strong ambition translates into a progressive rarefaction of land easily available for the development of large photovoltaic plants, potentially inducing more conflicts of use than today. For this reason, CNR, the Rhone concessionaire and the leading 100% renewable electricity producer in France, is interested in new types of sites to promote photovoltaic field and support the development of the territories in a sustainable and innovative way all along the river Rhone.

First of all, floating photovoltaics is an important field, given the large number of artificial lakes and waterways in the territories.

Winner in February 2018 of a call for tenders from the Energy Regulatory Commission and inaugurated in the spring of 2019, Ô SOLAIRE project is the first floating solar plant of CNR. Located on the irrigation lake La Madone, in southwest of Lyon, Ô SOLAIRE innovates by combining solar power generation and development of aquatic biodiversity - with 16 fish sanctuaries and scientific monitoring over 3 years - and this in a constraining context (industrial lake, high variation of the water level according to irrigation needs,
area accessible to the public.), The development of floating photovoltaics allows the local irrigation syndicate to consider the self-consumption of the energy needed for irrigation pumps, thus providing a solution to the risk of an upward trend in the price of electricity, weighs heavily on the cost of irrigation and therefore on the costs borne by farmers. Indeed, with 230 kWp of photovoltaic solar panels, Ô SOLAIRE will produce as much electricity as the lake's irrigation pumps consume in one year, being 265 MWh.

The deployment of floating solar on savings lakes and supply channels along our rivers would enhance these sites, and provide renewable and local energy to the specific needs of territories by the water.

Solar innovation along rivers is not limited to water areas. By managing almost 500 kilometers of linear sites, CNR is also interested in the development of long-distance plants, on dikes, bike paths, roads and railways that run along them. The bifacial linear photovoltaic plant of 350 m at Sablons, under construction in 2019, is the first linear park of CNR, before two future projects, of 2 and then 10 km.

Rivers and shores, from the Rhone and elsewhere, at the crossroads of transport, energy and the environment, are privileged vectors to promote these solar innovations and to be at the heart of the energy transition.

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Titre:
Le solaire innovant au fil de l’eau

Résumé:
La Programmation Pluriannuelle de l’Energie (PPE) planifie pour 2023 une accélération significative du développement des énergies renouvelables, positionnant la France en capacité d’atteindre les objectifs de la loi Transition Énergétique pour 2030. En particulier, les objectifs de la PPE permettront d’augmenter de plus de 70% la capacité installée des énergies renouvelables électriques par rapport à 2014, la capacité photovoltaïque devant donc atteindre 20,4 GW d’ici 2023.
Cette ambition forte se traduit par une raréfaction progressive des terrains facilement disponibles pour le développement de grands parcs photovoltaïques, induisant potentiellement davantage de conflits d’usage qu’aujourd’hui.

Pour cette raison, CNR, concessionnaire du Rhône et 1er producteur d’électricité d’origine 100% renouvelable en France, s’intéresse dès à présent à de nouveaux types de sites pour développer du photovoltaïque et aménager durablement et de manière innovante les territoires le long du fleuve Rhône.


Le solaire flottant offre l’opportunité de répondre à ces enjeux en donnant de nouvelles fonctionnalités à ces environnements aquatiques.

Lauréat en février 2018 d’un appel d’offres de la Commission de Régulation de l’Énergie et mis en service au printemps 2019, le projet Ô SOLAIRE est celui du 1er parc solaire flottant porté par CNR. Localisé sur le lac d’irrigation de la Madone au sud-ouest de Lyon, Ô SOLAIRE innove en combinant production d’électricité solaire et développement de la biodiversité aquatique, et ce dans un contexte technique contraignant. Au-delà d’être un précurseur en France pour le solaire flottant et d’acquérir une expérience décisive pour ses installations à échelle industrielle à venir, CNR a le souhait d’accompagner le développement de cette nouvelle filière prometteuse dans une direction respectueuse de son environnement et de son contexte.

Le projet a été imaginé lors des échanges réguliers entre CNR et le SMHAR, Syndicat Mixte d’Hydraulique Agricole du Rhône, qui a en charge le réseau d’irrigation agricole autour de la métropole de Lyon. Le développement du photovoltaïque flottant sur le bassin d’irrigation de La Madone – retenue collinaire de 340 000 m³ construite en 1991 et plus grande réserve d’eau du réseau d’irrigation sur le secteur de Millery-Mornant - permet au syndicat d’irrigation local d’envisager à terme l’autoconsommation de l’énergie nécessaire aux pompes d’irrigation, apportant ainsi une solution au risque d’évolution à la hausse du prix de l’électricité qui pèse fortement sur le coût de l’irrigation et donc sur les charges supportées par les agriculteurs. En effet, avec 230 kWe de panneaux solaires photovoltaïques, Ô SOLAIRE produira autant d’électricité que les pompes d’irrigation du lac en consomment en une année, soit 265 MWh.

Au-delà d’apporter une réponse aux problématiques du monde agricole du secteur de Millery-Mornant, Ô SOLAIRE a été réfléchi pour contribuer aux autres spécificités du site. Initialement créé pour l’irrigation, le bassin voit son niveau varier en fonction du besoin en eau des cultures agricoles. Successivement immergées et émergées, les berges du lac restent alors vierges de toute végétation. Cette absence gêne le développement pérenne de la population aquatique. Ainsi, 16 frayères et nurseries ont été installées sous Ô SOLAIRE. Le principe consiste à mettre à la disposition des jeunes poissons un habitat leur permettant de se protéger en attendant d’atteindre la « taille refuge » et ainsi contribuer efficacement à l’accroissement des populations adultes. Les habitats artificiels installés sur Ô SOLAIRE permettent de donner une fonction écologique de nurserie et de frayère à la plateforme flottante, c’est-à-dire propice à la reproduction et au développement des espèces aquatiques. Une collaboration étroite avec les collectivités locales et les institutions liées à l’activité de pêche, ainsi que l’élaboration d’un suivi scientifique sur 4 ans permettront d’évaluer les fonctions environnementales de la plateforme et d’accompagner les campagnes d’alevinage pour des procédures durables.
Enfin, en intégrant l’énergie solaire dans un projet global et innovant sur un lieu partagé, Ô SOLAIRE illustre la transition énergétique et sensibilise les usagers du lac aux énergies renouvelables et à la biodiversité des lieux en expliquant le fonctionnement de la plateforme grâce à un parcours pédagogique.

Le déploiement du solaire flottant sur des bassins d’épargne et d’alimentations de canaux le long de nos rivières permettrait de valoriser ces sites, et de mettre à disposition une énergie renouvelable et locale aux besoins spécifiques des territoires aux bords de l’eau.

L’innovation solaire le long des rivières ne se limite pas aux zones en eau. En assurant la gestion de terrains linéaires sur près de 500 kilomètres, CNR s’intéresse aussi au développement de parcs sur de longues distances, aussi bien sur les digues, les pistes cyclables, les routes que les voies ferrées qui les longent. La centrale photovoltaïque linéaire bifaciale de Sablons de 350 m, en cours de construction en 2019, est le premier parc linéaire de CNR, avant deux prochains projets, de 2 puis 10 km.

L’innovation solaire le long des rivières ne se limite pas seulement aux zones en eau. Elle peut permettre d’aménager un territoire fluvial de manière plus large, en équipant non seulement les rivières elles-mêmes avec du solaire flottant, mais aussi les digues qui canalisent les cours d’eau. Ces digues pourraient être aménagées aussi bien au niveau des berges, que des crêtes de digues souvent aménagées comme des chemins, des routes ou véloroutes.

La France totalise à elle seule près de 12 000 km de linéaire fluvial. A l’international, on compte plusieurs centaines de milliers de kilomètres. Plus largement, le photovoltaïque linéaire permettrait de développer du solaire le long des routes et voies ferrées. Le potentiel s’avère extrêmement important.

Les terrains linéaires sont peu propices actuellement pour le développement du photovoltaïque. En effet, il faut pouvoir développer du photovoltaïque sur ces terrains, sans conflit d’usage. La configuration étroite de ces terrains laisse peu de marge de manoeuvre pour l’implantation des panneaux solaires qu’il sera difficile d’orienter et incliner de manière à favoriser la production. De plus, la production d’énergie sur des terrains linéaires de plusieurs kilomètres souleve le problème de l’évacuation de l’énergie. En effet, les architectures électriques classiques ne sont pas adaptées car elles génèrent beaucoup de pertes d’énergie. Par ailleurs, ces terrains sont particulièrement exposés à des ombrages ponctuels et momentanés, qui impactent les performances de la centrale dans sa globalité.

Lauréat en février 2018 de l’appel d’offres innovation de la Commission de Régulation de l’Energie, le projet de Sablons (Isère) constitue un premier projet photovoltaïque linéaire, situé sur une digue. Il couvre un linéaire de 350 m, pour une puissance de 100 kWc. La mise en service est prévue début 2020. Il innove puisqu’il est compatible avec la fonction première de la digue en respectant les enjeux de sûreté, les contraintes d’exploitation, et la sécurité des personnes. Premier parc photovoltaïque accessible au public, il illustre la transition énergétique en permettant au grand public de voir de près des panneaux en fonctionnement, les incitant peut-être à mieux accepter ces installations dans leur cadre de vie habituel.

CNR étudie également d’autres projets sur des linéaires plus grands, de l’ordre du kilomètre, et de la dizaine de kilomètres.