GOTRIS
Co-modal traffic management
Project report

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PART 1 – THE GOTRIS PROJECT

The GOTRIS project was a research and innovation project funded by Vinnova, Swedish Transport Administration (STA), City of Gothenburg, Region Västra Götaland, Region Värmland, Kristinehamns kommun and Karlstads kommun. The project started in August 2012 and ended in December 2014.

Background

During the period July 2010 to January 2011, Victoria Swedish ICT, together with a number of partners (see facts box), conducted the GOTRIS 1 project. GOTRIS 1 was a preliminary study to show how Intelligent Transport Systems solutions (ITS solutions) can support a sustainable transport system on and over the river Göta Älv and Lake Vänern. The name GOTRIS comes from River Information Services (RIS) for Göta Älv.

The preliminary study showed a number of inbuilt differences and conflicts of interest, all of which resulted from a lack of access to infrastructure resources on which the interested parties depended on to run their operations.

Four areas in particular were identified in which there were conflicts of interest between the actors (see below):

The development of Gothenburg vs regional development of Västra Götaland and the Lake Vänern area

Much of the tension identified concerns the river Göta Älv constituting a barrier through the city of Gothenburg. The island of Hisingen has industry and ports as well as large residential areas. With the development of Norra Älvstranden in the past 10 years, Hisingen has become more important as a place of work, primarily for service companies.

There is a need to connect the central parts of Gothenburg to the centre of Älvstaden on both sides of the river. This requires infrastructure investment and efficient transport routes across the river. New river connections, such as a cycle bridge, a replacement bridge for Göta Älvbron that needs to be replaced a new railway bridge next to the existing railway Marieholmsbron, are considered important to the city of Gothenburg's development and have been central issues in the public debate. The Port of Gothenburg has identified the extension of the railwaybridge, Marieholmsbron, and a double track to the port as important for its survival.

There is a current proposal to replace Göta Älvbron and a decision of a new railway bridge by Marieholm with greater capacity than the current connection. Considerations to the city planning have resulted in a proposal of a new lower bridge with a height of 12 meter, which will be a greater obstacle for the shipping industry than the existing bridge, Göta Älvbron.

1 http://reports.viktoria.se/gotris/
Bridge heights vs vessel heights

The infrastructure measures discussed above will have direct consequences for shipping in many cases. A joint consultation group coordinated by the County Administrative Board in Västra Götaland has been working on this issue in dialogue meetings.

The optimum bridge heights for different types of traffic differ markedly, with 4 metres for pedestrians, 10 metres for the railway and at least 27 metres for shipping. The current proposal for a new Göta Älvbron bridge is for a height of 12 metres instead of the current 18.3 metres. With the current level of traffic, this would increase the number of openings of the Göta Älvbron bridge for merchant vessels from an estimated average of two to five. The number of leisure boats requiring bridge openings will also increase with a lower bridge from one to four per 24 hours. A bridge opening on Göta Älvbron creates in average a three minutes delay for the public transport-buses and trams affected by the opening and after 15 minutes no residual effect can be measured on public transport from the opening.\(^2\)

ITS functions and IT support will not be able to change the fact that if a bridge is lower than the height of a vessel, the bridge must be opened for it to pass, which disrupts other traffic that uses the bridge. The lower the bridge heights, the more often they will have to be opened. What ITS support can do, however, is to alleviate the effects of these bridge openings, including optimising the passage of vessels to minimise disruption. The negative effects of low bridge heights will be accentuated in pace with the growth in shipping, train services and road traffic. These effects can be reduced, however, with good planning and ITS support and management.

Commuter trains vs ‘Väner shuttles’

Part of the planned development of Lake Vänern traffic relates to possibilities of feeder traffic to and from the Port of Gothenburg with containers, so-called ‘container shuttles’\(^3\). Containers that arrive in the Port of Gothenburg will then be transhipped onto a ‘Väner shuttle’ and continue via the river Göta Älv to Vargön, Kristinehamn or another port in Lake Vänern. Raw forest material for energy production may also be transported to Gothenburg on ‘Väner shuttles’.

An increase in the number of passages requiring bridge openings will naturally lead to reduced crossing capacity for trains to and from the Port of Gothenburg, which will result in the paradox of increased shipping on the river Göta Älv being seen as having a negative effect on the port’s expansion potential. This is in view of the Port of Gothenburg’s investment since 2000 in feeder traffic for containers via the railway. With the expected increase in goods to the Port of Gothenburg, it becomes clear, however, that the railway capacity is and will continue to be a limitation. An extended railway in the port with double tracks and a new Marieholmsbron bridge are therefore priorities for the port. These infrastructure projects have now been started.

If instead, the ‘Väner shuttle’ handles the increased transport demand, this concept could significantly increase the expansion potential of the port. Processes, routines and integration requirements have already been developed and could be transferred to the ‘Väner shuttle’ concept in partnership between the port and the transport actors.

Compulsory vs exemption from compulsory pilotage

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\(^2\) Piverkan av broöppning på kollekrivtrafik över Götra Älvbron (Viktoria Swedish ICT, Trafikkontoret, 2014)

\(^3\) http://www.trafikverket.se/PageFiles/113113/trafikslagsovergripande_strakstudie_och_atgardsvalsanalys_gota_alv_vanerstraket_sammanfattande_slutrapport_20130404.pdf
A central question in the GOTRIS project has been whether the river Göta Älv and Lake Vänern are classified as ‘inland waterways’ (IWW) according to the EU’s definition. In January 2011, a report was issued by the inquiry ‘Genomförande av EU:s regelverk om inre vattenvägar i svensk rätt’ (SOU2011:4) (enforcing the EU regulations on IWW in Swedish law), which examined the conditions for Sweden adopting the EU’s regulations on IWW. The aim of such an adoption would be to apply the legislation and regulations they cover. This could involve relaxing the regulations on inland shipping in Sweden, which could lead to significantly lower costs for shipping on the river Göta Älv. The relaxations could include vessels being run with fewer staff. With this, shipping would become competitive in a new way compared with the railway and lorries, and the conditions would then be right for a ‘container shuttle’ between the Port of Gothenburg and the Lake Vänern area.

The change in traffic on the river Göta Älv predicted with the introduction of ‘inland waterways’ would primarily constitute a potential increase in transport between the Lake Vänern area and the Port of Gothenburg. This is traffic that, in principle, does not currently exist, and such an increase would not have a negative effect on pilotage. A coordinated traffic management system in the form of RIS would also demand skills that largely overlap those of the pilots.

The preliminary study also identified the possibility of trying information sharing between the different types of traffic in a demonstration project to show how a traffic management system for the river (River Information Services) could address the identified conflicts.

In spring 2012, the project consortium applied for funding for such a demonstration project from Vinnova in the call for challenge-driven innovation. The project was granted funding by Vinnova as well as by the STA, the city of Gothenburg, Region Västra Götaland, Region Värmland, the Municipality of Kristinehamn and the Municipality of Karlstad.
Project scope

The GOTRIS vision is to develop a platform to demonstrate co-modal traffic management of different modes of transport on the river Göta Älv. By bringing together all the actors and letting the railway, shipping and road traffic share information and services in a RIS for the river Göta Älv, the project will demonstrate how navigation on Lake Vänern and Göta Älv can be managed for passages of bridges and locks to reduce disruption to road traffic and rail transport while optimising vessel traffic.

During the project, a pilot version of the GOTRIS platform will be developed in which information sources from, for instance, the STA, the city of Gothenburg and the Swedish Maritime Administration (SMA) will be integrated. Models for control and optimisation as well as functions for vessels, traffic management systems and road systems will also be developed.

A fully developed GOTRIS platform could then be designed to create well-functioning freight traffic over the river to facilitate expansion of the Port of Gothenburg, while the traffic on the river Göta Älv will be optimised with the possibility to expand. From a societal perspective, efficient environmentally friendly transport can be achieved (rail and shipping encouraged) by minimising waiting times and ship bunker use. From the perspective of the city, a well-functioning and attractive city with minimal interference from bridge openings could be achieved.

Expectations of a River Information Service platform for the river Göta Älv

During the preliminary study, the project partners agreed on the following expectations of an implemented RIS platform (long-term implementation of RIS for the river Göta Älv). Even though a demonstration project cannot create these effects during such a short time, these expectations have determined the direction of the project.

- To create a compromise solution between affected actors with different agendas and requirements for traffic on and over the river Göta Älv.
- To increase knowledge sharing between actors and thereby understanding of the different requirements of the representatives and implementers of the different modes of transport.
- To create public benefit by reducing disruption in the conflict between opposing national interests.
- To coordinate goods train services over the river to/from the Port of Gothenburg with shipping on the river that requires bridge openings.
- To coordinate information on bridge openings with road and tram services in Gothenburg.
- To provide prerequisites for increased goods train services over the river.
- To provide prerequisites for well-developed inland shipping and regional growth in Värmland and Västra Götaland.
- To provide prerequisites for green growth – transferring goods from roads to shipping.

Project deliverables

In the project description, the partners agreed on a defined set of deliverables in the project. At the end of the project, it shall have:

- Demonstrated in a real environment how ITS can be used to manage more efficiently the modes of transport that compete for the same resource – passage on and over the river Göta Älv.
- Produced decision data for managing common organisation, regulations and control principles for the traffic on and over the river Göta Älv.
The project shall also have achieved the following results:

- Developed a base platform for GOTRIS on which data sources can be integrated, databases built and managed, and digital services developed and implemented (the GOTRIS platform).
- Developed models for forecasting travel and arrival times for vessel traffic on the river Göta Älv.
- Integrated information sources from the Swedish Traffic Administration, the Swedish Maritime Administration, the city of Gothenburg and others required by the system.
- Developed user functionality for the vessels, traffic management and planning functions in the traffic system.
- Verified possibilities for third-party functional development on the platform.
**GOTRIS demonstration platform system (GDPS)**

To demonstrate the ideas behind GOTRIS, the project needed to develop a platform on which different services and subsystems could be deployed. Furthermore, in this document, it will be referenced as GDPS, the GOTRIS demonstration platform system. In this section, we describe GDPS from an overarching view, and the more technical aspects of GDPS are described in PART TWO – A TECHNICAL VIEW OF GOTRIS.

**GPDS – the GOTRIS hub**

We named the central integration platform the GOTRIS hub to illustrate that the whole platform consists of information interfaces connected to a common information platform on which the data are sometimes aggregated or processed and then distributed through a number of services. The hub was designed to stretch further than a mere demonstration project. It was developed in a way that allows it to be easily transformed into a production environment, even though some actions are recommended for further development in this report.

The GOTRIS platform is basically built up from a set of well-defined subsystems, each of which has a specific task.

- The Voyage module imports data from SafeSeaNet Sweden (SSNS) on approaching vessels and their planned voyages. This is combined with pilot planning data (in the project, this was entered manually by the pilot planner from integration, so SMA subsystems were not possible at the time) and generated a voyage description published in the GOTRIS hub.
- The AIS module imports data from the SMA AIS flow, filters them to handle the GOTRIS area and transform them into AIS messages that are published in the GOTRIS hub.
- The Train module imports data from STA train planning systems (UTIN), selecting data that are relevant to the train bridges in the Göta Älv area. These are published in the ‘Time table for trains on the bridge’ in the GOTRIS hub.
- The Forecast module is based on subscribed AIS messages, subscribed voyage descriptions and known calendars (trains, restrictions, etc.) for the bridges. The Forecast module continuously calculates and publishes forecasts for every ship that is in the GOTRIS area (or heading towards it).
- The FrontEnd is the single interface for external subscribers or services to reach information from GOTRIS. It contains authentication and information security functionality. In the front-end server, a series of services is published (see below) and used in the different user interfaces developed in the project (Tablet, Web, API).

**GOTRIS services**

A series of services has been developed and tested during the project. The services are based on a series of use cases described later in this document, user input and the priorities of the project.

**Pilot tablet services**

For the purpose of supporting the pilot in his/her duties and work, a set of services was developed and implemented on the GOTRIS tablet. The services could easily have been developed and implemented in the pilots’ regular ‘pilot plug’ or ‘pilot computer’, but since GOTRIS was only a demonstration project, the decision was to develop and deploy it on a separate unit. There was awareness in the project that this would mean an extra tool for the pilot to master and carry, but this was still found to be the best solution.

The services can be described as follows:
• Pilot overview: this service was implemented as the start-up screen for the pilot when logging on to the assignment (vessel). This is elaborated on in Appendix A – Gotris Tablet services.
• Weather and hydrographic services: these were developed to give an easy overview of the external factors influencing the voyage (weather, visibility, flow). It is elaborated on in Appendix A – Gotris Tablet services.
• Scheduled service: shows the current ‘itinerary’ for the vessel, taking into account all obstacles, background facts and meetings. It is elaborated on in Appendix A – Gotris Tablet services.
• Schema service: shows the current train schedule for the bridges in the system.
• Ship data configuration service: option to change the data used to optimise the ETA prediction etc.

![Pilot tablet opening screen](image)

**Figur 1** Pilot tablet opening screen

**Bridge/lock management services**
A set of services was developed to support the tasks and work of the bridge and lock operators.
• Schema service: shows the current trains and planned vessel passages for a single or multiple obstacles (bridge/lock)
• Passage confirmation services: approval from the obstacle operator for a ship to pass during a certain slot.

**Voyage registration service**
This is a manual service to create or update a voyage in GOTRIS. Voyages are automatically imported from the approach registration in SSNS, but for the reasons explained above, the information needs to be complemented with pilot planning information when this is ordered by the agent. During the demonstration project, this was done manually by the channel operations centre. However, such manual update functionality has proven to be useful for handling exceptions occurring during the daily operation of the system.
The GOTRIS idea

The first and foremost reason for the GOTRIS project is based on the idea of ‘adaptation through external actors’ intentions’. By knowing the intentions of the other actors in a system (of systems), each actor can optimise its own performance and actions. Each actor incrementally and dynamically adapts the changes in the actor systems. Translated into the transport system of the river Göta Älv, this means that the train operator can plan the passages of trains on the bridge better if it knows in advance when during the day to expect passing vessels. It is better to position a train on the other side of the river in the morning if several bridge openings are expected in the afternoon. At the same time, the captain or the pilot of the vessel can adjust the speed of the vessel to arrive more precisely at the bridge before there is a slot to open it without interfering with the train services. Cyclists who are aware of a bridge opening at Marieholm can choose to take another route to work, and the public transport passengers, seeing that the bus will be delayed by 10 minutes, may prefer to choose the ferry to Hisingen island.

Another cornerstone of the GOTRIS project is that it is possible to create complex, operational, coordinating platforms outside the traditional organisations such as the STA, the SMA and the city of Gothenburg without large infrastructural and integralational projects. When there is a need to coordinate functions where the responsibility overlaps, or between different organisations or authorities, the normal approach is to create new organisations with supporting enterprise systems. The GOTRIS approach shows how to create such coordination platforms based on ability and willingness to publish enterprise information in a way that enables external integration of that information (data outlet, API, information hubs, etc.). The GOTRIS platform (and its integrations into seven different data sources) could actually have been built (almost) without any technical support from the data-providing organisations if the information had been available in some sort of public or semi-public information hub.

By combining these two perspectives, the project aimed to develop a demonstration platform for a collaborative information-sharing and coordination system in which all relevant actors provide and receive information that is critical to their operational situation. Based on this information, the project also aimed to develop a set of services supporting the different actors in coordinating the traffic on and over the river Göta Älv.

ETA predictions, passage predictions and confirmation, pilot information tablets, bridge/lock traffic overviews, etc. are examples of services developed in the project.

How it works

GOTRIS subscribes to information from various data sources (APIs). This means that GOTRIS will be ‘aware of’ any changes in the traffic situation on the river.

- SSNS: arrival notifications from any ship planning to visit any port in the Göta Älv/Vänern region (the GOTRIS area)
- SMA pilot planning (manual): any pilot assignment for any of the vessels planning to visit or leave any of the above ports
- Any change in position of any vessel in the GOTRIS area
- Any planned passage of trains on any of the three railway bridges crossing the river
- Wind, water flow and visibility for the river

A vessel notifies SafeSeaNet 24 hours prior to its arrival. GOTRIS then automatically creates a tentative voyage based on the known criteria. This tentative voyage is immediately distributed so that bridge, train and lock operators can see that a ship is due to pass within the next 24 hours.
Five hours before its arrival in the GOTRIS area, the vessel orders a pilot to assist it (mandatory on the river Göta Älv for vessels with captains without a pilot exemption certificate). This information is added to the voyage in GOTRIS, making the planning more precise.

For every vessel with a known voyage, GOTRIS continually generates an ‘itinerary’ for the river with preliminary allocations of slots for the bridges and locks. This itinerary is updated dynamically when there are deviations from the plan. Speed limits, geographical constraints and even delays or re-planning in the train system are taken into account.

When the vessel arrives at the pilot station and the pilot is on board, the pilot activates the GOTRIS tablet, which displays the itinerary, proposed slots, suggested speed recommendations, weather information and estimated meetings. The pilot enters the local constraints (depth, max speed, min speed, under bridge clearance, etc.) and that the GOTRIS voyage has started.

As the vessel approaches a bridge or other object that is ‘GOTRIS regulated’, the system recognises the ‘prewarning time’ set for this particular object. In the demonstration project, this was set to one hour. So, one hour prior to arriving at the railway bridge, the train operator would receive a notification that the preliminary slot for the vessel to pass the railway bridge needed to be confirmed. In most cases, the operator would confirm the time, as it was generated from the actual time scheduler, and it would fit very well, but it could change the time to another slot.

Once it has been confirmed, the pilot on board sees that a time slot has been confirmed and a suggested speed to arrive at the bridge ‘just in time’ for the opening.

At this point in time, the opening time of the bridge is communicated to any third-party information service that wants to be informed about the bridge opening. This could be public transport operators, the road administration or the city, which may want to inform travellers on VMS signs about a forthcoming interruption. During the demonstration project, ‘tweeting bridge’ functionality was developed but not tested with a live audience. Any person could subscribe to information about openings via Twitter, email or Facebook.

Figur 2 GOTRIS - how it works
The roles in GOTRIS

The pilot (SMA)
The pilot works as the representative of the captain or shipowner during the time the vessel sails through the GOTRIS area. When the pilot is on board the vessel, his/her focus is on taking the vessel from A to B as fast as possible in the most optimised way, taking into account efficiency and safety. In GOTRIS, the pilot is the actor who will receive ‘advice’ from the system on how the vessel should perform when travelling through the GOTRIS area in the most optimal way.

The train operator (STA)
The train operator is responsible for the infrastructure ‘obstacle’ causing the vessel to deviate from an optimal voyage. The primary objective of the GOTRIS system is to approve the allocation of a time slot for the vessel to pass under the railway bridge. The train operator is also a consumer of the information published in GOTRIS on planned passages of the vessel, for which the bridge operator is responsible.

The lock operator (SMA)
The lock operator is responsible for the flow through the locks. The primary objective of the GOTRIS system is to approve the allocation of a time slot for the vessels in the lock. The operator is also a consumer of the information published in GOTRIS on planned passages through the lock, for which the operator is responsible. During the pilot phase, the approval part of GOTRIS was not used for the locks.

The bridge operator (SMA and the city of Gothenburg)
The bridge operator is responsible for the infrastructure ‘obstacle’ that causes the vessel to deviate from an ‘optimal’ voyage. For a bridge where ‘slot allocation’ is to be practised, the role and functionality is the same as for ‘the train operator’ above. However, slot allocation for road-bridges was only used in the pilot project for Göta Älvbron. For a bridge without slot allocation, the operator is only a consumer of the information published in GOTRIS on the expected passing of the vessel. For Göta Älvbron bridge, functionality called ‘coupled obstacle’ was used during the project, meaning that, in practice, the slot allocation was made as a result of an approved passage at Marieholmsbron bridge.

The channel operations centre (SMA)
The channel operations centre’s areas stretch from south of Göta Älvbron to north of Gälle Udde in Lake Vänern. The centre is responsible for providing traffic information and for services such as operating some of the road and railway bridges that cross the river as well as the locks in the river. When it comes to the bridges, the role and functionality are the same as for the ‘bridge operator’ above. They also enter the time the pilot was booked in GOTRIS.

Secondary roles
There are several possible secondary users of GOTRIS services that could use the information generated to adapt their intentions.
- Cyclists and pedestrians could subscribe to ‘planned bridge openings the next hour’
- The public transport organiser (Västtrafik) could subscribe to booked openings for Göta Älvbron and include them in the information to its customers.
- Leisure crafts travelling on the river could subscribe to third-party services such as ‘the river app’
The distributed approach to multi-actor collaboration

The approach to designing the architecture of any system must reflect the context in which it is going to be deployed and work. A dedicated traffic coordination system that is built, managed, maintained and operated by one organisation with coordination responsibility may very well be designed as an enterprise system with all parts of the system under the strict governance of one organisation.

However, GOTRIS was designed with the intention that several modes of transport and governing organisations share responsibility for information and services that it enables. This would therefore crave a completely different approach, a distributed one in which services and information could be provided from several sources and organisations.

A basis for the GOTRIS approach was to provide a neutral, centrally organised ‘information hub’ that would work as a ‘switchboard’ of services enabled on the platform. The hub would also be responsible for sensing the ‘correctness’ of the different services as well as issues such as access, metadata and possibly data quality.

The different services provided on the platform would be produced, maintained and implemented by the different organisations and actors involved. Examples of services could be:

- Provide AIS data
- Generate ETA forecasts
- Pilot interface
- Train passage timetable
- etc.

Organisations providing these services could be:

- STA
- SMA
- the city of Gothenburg
- Västrafik
- the emergency services
- third-party developers
- etc.

One organisation should be able to develop, deploy and run a new service, without consent, integration or further assistance from any other partaking organisation as long as the organisation complies with the governance principles (identification, quality, service level, etc.) stipulated by the federation (governing organisation).

This would mean that, for example, the train timetable service could be developed by the STA, the ETA (estimated time of arrival) of the forecast engine by a third party (in this case SSPA), the pilot-support interface by SMA (in the project developed by InPort), the train operator interface by the Swedish Transport Administration (in the project developed by InPort) and a ‘bridge-opening alert’ for public transport users by Västrafik (public transport responsible for Region Västra Götaland).

In the GOTRIS project, we designed the system based on this architectural approach, however, little focus has been put on the implementation of the above suggested governance principles, with more focus on the technical implementation of the information hub. There are several challenges with the distributed approach that we have not addressed in the project, such as service-level governance (e.g. what guarantee should the STA give on the information quality in order for the SMA to use that information to optimise the pilot behaviour in piloting assignments), fault tolerance in distributed
systems (how to ensure that a service using information from another service is aware of any quality or technical problems in the other service), etc.

Even though all these aspects have not been thoroughly tested in this project, we believe that GOTRIS is one of the first attempts to show how a federated system for traffic management of several modes of transport can be designed.

The non-intrusive approach

The idea behind GOTRIS was that all the information needed for the optimisation was already available in other systems or data streams. GOTRIS was designed to be able to function without any ‘human intervention’ or data input. This assumption is based on the idea that all information is available through (publicly) accessible APs. This is not yet the case and despite a very clear direction from the Swedish government on making public data available, the transport administrations are still keeping most of the information proprietary. In this project, we gained special access to AIS and SSNS data but not to the pilot planning system. This meant that information on ordered and planned pilot assignments had to be entered manually by the channel operations centre. In an implementation of GOTRIS, it would of course be possible to accomplish a fully integrated connection for pilot planning data.

During the operational phase, we tried to keep the interaction between the actors to a minimum.

The pilots argued strongly that they could not input any data during their actual pilot assignment. For this reason, the ‘confirmation process’ was designed to be one-sided, meaning that a proposed passage under a bridge was only confirmed by the bridge operator and then implicitly confirmed by the pilot.

The only data the pilot has to enter is the ship/voyage-specific data that is entered prior to the voyage (draft, designated speed, under-bridge clearance). This could also be automated in an implemented GOTRIS by integrating it into commercial ship databases (e.g. IHS Fairplay, MarineTraffic).

Our conclusion is that GOTRIS can be implemented in an ‘automated’ mode in which practically no manual input is needed to run the system. We do believe that there still needs to be functionality to identify and correct the automated data since these data sources do not provide 100% data quality.

Use cases

A series of use cases was defined to capture the correct approach in GOTRIS to encounter different imaginable situations.

Twelve different scenarios were described and used in a use case workshop in which pilots, train operators, bridge operators and channel operations centre staff were represented. The result from that workshop formed the basis of some subsequent design decisions made in the project.

The use cases are described in Appendix B – GOTRIS use case specification (in Swedish).

During the project, we also discovered a series of use cases not identified prior to the design that we had to handle by adjustments or manual routines during the project:

**Turn-around tour:** To be able to detect and handle voyage descriptions that may be inconsistent, GOTRIS was designed to auto-delete voyages that contradict the current behaviour of the vessel, e.g. if the voyage imported from SSNS said it was going south but the vessel was actually travelling north, the voyage would be deleted and the vessel would go into ‘non-GOTRIS mode’. During the project, we discovered that vessels sometimes have to go in the opposite direction after a port call (e.g. Stallbacka), sometimes for 30 minutes, before turning around and going in the right direction. This
behaviour was not known in the design phase, which led to user reports of ‘lost voyages’. A future implementation should take this into consideration.

**Coupled obstacles:** During the development phase, we identified examples of obstacles that were tightly coupled to another obstacle in the allocation of slots, e.g., Göta Älvbron and its openings are coupled to Marieholmsbron railway bridge. If a slot is given at Marieholmsbron, implicitly a slot is allocated for Göta Älvbron, and no separate confirmation is needed for that bridge.

**Situations in which the one-dimensional model of Göta Älv is not enough:** GOTRIS was designed with a one-dimensional model of the geographic objects along the river. Its position was expressed as the distance from the entrance to the GOTRIS areas. This is possible as Göta Älv stretches in one direction and Lake Vänern is (basically) confined waters (all ships that enter eventually exit as well). This was done to be able to obtain an effective Forecast module without access to electronic chart system data. In a few cases, we found that this approach was insufficient. In the example of the Port of Vargön, GOTRIS was initially unable to differentiate between the forecast for Vargön and that for north of Brinkeberskulle (the same distance from the entrance point). In Lake Vänern, we also experienced some drawbacks with this one-dimensional model.

Ways of addressing this in a future implementation of GOTRIS are elaborated on later in this document.

**The Living Lab**

We chose to call the GOTRIS demonstrator the Living Lab. It was a collaborative approach between several organisations that actively participated in the demonstrator to test how GOTRIS worked in a live environment. The organisations that actively participated are presented under ‘Organisations’ below. In addition to these, there were also organisations that developed the GOTRIS system, which assisted the actively participating organisations with support, maintenance, improvement and continuous evaluations.

The Living Lab was divided into five different phases, which are described in more detail under the Living Lab phases:

- Simulation environment
- First test on a vessel with one pilot
- Starting the demonstrator on the southern part of the river
- Starting the demonstrator on the whole river
- Focus weeks

The aim of the field trials in GOTRIS was to test if it is possible to enable a sustainable transport chain on and over the river Göta Älv that could be facilitated via active collaboration across different organisations relating to different physical infrastructures (such as bridges and locks). When the project started, the planned approach was to introduce GOTRIS to some of the pilots and then inform the other actors of which vessels sailing on the river had a pilot equipped with GOTRIS on board. This approach was revised after the simulator trials as the pilots suggested that we should change the scope and instead start with the field trials for the southern part of the river. This approach made it easier for all the actors to know which vessels were participating in the trials.
Organisations participating

The pilot (SMA)

The pilots were assigned to participate in the GOTRIS Living Lab by SMA. In total, 19 pilots (all involved in Göta Älv pilotage) participated during the nine months that the different phases took place.

The train operator (STA)

A large number of staff from the STA participated in the demonstration project at the Gothenburg train operations centre (Tåg X).

The lock operators and the channel operations centre (SMA)

The lock operators are located in the channel operations centre in Trollhättan and are responsible for the locks in the river Göta Älv, as well as in Falsterbo and other places. They also operate most of the bridges along the river (Göta Älvbron bridge excluded). All the staff was involved in the demonstration project at some point.

The bridge operator (SMA and the city of Gothenburg)

The bridge operators of Göta Älvbron are currently located in the control tower on the bridge. Each shift, one or two persons manage the control and opening of the bridge. In total, eight bridge operators were involved in the Living Lab phase.

Secondary roles

There are several possible secondary users of GOTRIS services that could use information generated to adapt their intentions.

- Cyclists and pedestrians could subscribe to ‘planned bridge openings for the next hour’
- The public transport organiser (Västtrafik) could subscribe to booked openings of Göta Älvbron to include this information for its customers.
- Leisure crafts travelling on the river could subscribe to third-party services such as ‘the river app’

The user advisory group

The user advisory group was formed as an arena in which the usage of the system could be discussed, suggestions brought forward and ideas generated based on the users’ experiences from the trials. At least one user per user organisation was appointed to be the spokesperson of the user group. The user group had four meetings during the trials, unfortunately all the user groups were not represented at all the meetings.

The Living Lab phases

As previously explained, the Living Lab was divided into different phases. We did this because we wanted to be able to validate that the system worked before we took it into a real-life environment to familiarise users with the way it worked and to see if we needed to make any changes. We also wanted to make the introduction smooth for the users.
Entering the simulator

Earlier in the report, we have described that we had to create a simulation environment of the river Göta Älv in order to perform the first phase of the Living Lab, familiarisation and concept evaluation of GOTRIS. This phase was carried out 4-8 November with eight pilots testing the system during this week. One pilot carried out the test before lunchtime and another did the same test after lunch. After each test, the pilot was interviewed to obtain feedback on how he/she thought the system and the tablet worked and to make suggestions for improvements. The test also gave the pilots a chance to familiarise themselves with the system.

After the first phase of the Living Lab, the developer went back to try to incorporate some of the changes that the pilots wanted in order to improve the system so it would work more like they wanted it to, as they were going to use it for every trip on the river.

First test on a vessel with one pilot

The second phase of the Living Lab was conducted during one day with one pilot on a vessel going from Lilla Edet on an outbound trip passing through one of the railway bridges (Marieholmsbron bridge) and Göta Älvbron, which is the bridge used for cars and public transportation (buses and trams) in Gothenburg. The test was carried out during the late evening and early morning of 19-20 December. People from Viktoria Swedish ICT acted as train operators as it was too early to incorporate real train operators for one test trip before the Christmas holidays. Due to a power outage in the city of Trollhättan, the locks lost power, which delayed the vessels for several hours.

Starting the demonstrator on the southern part of the river

The live field trials started on 31 January on the southern part of the river. In total, ten pilots, five each week, worked on the southern part of the river. Some of the pilots also had a certificate to work on the northern part of the river.

Starting the demonstrator on the whole stretch of the river

On 20 May, we introduced the northern part of the river to the live trials, which gave us an opportunity to test GOTRIS on the whole river for all vessels using a pilot. During this period, all 20 river pilots were equipped with a GOTRIS tablet and were able to see the time slot at each railway bridge, suggested meeting places for other vessels, weather information and suggested speeds to reach the bridge and locks at the right time.

The focus weeks

The last two weeks of the trials, between 17 and 29 September, were assigned as ‘focus weeks’ when all voyages should be performed as close to the ‘GOTRIS procedures’ as possible. During the focus weeks, we highlighted the importance of train operators booking a time for vessels to pass through the bridge in the GOTRIS system, as this had not been done sufficiently earlier in the tests. We also highlighted the importance of the pilots following the suggested speed and time recommendations that GOTRIS provided for the bridges. Furthermore, we asked the bridge operator to remind the train operators to use the system to confirm a time for the ship if this had not been done in GOTRIS one hour before.
Evaluation and user-experience gathering for the GOTRIS project

Chalmers had the role of performing the evaluation activities for the project and the GOTRIS concept. The role involved assisting in the early phases of the project with the initial design and functionality and to perform an evaluation of GOTRIS.

User-experience gathering in the Chalmers ship simulation environment

Chalmers was involved in a preliminary evaluation of the GOTRIS demonstrator. In this evaluation, several test trials were completed by one of the main groups of users, the pilots, at one of Chalmers’s simulators. The main purpose was to observe how the pilots coped and interacted with the prototype in different work situations when passing the river Göta Älv and to obtain opinions related to the use of the prototype directly during the trials, allowing for any necessary changes to be made prior to publishing the pilot studies.

Four different methods were used to evaluate the prototype in this evaluation. The methods consisted of observations during the trials, in which the pilots were asked to relay their immediate thoughts and responses. A survey, QIUSS4, was also conducted in order to perform quantitative analysis of four factors: effectiveness, efficiency, satisfaction and safety. The participants were also interviewed about their attitudes to using the prototype, and their confidence in and opinions on any necessary redesign in order to produce a good implementation of the product. Lastly, there was a debriefing with the present design team to find out their first impressions and other opinions on the simulations.

A manager from the SMA in the Vänern/Göta Älv area selected the pilots. Students from the Master mariner programme acted as mates.

The participants in the simulator crew were instructors, coordinators and observers as well as information pilots. These pilots relayed on-going feedback to the simulator staff throughout the trials. In the last trial, they also participated on the bridge.

The trials consisted of two scenarios on the river, one southbound and one northbound, with known parameters for bridges, meetings, wind, current and fog; see Figure 3.

The result regarding the use of the prototype was that it was used, especially at the beginning of the routes, together with a specified speed recommendation. However, in foggy weather or when the vessel approached a bridge, the increased need for concentration shifted the pilots’ attention from the demonstrator to the reality outside. The pilots were keen on manoeuvring but wanted margins for handling unknown...

Figur 3 Simulation area simulator tests

4 Quality In Use Scoring Scheme – Method used evaluating user experience
situations. The pilots’ opinions varied on the arrival times and their use of different parameters on the demonstrator.

The interaction between the demonstrator and the pilots during the simulations was good. However, there was some confusion regarding the interface and accuracy of the design. Several suggestions for changes were suggested, for example the parameters shown on the screen were not easy to understand. Furthermore, a loss of internet connection without alert signals caused problems.

The communications showed dual behaviour. There was a need for information on the screen as well as for close interaction between the pilot and the staff around the river.

The current makes it difficult to advance slowly, especially on southbound routes.

In QUISS, the average score was just below 3 for all parameters and that is a reasonable level for a prototype.

To summarise, the simulations are possible win-win situations. The demonstrator needs to be flexible and easy, and an alert signal for loss of internet connection is required as well as secured functionality and remodelling of the prototype.

See further in Appendix E - User experience evaluation

Vessel observations together with respondent interviews

The observations were made while the pilot was working on a vessel, at the same time as the respondent’s ongoing interview was recorded.

Two stretches were used during the evaluation. The southern stretch consisted of four on board visits/runs. One run went south from Surte to Gothenburg and the others north from Tångudden to Ström. Two of the vessels followed each other through the channel. The last pilot (who did not have an on board visit) was interviewed after the pilot change on the home journey; this was not recorded.

The northern stretch consisted of three on board visits/runs. One run went north from Ström to Vänersborg and two south from Vänersborg to Ström.

The weather conditions were good on these voyages, which affected the possibility of conversations. All the respondents were informed of their rights as respondents and approved the use.

The observations have been compiled with selected transcribed parts of the conversations.

Questionnaire for pilots during piloting

A web-based questionnaire was produced to evaluate the pilots’ experiences and use of GOTRIS together with the pilot tablet on their last voyage and for the whole working week. The aim was for the questionnaire to be available before the end of the last shift and that it could be answered. The first mailing was on 6 March, which was three days later however. The questionnaire was produced in consultation with Viktoria ICT and Chalmers through testing.

The material was compiled electronically direct on the website for evaluation.

It should be noted that the questionnaire has been issued every week, and in average 50% have been answered. This represents only 2-3 answered questionnaires each week, which might be seen as a low figure, but since it has been answered by different pilots over a period of 8 months it should be seen as representative for the pilots view, especially when looking at trend-data throughout the project.
Questionnaire for pilots after finishing the demonstration-part of the project.

A selection of questions considered of interest after finishing piloting was put together as a web questionnaire in consultation between Viktoria ICT and Chalmers through testing. These were sent out to all the participating pilots in the project. Several reminders were sent as the initial response rate was low, which resulted in answered questionnaires from all the pilots. The material was compiled electronically direct on the website for evaluation.

Final interviews

A number of respondents of the participating pilots, interested parties and financial backers of the project, total x, were selected. The selection was decided by availability. The interviews were conducted on location in three cases: with the train dispatchers, bridge masters and day men, and at the channel operations centre. The remaining interviews were conducted by phone.

All the respondents were informed of their rights as respondents and approved the use. The interviews were put together from whole or selected transcribed parts of the conversations.

Findings from the evaluation activities are described further down under the section “user experience and also in Appendix E – User experience.

Evaluation tools developed in the project

Simulation environment Göta Älv South

In order to run simulator tests of GOTRIS prior to running it on live vessels, the project needed to have access to a ship simulator environment. The partner Chalmers, together with SMA, hosts one of the largest and most advanced simulator facilities in Europe, but no simulation environment for the river Göta Älv had been developed prior to the project. Chalmers, together with its simulator supplier TRANSAS, then developed a simulation environment of the southern part of Göta Älv (Surte to Frihamnen). This development made it possible for the project to perform the first phase (familiarisation and concept evaluation) with eight pilots during one week of intense testing. The AIS feed to the simulator was fed into the GOTRIS platform, generating simulated itineraries for pilots assisting the vessel. This enabled realistic testing of the pilot tablet and other functionality without having to do these on real vessels.

After the project, the simulation environment could be used for training and other research purposes connected to inland river shipping.
Marine traffic analyser (MTA)

The Marine Traffic Analyser (MTA) was developed by Chalmers to process and compile vast amounts of data generated from GOTRIS into clear KPIs defining how to monitor the performance of traffic and the GOTRIS platform during and after the project.

During the project, data were collected from January to December 2014. During this time, approximately 13 million AIS positions were stored, 389 million forecasts generated and, additionally, records of ship passings, bookings, weather and other data. To be able to process all this data and extract any conclusions about behaviour and effects, we needed a structural data-processing approach.

We defined three main areas where the MTA could contribute analysis:

A. Ships’ behaviour during voyages (speed, averages, etc.). This could be used to identify differences in the performance of shipping when using GOTRIS compared with not using GOTRIS.
B. Quality of the GOTRIS forecast compared with actual behaviour. This was used to calibrate the GOTRIS forecast methods to reflect, in the best possible way, how a ship is to perform on the river.
C. Compliance with GOTRIS principles by the different actors. With these analyses, we can identify to what extent the passages are confirmed and to what extent ships pass bridges according to allocated slots.

MTA is also used to generate data used for the environmental analysis described later in this document.

A description of the MTA can be found in Appendix C – Marine Traffic Analysis tool.

Results and conclusions

Hard facts and number crunching

During the project, extensive operational data were collected. Data from the GOTRIS cloud were exported to a statistics database on a weekly basis. These data were used during the project for evaluation and project measuring purposes. They also provide valuable knowledge on traffic volumes and behaviour on the river Göta Ålv.

The data have been used for the effects analysis of this project and will be available for the project partners for future research and analysis of inland waterway transport.

In the material, 499 voyages have been recorded (from pilot station to pilot station). Voyages with a destination inside the river Göta Ålv area have not been included in the material below.

Voyages and bookings

During the test, 102 unique vessels conducted 499 voyages covering the whole stretch of the river Göta Ålv. In theory, there should be the same number of northbound as there are southbound vessels. This should result in two passages under the Marieholm railway bridge per vessel. However, some data have been filtered out due to incompleteness, so there will be some deviations from these assumptions.

During the demonstration phase, there has generally been a low degree of confirmations on the proposed passings of vessels. This phenomenon has been discussed frequently with the stakeholders.
during the project and will be discussed further in this document. On average, 31% of the passings under Marieholmsbron bridge have been confirmed by the train operations centre.

The material has been divided into different time periods. Feb-March can be seen as a 'familiarisation period' when the pilots and Tåg-X learnt the system. We see a low confirmation rate (bookings, 16%, Marieholmsbron bridge) and also a high deviation from the confirmed and actual passings (Marieholmsbron bridge, -0.349 hours). This means that, in general, vessels passed 20 minutes before the confirmed passing (in reality, some vessels passed in the confirmed slots while others did not adjust their speed and arrived significantly earlier than the time slot and were let through by Tåg-X).

During April-June, which was the main trial period, we can see that the adherence from the pilots and Tåg-X improved significantly. A 38% booking rate for Marieholmsbron bridge and a median difference between the time slot and the actual passing of -0.03 hours is still a very high standard deviation (exploring the material, we can see that GOTRIS could very often not identify many available slots at the bridge due to the standard opening time of 12 minutes). In reality, vessels were let through in shorter slots, which were identified by Tåg-X but not by GOTRIS. This led to an adjustment of the standard time slot to 8 minutes, which resulted in GOTRIS finding more of the same slots as Tåg-X. When several vessels are let through at a significantly earlier time than that confirmed, the standard deviation increases.

July-15 September covered the holiday period with many leisure crafts on the river. The project organisation was minimised and there was no, or minimal, active follow-up or management.

The last period, the focus period, was assigned to two weeks of high adherence from all user groups to GOTRIS working procedures. Several changes are noted in the material for this period. A very precise passage pattern can be seen with a significantly lower standard deviation and the highest confirmation rate during the demonstration (38%, Marieholmsbron bridge).

From this we can draw the conclusion that if there is a high confirmation rate (the TCC participates fully in the GOTRIS procedures), the pilots will adjust and adhere to the GOTRIS procedures.

<table>
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<tr>
<th></th>
<th>Totally</th>
<th>February – March</th>
<th>April – June</th>
<th>July – 15 September</th>
<th>16-30 September</th>
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<td>42</td>
<td>61</td>
<td>51</td>
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<td>Voyages (pilot station – pilot station)</td>
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<td>121</td>
<td>220</td>
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<td>111</td>
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<td>Railway bridge passages</td>
<td></td>
<td></td>
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<tr>
<td>Marieholmsbron</td>
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<tr>
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<td>750</td>
<td>176</td>
<td>325</td>
<td>209</td>
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<td>- Bookings</td>
<td>230 (31%)</td>
<td>29 (16%)</td>
<td>118 (36%)</td>
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<td>-0.05</td>
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**Table 1 Voyage statistics**

For the bridges on the northern stretch, there were practically no confirmations from Tåg-X (average 4%), but for the confirmed passages, there was surprisingly precise adherence compared with Marieholmsbron bridge. However, there were too few confirmed bookings to draw any conclusions from this.
Forecast quality

By forecast quality, we mean the correspondence between the estimated and actual passing times of a specific object. Since GOTRIS produces constant updates for every vessel passing every waypoint of the voyage, the forecasts are not as discrete as the figure shows below. To simplify the representation, we have chosen to look at the forecast at a discrete set of hours before the actual passing of a certain bridge (1-5 h). It is to be expected that the forecast will be more precise the closer the estimate is to the actual passing time, sometimes described as the funnel effect (Lind M., Haraldson S., Holmberg P., Karlsson M., Petersson A., Hägg M., 2014; Punctuality as Performance Metrics for Efficient Transportation Systems, ITS World Congress, Detroit, USA). We can also see in the GOTRIS data that such a funnel effect also exists here. These figures can be used to establish an appropriate ‘prewarning time’ for a certain obstacle (see section ‘Co-modal adaptation’).

<table>
<thead>
<tr>
<th>Prognosis time before actual passing</th>
<th>-1 h</th>
<th>-2 h</th>
<th>-3 h</th>
<th>-4 h</th>
<th>-5 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prognosis deleted if an error of more than x minutes occurred</td>
<td>60</td>
<td>60</td>
<td>90</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Marieholmsbron</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Average (min)</td>
<td>-6,52</td>
<td>-7,46</td>
<td>-10,67</td>
<td>-15,36</td>
<td>-17,63</td>
</tr>
<tr>
<td>- Standard deviation (min)</td>
<td>19,86</td>
<td>21,94</td>
<td>26,74</td>
<td>32,20</td>
<td>40,01</td>
</tr>
<tr>
<td>- Median (min)</td>
<td>-3</td>
<td>-4,95</td>
<td>-6,8</td>
<td>-10,55</td>
<td>-12,2</td>
</tr>
<tr>
<td>Järnvägsbron Trollhättan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Average</td>
<td>-4,81</td>
<td>3,55</td>
<td>3,49</td>
<td>4,10</td>
<td>5,10</td>
</tr>
<tr>
<td>- Standard deviation</td>
<td>16,88</td>
<td>23,62</td>
<td>28,38</td>
<td>33,24</td>
<td>40,33</td>
</tr>
<tr>
<td>- Median</td>
<td>-1,5</td>
<td>5,1</td>
<td>2,9</td>
<td>3,9</td>
<td>3,9</td>
</tr>
<tr>
<td>Järnvägsbron Vänersborg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Average</td>
<td>2,14</td>
<td>-1,34</td>
<td>1,17</td>
<td>4,15</td>
<td>3,69</td>
</tr>
<tr>
<td>- Standard deviation</td>
<td>19,76</td>
<td>23,53</td>
<td>27,22</td>
<td>37,58</td>
<td>40,55</td>
</tr>
<tr>
<td>- Median</td>
<td>1,95</td>
<td>0,2</td>
<td>2,55</td>
<td>4,8</td>
<td>4,8</td>
</tr>
</tbody>
</table>

Table 2 Forecast statistics

The forecast errors are relatively small on average, except the standard deviation increase. For Marieholmsbron bridge, the absolute value of the average increase in the difference estimates a later passage than actually happens.
To draw conclusions from the figures in the table above, it is necessary to understand the logic behind the relation between the forecast and the actual passage of a bridge.

A high deviation does not necessarily mean that the forecast by GOTRIS is of low accuracy, even though this can be the case.

A forecast that cannot be met by the vessel (i.e. most of the vessels pass the bridge after the time that GOTRIS suggests) indicates that there are factors that GOTRIS has not taken into consideration. We have identified several such factors, e.g. fog, slowing down due to moored vessels, meetings, etc., for which GOTRIS could be improved in a implemented version.

In cases when vessels pass the bridge before the time scheduled in GOTRIS, it is usually due to the fact that the train operator has opened the bridge at an earlier slot, which was not known to GOTRIS. In this case, the variance is due to incoherent information from the train system (i.e. there were actual slots for vessels to pass that GOTRIS had not been informed about). In the first period (Feb-March) the system was configured to look for available slots of 12 minutes for Marieholmsbron and 15 minutes for the railwaybridges in Trollhättan and Vänersborg, which were the official minimum requirements for these bridges. However, during this period we found that GOTRIS found very few slots for the vessels, but the vessels were let through in slots as short as 8 minutes in reality. By the second period, starting in april, we adjusted those figures to 8 resp. 12 minutes, resulting in a better precision in the estimates (Percentage of pilots saying GOTRIS giving accurate estimates 13% for Feb-March and 63% for April-June).

From the table above, it can be seen that for the railway bridges Marieholmsbron and Trollhättan, the mean and median values indicate earlier passings than the forecast indicated. This means that most of the vessels had been 'let through' earlier than the slot suggested by GOTRIS.

For the bridge in Vänersborg, we can see the opposite: that the vessels pass later than the forecast estimated. We can see that for southbound vessels this is higher, which indicates that the time deviance is created between the pilot station and the bridge, and the definition of Pilot Time could deviate from the GOTRIS’s definition of 'leaving the pilot station'. This needs to be elaborated on before an implementation phase of GOTRIS.

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Tåg-X was instructed to decline a proposed slot, and propose another slot for the vessel, if safety-margins were not deemed to be enough.
Effects of GOTRIS

User experiences

A collaborative system like GOTRIS, is very dependant on the users following the intentions of the system. For this reason, a high focus has been put on how the users experience the use of the system and services. Especially, the pilots have to trust the system in order to follow advice and use information produced. For this reason both quantiative and qualitative methods have been used to capture the users view of the project (see appendix E - User evaluation)

Pilots

As described above, the pilots experiences were measured every week during the project to have a direct response to changes and adjustments made in the system. The example earlier where the experienced quality of the prognosis increased when adjusting the slot-margins for the bridges is an example where we could measure an improvement in the system due to a change. The pilot’s general views on GOTRIS have followed an expected distributed curv throughout the project, where initially a few have been positive, a few have been neutral, and a major part has had a negative view of GOTRIS. Since all questionaires have been anonymous, we have not been able to follow if there have been a correlation in this throughout the project. Throughout the project the distribution have shifted towards a more positive attitude towards GOTRIS.

<table>
<thead>
<tr>
<th>Period</th>
<th>1-2 (Positive)</th>
<th>3 (neutral)</th>
<th>4-5 (Negative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb-March</td>
<td>10%</td>
<td>20%</td>
<td>70%</td>
</tr>
<tr>
<td>April-June</td>
<td>20%</td>
<td>24%</td>
<td>55%</td>
</tr>
<tr>
<td>July-August</td>
<td>40%</td>
<td>20%</td>
<td>40%</td>
</tr>
<tr>
<td>September</td>
<td>43%</td>
<td>29%</td>
<td>28%</td>
</tr>
</tbody>
</table>

Tab 3 Pilots view on GOTRIS

The summaries above show that the pilots in a higher extent think GOTRIS is beneficiary for the collaboration between actors than supporting them in their operation. However where the pilots view on support in their operations in general were increased along the project, the idea of collaboration slightly shifted the opposite as the project ended.
Theese views are supported by the final interviews with three of the pilots, where they initially experienced a low precision of confirmed passages, a low precision of estimated openings and a big uncertainy in general.

The final questionnaire shows also that 73% of the pilots have tried to arrive earlier to the bridge than the confirmed slot, indicating a low trust in the ability of GOTRIS to provide the optimal route. This is also related to the low degree of confirmation (86% of the pilots claimed never or very seldom) by Tåg-X. This correlates well with the actual confirmation rate of 31% for the southern stretch throughout the project.

The interviews points to several reasons for a low trust in the system, where low confirmation rate is one, but also factors as an extra tool to be used onboard in addition to other tools, “too tight onboard to work with GOTRIS” and also that passage were not allowed eventhough a slot was approved. Some mean that with less than 15 vessels per day on the river, there is no need for such a system.

Generally, the interviewed pilots were less positive to GOTRIS than what the final questionnaire showed.

For a future implementation the major improvements lacking is integrated user interface (with normal systems and tools), improved prognosis for northgoing vessels. A system only giving information, but where interaction is done via VHF is more preferred with the pilots. It is also suggested by some pilots that the pilot should do a booking whereas Tåg-X\(^6\) is to confirm this. This is contradicted by a general wish by the pilots to avoid interactions with the system during the voyage.

The most appreciated functionality in GOTRIS have been allocated time slot, train schedule for the bridge and weather information, whereas meeting prediction, timetable and speed advice were not seen to support the pilot.

From both the questionaires and the interviews it shows that the foremost advantage with a system like GOTRIS from the pilots point of view is the increased information transparency, the increased planning horizon and that the cooperation between the actors have improved.

**Train operators**

In the interviews with the train operators, they express that the fact that GOTRIS have been working in parallel with the existing procedures\(^7\) (VHF, telephone 30 minutes beforehand) have been seen as a hurdle for them, not giving them the benefit which GOTRIS could have given (less telephone calls). The system has thererfore just created additional work, but little gain. The foremost advantages have been the overview of the traffic and increased collaboration. They show a generally positive attitude towards the idea with GOTRIS, especially if it will bring environmental gain.

The lack of incentives, and that GOTRIS is conceived as an “extra system” on top of current routines, can be seen as a reason for the low degree of confirmation discussed earlier in this document.

**Bridge-operators and lock\(^8\)-management**

\(^6\) Train controle center is referred as Tåg-X.

\(^7\) This was a decision early in the project to keep existing routines, with VHF-contact 30 minutes prior to passing the bridge, to avoid potential incidents due to new routines. In a future implementation, it is seen likely that GOTRIS routines could be integrated in the existing routines, avoiding double routines.

\(^8\) During the demonstration, GOTRIS was not used specifically for lock-planning, eg no slot-allocation or confirming of slots. Lock-operators could though use GOTRIS for overview of the traffic.
Bridge-operator organisation is organized somewhat different in different stretches of the Göta Älv. For the bridges in the city of Gothenburg (Göta Älv bridge (road, tram, pedestrians), Marieholm bridge (rail, pedestrians)) it is personell from the City of Gothenburg who is operating the bridge, and for the rest of the bridges, it is controlled from the channel control center in Trollhättan (SMA) or other personell from SMA. Interviews have been conducted with personell from both organisations.

The foremost advantage identified was the oversight GOTRIS gave, giving a fair warning over approaching vessels. Today, this can be obtained by listening on the VHF when pilots call out different waypoints, but in the system this is given so that the operator at any time can see the status.

The interviews show that the operators have felt a lack of commitment from the train-operation side. Especially for the northern stretch where very few confirmations of passages have been made. They still identify a problem in the “negotiating” of getting access to a bridge, and that the identified slot, not always rendered a passage. There were expectations that GOTRIS would simplify this, but this was not realized due to low level of confirmation.

An important opinion revealed in the interviews is the importance of personalisation, whereas pilots tend to have a specific way of running the ships. The operators have a good overview over the different pilots “profile” (fast, slow, cautious etc), which GOTRIS were not aware of. Gotris could therefore have a more “learning” approach if personalized, which could give better estimates from the system.

The interviews also revealed some concerns that a traffic-management system, indirect competed with their profession.

Some areas of concerns identified was the need for them to manually enter information of pilot-schedule, the lack of possibility for implementing some of the improvement suggestions that arose during the project and also that GOTRIS were added to the normal routines, and did not replace the old routines (“we still had to call Tåg:X”).

Stakeholder experiences

Stakeholders here represents the regions, municipalities, administrations and also shipowners. Since these have different perspectives expectations on the project, the responses are more diverse than for other groups.

In general, the different stakeholder organisations have had high expectations of what could be achieved with GOTRIS. Several connected the project to the issue of the new bridge (described earlier), and also that there were a political aspect of this.

Several points out that GOTRIS is less critical when the traffic density on the river is as low as it is today, but the need for such a system will be evident when a much higher density will occur. Also the fact that GOTRIS is challenging some occupational roles, can be seen as problematic.

Almost all respondents emphasize the importance of transparency and sharing of information, and that the predictability for other means of transport (than its own) is the greatest benefit. They also identify the need for highlighting the organisational aspects and procedural work (agreements, responsibilities) which did not have enough emphasis in the project. Reviewing all interviews one

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9 It was not possible for SMA to digitally publicize this information to the project, so the ordering of pilots was needed to be manually entered throughout the project by the canal-operation center. In a implemented GOTRIS this would be automatically entered.

10 Three iterations of software improvements were conducted during the project, and only one after the actual trials have started, which made some of the suggestions have been left for future implementation.
could see that the concept was recognized and supported on a management level, but not anchored in the same way on an operational level in the participating organisations.

The stakeholders recognize the need for further development for such a platform, and emphasising integration in respective organisations systems (should not be a separate interface).

Environmental effects

The environmental effects of GOTRIS should be viewed from two perspectives. First, what effects has the current project shown? Second, what potential future effects could a full implementation of GOTRIS have?

Background

The direct environmental effects of GOTRIS are mainly related to the emissions from ships transiting the river Göta Ålv. These emissions emanate from fuel consumption, which in turn is related to several aspects such as ship speed, engine power and fuel consumption, loading, river flow, depth and width, etc.

Indirect impacts arise from changes in the transportation system such as increased or reduced transport by road, rail or ship due to changes incurred by GOTRIS. However, one of the goals of GOTRIS is to enable transit times for ships transiting the river to remain similar to the current ones but with better planning accuracy. This means that external effects such as an increased need for ships, changes in the mode of transportation or the need for ships to increase their speeds when outside of the GOTRIS area are not expected in a future implementation of GOTRIS. However, a case study addressing such external effects, should they appear, has been conducted and is presented in Appendix D – GOTRIS Environmental effects.

Methodology

The environmental study has addressed ship fuel consumption based on data collected during the GOTRIS project. The fuel consumption has been calculated based on ship speed from GOTRIS coupled with information about specific ship data such as design speed and fuel consumption or engine power.

The calculated ‘actual’ fuel consumption has been compared with the estimated fuel consumption, which would have been the case if the ships had followed the forecast given by GOTRIS.

A total of 24 random voyages conducted during the focus weeks have been analysed.

Results

The full environmental effects of the current project are difficult to assess. This is due to the fact that not all aspects of the system have been used to their full potential. As discussed in the section ‘Voyages and bookings’, the lack of validation of bridge openings has created a discrepancy between the ‘real world’ and the GOTRIS forecast.

However, it is possible to show a comparison between the calculated actual fuel consumption and the estimated fuel consumption should the ships have followed the GOTRIS forecast fully.
Fig 4 Fuel consumption

**Figure 4:** Actual vs estimated consumption. The actual consumption is 100% and the estimated consumption, should the forecast have been followed, is shown in the figure. The average consumption reductions are shown in the figure, with upper and lower bounds of uncertainty.

As seen in Figure 4, most trips would have consumed considerably less fuel, and hence resulted in reduced emissions, if the forecast had been followed fully. The higher emissions for trip 14 are due to the ship having travelled at a rather slow speed in relation to the GOTRIS forecast. Some trips, such as number 10, are very close to having the same estimated as actual fuel consumption. These are trips when the ships have followed the GOTRIS forecast very closely and, hence, the fuel consumptions are very similar. On average, it would be possible to reduce the fuel consumption by 12-20% by adhering to the GOTRIS forecast. The maximum fuel consumption reduction that could have been achieved for a specific ship, if adhering to the GOTRIS forecast, was 39%.

**Future implementation of GOTRIS**

The environmental effects of GOTRIS should be evaluated in light of the possibilities that a future full implementation of GOTRIS entails. The environmental analysis has shown that most of the analysed ships travelled through the river at somewhat higher speeds than prescribed by GOTRIS. This means that there is a speed difference between the optimal speed as forecast by GOTRIS and the actual speeds of the ships. If the speed indicated by GOTRIS had been adhered to, lower fuel consumption could have been achieved for most ships transiting the river Göta Älv.

**GOTRIS could lead to reduced emissions from ships**

Slightly lower speeds, as forecast by GOTRIS, will result in reduced fuel consumption due to lower speeds. Lower fuel consumption is directly related to lower emissions of carbon dioxide (CO₂) and sulphur oxides (SO₂). This means that lowered fuel consumption by a certain percentage can be translated into lower emissions of CO₂ and SO₂ by the same percentage. Nitrous oxides (NOₓ) and particulate matter (PM) are related to ship speeds, engine usage and other aspects. Hence, it is not as straightforward to address NOₓ and PM emissions, and there are no definitive results relating to NOₓ and PM emissions from this study.

**Environmental case studies**

A few example case studies will be available in Appendix D – Case study, showcasing the type of reductions that could be possible with a future implementation of GOTRIS.
Rebound effects, such as increased shipping due to a successful implementation of GOTRIS, could have a negative effect on emissions, but this must be put in relation to the increased road traffic without an increase in river transportation as a baseline option. This, in turn, can have negative effects such as more lorries, and wear and tear on roads as well as increased noise and other pollution from lorries. Effects such as these could be further studied through a future cost benefit analysis relating to the future scenarios for transportation in the Göta Älv area where all modes of transport are interrelated. This, however, lies outside of the scope of this study.

**Limitations**

Accurate emission reductions are difficult to calculate due to the complexity of the sources of emissions. The amount of emissions is related to the ship’s engine power, fuel consumption (which was estimated in some cases and based on available information in others), speed through the water (which is affected by steaming upstream or downstream, the river flow, which is affected by the time of the year, etc.), river depth and width, amount of carried goods, etc. These limitations all reduce the accuracy in the results obtained.

**Conclusions**

The environmental analysis has shown that most of the analysed ships would have consumed less fuel, and thus had lower emissions, if they had adhered fully to the GOTRIS forecast. A future implementation of GOTRIS in which the ships are able to act fully on the information given by GOTRIS will result in lower emissions of CO₂, and SO₂ and, most probably, NOₓ and PM within the GOTRIS area, compared with a future without GOTRIS. If the transit time through the GOTRIS area does not increase too much, then the lowered fuel consumption and emission reductions will not be offset by a need to increase the speed while at open sea and, hence, the reductions will be maintained throughout the voyage, with the river transit forming a smaller part of the total voyage.

From the interviews and the questionnaires we can see that nor pilots or the representatives from the shipowners believe that fuel and environmental impact can be much influenced by a traffic management system.

**Future outlook**

A future implementation of GOTRIS opens up the possibility of creating a full-scale environmental lab in which the whole GOTRIS area could be used as a lab for studying ship emissions on a large scale. Combining the current version of GOTRIS with additional data sources, such as more information on river flow, river depth and width, and ship-specific data, e.g. instantaneous engine power and fuel consumption coupled with emission monitoring of certain vessels that transit the river often, would create a full environmental lab. In this full-scale lab, triangulation of data from various sources could showcase the effects of GOTRIS on a large and automated scale.

**Co-modal adaptation between modes of transport**

As stated earlier, one of the key design ideas behind GOTRIS is the possibility of a specific mode of transport (or instance of) adapting its behaviour based on the information from the intentions of other modes of transport. For this reason, it is vital to include a discussion in this report on the extent to which we can see that GOTRIS has contributed to this or proved this thesis in the demonstration project.
Levels of regulation

In the project, we have worked on three levels at which GOTRIS can influence different modes of transport:

- Informing (e.g. ‘you will be meeting three vessels during your trip, and three trains are due to pass during these hours’)
- Coordinating (e.g. ‘You are advised to pass the bridge at 13:30 hours’)
- Regulating (e.g. ‘You have an allocated slot to pass Marieholmsbron bridge at 13:32-13:40’, use 6 knots to reach the bridge at the correct time)

In practice, we have tried all three levels during the project. For the train bridges we have tried the regulating model in which a slot has been allocated, approved by the train operator and then ‘enforced’ as the slot in which the ship must pass. Instructions to the train operators have been that once a slot is allocated to a ship, any corrections in the train timetable have to take into account that this slot is dedicated to a ship (delays, early trains, etc.). A ship that keeps its passing time has precedence over the trains.

For the locks and road bridges, GOTRIS has been working in a coordinating role, proposing a passage slot and informing of the optimal speed to reach there in time, but no confirmations or agreements on that time slot are made between the actors.

For the other actors involved, GOTRIS works at the informing level, showing the best, at the known point, information on what is to be expected on the river that day: which ships plan to pass a certain obstacle but no guaranteeing that this will be the case.

Prewarning times for future bridge openings

The background description earlier in this document mentions the conflict of interests between shipping on the river and the city of Gothenburg when it comes to the Göta Älvbron bridge crossing the river in the city of Gothenburg. This bridge carries cars, buses, trams, cyclists and pedestrians. It would not have been possible to implement a ‘slot allocation’ based on tram or bus timetables, and the flow of other traffic is more or less constant. Instead, the information is used to warn these modes of transport and to minimise the negative effects of bridge openings.

By informing other actors about a bridge opening in good time, public transport, cyclists and pedestrians can adapt their travel plans accordingly. A car driver can choose an alternative route if he/she knows with certainty at what time the bridge will be opened. A certain scheduled bus route can be deviated or shortened for a particular tour if the information is given in fairly good time.

We have had a hypothesis in the project that such a prewarning time should be at least one hour, and possibly longer, to allow any mode of transport to adjust to an upcoming opening. The question we then tried to answer is how far in advance a slot/passing can be allocated with the certainty that the passing will actually be at that point in time. We have called this prewarning time. In GOTRIS, we have been able to configure the prewarning time for each obstacle (bridge or lock). We have also seen the need to have different prewarning times for north- and southbound traffic on the river. In the demonstration project, however, we only tried a prewarning time of 60 minutes.

To be able to facilitate a prewarning time for other transport modes, it will be necessary to use the regulating level of GOTRIS (allocation of slots and no or little deviation from the allocated times). In the demonstration phase of the project, we became aware of the built-in adversaries to the regulated mode (supported by material in interviews, polls, etc.). This means that the ship and the train operators cannot take advantage of the possible flexibility given in the train system when unplanned slots arise in the last 60 minutes before reaching the bridge. To maintain predictability for
other actors, no flexibility in passing the bridge can be permitted. This would mean that even if the train operator could let the ship pass in an earliest slot, in a regulated mode of GOTRIS, this should not be allowed, thus jeopardising predictability. We have seen in the statistical material that the ships passed earlier than the GOTRIS forecast stipulated by on average 6 minutes during the project. This should indicate that the ‘cost’ of having being notified 1 hour in advance for Marieholmsbron bridge (and Göta Älvbron bridge) would prolong the voyage by on average 7-12 minutes\(^\text{11}\). For a 2 hour prewarning, this would equate to 8-13 minutes.

**Prioritization between traffic modes**

One of the agreements in the demonstration-period was that a confirmed passage of a vessel (confirmed slot) should be regarded by Tåg-x as a "train running according to schedule”. This would mean that if a crossing train was NOT according to schedule, this had to wait for the passing of the vessel. This type of priority is standard operation when prioritizing trains today, and by seeing the confirmed slot as a booked “trainslot”, there would not be a problem in approving this beforehand.

However, interviews with train-operators show that this way of order, has not been used during the project, and it has been seen almost impossible to approve slots earlier because changes to the train-schedule can occur close to approach.

During the project, this was an agreed way of working, but in a future implementation, such a prioritization needs to be a firm agreement.

For the pilots, the notion of being prioritized, when keeping time-schedule, has been seen as very positive incentive for running GOTRIS.

**Conclusions on co-modal adaptation**

We have shown in the project that there is a conflict between predictability and flexibility. To be able to reach some level of predictability (inform other transport modes in advance), we have to accept a lower degree of flexibility (not allow deviations from earlier approved slots).

The effect (cost) of such predictability can be quantified. We can also conclude that a future implementation of GOTRIS should consider in which areas of the river the regulatory level needs to be used and where the coordinating level should be used. User behaviour during the preliminary study, and data drawn from the polls and interviews show that the regulatory level is conceived as an intrusion into the role the operators have been assigned. A low level of ‘confirmations’ from the train operators, a low adherence to proposed arrival times for pilots and a high ratio of vessels passing before their confirmed slots should rather be seen as high adherence to what is perceived (was perceived prior to the project) to be their task: to expedite the voyage on the river in the fastest way in a safe manner. In a future implementation of GOTRIS, with sections at the regulatory level, this must then be supported and enforced with agreements and incentives and a more dynamic description of the task for the involved actors (pilots and train operators).

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\(^\text{11}\) This is a simplification since the material includes ships that did not reach the slot in time (passed later than the forecast) and should not contribute to the average. With a StDev of 19 minutes and average passing time of -7 minutes, it could be assumed that the average delay could add up to (19-7) 12 minutes with a one hour prewarning.
Organisational development and agreements

Current organisation and rules for bridge openings along the river Göta Älv

The river Göta Älv is crossed by 12 bridges between the mouth of the river in Gothenburg and Lake Vänern. Nine of these have less than 27 metres of clearance and can be opened. The first bridge downstream is Göta Ålvbron bridge, which is operated by the city of Gothenburg. The bridge master is in close contact with the railway bridge by Marieholm and the openings are coordinated. Marieholmsbron bridge is operated by the Swedish Transport Administration’s traffic control centre for train services in Gothenburg. The traffic control centre tries to avoid bridge openings during rush-hour traffic for public transport when commuter travel is at its most intensive. The bridge openings between Jordfallsbron bridge by Kungälv and Vänersborg are managed remotely by the Swedish Maritime Administration’s channel centre in Trollhättan.

Bridge openings are performed via radio/telecommunication contact between the commander/pilot and the bridge master approx. 30 minutes before the vessel arrives. This procedure has worked satisfactorily for many years, but it makes little allowance for all modes of transport and none to allow affected road users to plan for the delay.

As the number of bridge openings and the volume of crossing traffic are expected to increase, at the same time, this procedure will be inadequate. More allowances and information will be needed for the different modes of transport to interact as smoothly as possible.

National interests

The railway traffic crossing the river Göta Älv is of national interest, as is the merchant shipping on Göta Älv. The goods traffic on the railway to and from the Port of Gothenburg is particularly important as it affects several railway routes in Sweden, and disruptions can have major consequences for other traffic. STA has formulated proposals for defining the national interests. For the national interest Vänern shipping, the Traffic Administration Region Väst has formulated the following proposed definition. The definition is based on the statistics of vessel passages registered for Göta Ålvbron bridge and Marieholmsbron bridge for 2010 (source: Trafikkontoret Gothenburgs Stad). In 2010, the number of merchant vessels averaged about 5 per 24 hours and at most 13 in 24 hours. The goods volume is just under 2 million tons per year to Lake Vänern ports. The volume was double that a few decades ago. This is primarily due to the amounts of paper and oil products that have chosen the railway or lorries over shipping. The market in the Vänern region is limited, and it is the Transport Administration’s view that even if shipping can take greater market shares in the future it can only double, or maybe a bit more, in terms of volumes. The number of vessels may therefore double, but probably not much more, in the future. At the same time, the lock system in Trollhätte Canal also limits capacity. The Transport Administration’s view is therefore that the national interest of shipping on Lake Vänern can be met if at least one bridge opening per hour is possible, except during the hours of 6:00-9:00 and 15:00-18:00 on normal working days. The exceptions have been requested by the city of Gothenburg and Västrafik and also by the rail services over Marieholmsbron bridge.

The Swedish Transport Administration’s proposals for future rules for collaboration and control

The parties responsible for traffic along and over the river Göta Älv agree that the management and control of traffic on and over the river must be upgraded with modern systems. Clear rules on how and when bridges are opened must be formulated and agreed on. The Transport Administration’s
proposed interpretation of the national interest of shipping on Lake Vänern forms the basis of an agreement.

By identifying an approaching vessel in good time, a ‘timetable’ can be created for the river passage. The vessel will be given directions on the right speed between bridges and locks as well as times of bridge openings to improve its planning – a ‘green wave’. In a system with traffic management, the average speed will probably be lowered for vessels, which can lead to reduced bunker consumption and thereby also a potential environmental gain. The vessel can save fuel by keeping an even speed, which also benefits the environment. Information on planned bridge openings can be given to other modes of transport and road users.

The allocation of train times over Marielohmsbron bridge, which will soon be a double bridge, must allow for compliance with the agreement of at least one passage every hour. The times that approaching vessels request are locked. Other free slots can be used for trains that are put in at short notice or to make up for delays.

By identifying a bridge opening in good time, information can be directed to other road users via different information services. Public transport can inform its road users, facilitating vehicle planning. Some trips can then be cancelled instead of having to wait.

The Swedish Transport Administration’s proposals for continued work and organisation

The continued work should include an agreement on rules for bridge opening procedures and factors that can allow for deviations from it, for example safety issues. There are currently three organisations that manage bridge openings. There should be discussion on improving cooperation.

The introduction of a traffic management system, for example GOTRIS, means that agreement ought to be reached as soon as possible on financing the development, implementation and operation. The parties to the agreement ought to be the STA, the SMA and the city of Gothenburg, all of which currently have organisations to operate bridge openings. The agreement should include a timetable for its introduction.

The ruling by the Land and Environment Court on permission for a new bridge over the river Göta Älv has been appealed against to the Land and Environment High Court. SMA’s view is that further work on such an agreement should be started as soon as there is a legally binding final ruling.

Desired system improvements for future implementation phases

GOTRIS architecture and platform

Even though the core of GOTRIS has been developed to be scaled up for an implementation phase, there are several areas in which the demonstration project has not developed the platform for a 24/7 implementation.

In Section 2 of this report, A technical view of GOTRIS, we argue for further enhancements of GOTRIS in a number of areas:

- End-to-end exception handling (to build in rules and procedures of how the system should react when faults occur on the different parts of the platform)
- Concentrated sourcing of the different internal GOTRIS modules (which have been sourced from different organisations during the demonstration project)
- User interfaces developed should be further developed and integrated in the different enterprise systems of the user groups (pilot tablet should be part of the SMA system portfolio, using services from GOTRIS, etc.)
- Fully integrated information services with the SMA pilot planning system
- Integration to a commercially available ship database
Further development of the train data imported into GOTRIS
Possible adaption of the MONALISA route planning services as a development of the one-dimensional GOTRIS model
Commercial sourcing of the GOTRIS platform with service level agreements (SLAs) for all integrations with external information sources
SLA (service level agreements) on information entered into SSNS about upcoming approaches
Revised logic in the confirmation-process should be considered, where VHF-request of a confirmation 1 (or what is appropriate for the obstacle at hand) hour in advance, could be confirmed by Tåg-X, in GOTRIS. This small change would cohere more with current procedures, but would still require an interaction from Tåg-X with GOTRIS.

Göta Ålv infrastructure
There are three main areas with regard to infrastructure improvements for the river Göta Ålv from a GOTRIS viewpoint.

Communication coverage
Standard land-based mobile communication is very much a possible communication infrastructure for GOTRIS. The coverage analysis performed early in the project (see Appendix F - Coverage Analysis Göta Ålv) showed that without any improvements, there was 4G coverage along the river, except a few short but vital distances. In the lock area of Trollhättan, communications often dropped, which caused some problems, as the vessel stays still for some time. Dialogue with commercial mobile net providers is recommended. An alternative would be to complement 4G coverage with dedicated WLAN solutions and automated roaming between 4G and WLAN.

Increased number of sensors
There are sections along the river that would benefit from additional visibility and water flow sensors. Visibility sensors could then be used to estimate expected deviations due to low visibility, something that GOTRIS has not taken into account in the GDPS. An automation of air draft measurements could be implemented at the entrance to and exit from the river, which would eliminate the need for pilots to enter this information in the system.

VMS signs
VMS (Variable message) signs adjacent to the bridges could communicate planned opening times for bridges or locks to leisure crafts. It could also be used to communicate different states of the openings to waiting vessels.

Organisation and collaboration
One of the biggest challenges in the project has been to achieve a high ‘confirmation rate’ for the bookings of passages. In the logic in which GOTRIS proposes a passage under a bridge and the system indicates to the train operator that this passage has been requested by the vessel, the train operator is supposed to confirm the suggested passage or another more suitable passage, but this has not worked smoothly during the project.

We currently have two separate organisations (SMA and STA) each with the objective to ensure that the traffic in its domain is optimised.
When one organisation is asked to perform tasks so that another mode of transport is optimised (which is possible from a longer perspective and will give the organisation’s own mode of transport advantages), there is a lack of incentive to participate in the synchronisation. 

The co-location of the different roles of traffic management of the river has not been addressed in the project but should be included in the considerations before an implementation.

Implementation strategy and challenges

Inter-organisational collaboration

As described earlier in this document, one of the greater challenges in the project has been to ensure the adherence to the procedures of slot-confirmation. The regulative level of GOTRIS described under section Co-modal adaptation between modes of transport, only works when there is a trust from both parties, that the other adhere to the rules-of-play. However, interviews shows that there is (in the use of GOTRIS) a lack of trust from the pilots side that they will be awarded a slot in time, and that the vessel in that situation will be prioritized befor late coming trains. There is equally distrust from the trainoperator that the pilot will adhere to the allocated slot, and not push faster through the system. This lack of trust motivates the low adherence which itself further re-enforces the reasons for that distrust. One should also note that these both groups also believe that todays manual routines (before GOTRIS) works reasonable well, but based on a future increase in river-traffic, that’s when the need of traffic-management really is needed. When implementing a future GOTRIS, it is nessecary to further strenghen the incentives for these users to participate by invoking this into standars operating procedures, and not as during the project, more or less voluntary extra procedures besides ordinary work. Much time should be spent on inter-organsialiational contacts, giving the user-groups better understanding of each others working conditions.

Sourcing strategies for host organisation

The set-up of the GOTRIS demonstration platform included a number of challenges to which we had to find ‘project-specific solutions’. This means compromises that should be avoided in a real set-up.

One of the criteria during the project was to have an agile and iterative approach to the development of the GOTRIS platform. We needed to have the option of performing incremental updates in the different subsystems of GOTRIS provided by different organisations in the project (GOTRIS hub STA, Calculation module SSPA, FrontEnd and Voyage module InPort, etc.).

On the other hand, the project needed a solid environment for sourcing the GOTRIS hub, which should be as near real conditions as possible. The solution in the project was that the different project partners sourced different parts of the platform: the parts they developed themselves. This gave us a chance to test the distributed and decoupled principles we had set up for GOTRIS in a very evident way. The millions of messages shuffled around between the different modules of GOTRIS were communicateed between different organisations and sourcing platforms and, not least, different locations.

This enabled a stress test on these very principles, highlighting some vital aspects:

- Fault tolerance between the modules (How should front-end functionality react when no forecasts are coming from the hub? How should the Forecast module act when no destination port is found in the voyage etc.)
- The need for dynamic filtering of data (import modules such as AIS, forecast, train data, etc.) must be adaptable to the need for information richness, e.g. the ship produces AIS messages 2-5 times per second. If the Forecast module runs forecast generation every 15 seconds, the AIS imports can be limited/filtered.
In a full deployment of a GOTRIS system, finding one sourcing environment for the main subsystems of GOTRIS should be considered, even though, from a design perspective, functionality is kept separated in subsystems.

**GOTRIS in relation to IWW and RIS**

Eventhough GOTRIS was not developed to fulfill the specification of a RIS (River Information Services) according to EU definition, the platform builds on the same assumptions and context. The prescribed services in a RIS is partly fulfilled, and can easily be complemented. In the process of implementing IWW into Swedish legislation, this work does not currently contain any intentions of implementing RIS in Sweden. However, the continued work in this implementation will include the RIS issue further on. In an IWW context one should regard GOTRIS and the functionality described in this report, as buildingblocks in creating a RIS. If a Swedish RIS should be of national character or regional, have not been discussed in this project, but with only two areas which would come into play for Swedish inland waterways, the synergy effects are obvious. One should therefore consider the option of taking a national perspective when discussing a future implementation of such a platform.

**The way forward**

The ambition and hope within the project was that the prerequisites for future inland waterways on the Göta Älv River were to be decided and clear. The decision of renovating the locks of Trollhättan, the design and height of the new bridge in Gothenburg – both important decisions for knowing if the predictions of increased river-traffic would be reasonable. We know that with today's traffic and situation, a GOTRIS-platform would increase the information transparency, but from a traffic management point of view, there is little need for the regulative part of GOTRIS described earlier in this report. The real need would be when river-traffic increases and interruptions occur due to infrastructure-projects concerning the river.

Since those decisions are not at hand, the timing for further investments in a RIS-platform for Göta Älv River, is not the best. The steering committee representing all project partners, have tried to find different solutions to keep GOTRIS running, awaiting those decisions, but all options have incurred costs that cannot be motivated before the future of inland shipping on Göta Älv is secured.

The GOTRIS platform will be closed down at year-end 2014, documented and packaged as far as possible. Since the project formally ends at this time, the project organisation and the steering committee is also dismantled. The ambition is though to for form a new group to take the concept and ideas of future traffic management for the river further towards implementation.

**Future implementation of a traffic management system for the river Göta Älv**

Even though there is uncertainty regarding the future renovation of the locks in Trollhättan, there is a strong conviction among the actors that there is a need for some type of traffic management system to handle the different interest and needs of the modes of transport affected by the river. Whether this is GOTRIS with further development or another system, there are many years of experience of developing collaborative platforms for inland waterways in this project. The intellectual properties of the actual artefacts developed in this project lie with the different project partners of GOTRIS as described in the consortium agreement used.

Already in 2015, the work continues in the continued "Stråkstudie Göta Älv" with a separate workinggroup investigating organisation, financing and responsibilities for the implementation and maintenance of a future RIS for Göta Älv river.

Two major infrastructure projects are already in progress with the replacement bridge for Göta Älvbron and the second railway bridge of Marieholm, which will further increase the need for traffic management tools for the river.
Dissemination and communication

During the project, we made presentations at several conferences for organisations and municipalities around the river Göta Älv and Lake Vänern.

Presentations and conferences

27 September 2012, Mathias Karlsson from Viktoria Swedish ICT made a presentation of GOTRIS to the interest group Vänersamarbetet in the city of Vänersborg.

23 November 2012, Per-Erik Holmberg from Viktoria Swedish ICT made a presentation of GOTRIS to the Swedish Shipowners’ Association, which is an interest group representing Swedish shipowners in Gothenburg.

28 May 2013, Per-Erik Holmberg from Viktoria Swedish ICT made a presentation of GOTRIS at the Swedish Transport Administration’s ITS and logistics seminar.

1 October 2013, Per-Erik Holmberg from Viktoria Swedish ICT made a presentation of GOTRIS at the Swedish Transport Administration’s GEO, Digitalization for better use of the infrastructure.

13 November 2013, Peter Grundevik from SSPA presented GOTRIS as one of its key projects at Conference Vessel, Human and Environment at the Kalmar Maritime Academy in Kalmar.

4 December 2013, Almir Zerem from the Swedish Transport Administration made a presentation of the GOTRIS pilot during a business architecture breakfast meeting, Dataföreningen Kompetens in Malmö.

1 September 2014, Per-Erik Holmberg and Mathias Karlsson made a presentation of GOTRIS to Jukka Savo who is the policy officer for the European Commission, Directorate General for Mobility and Transport, Maritime Transport & Logistics when he visited the Swedish Maritime Administration in Gothenburg.

9 September 2014, Mathias Karlsson from Viktoria Swedish ICT made a presentation of the article ‘Co-modal adaption between modes of transport River Information Services for river Göta Älv’ at the conference ITS World Congress in Detroit.

10 September 2014, Mikael Lind from Viktoria Swedish ICT made a presentation of the article ‘Punctuality as performance metrics for efficient transportation systems’ at the conference ITS World Congress in Detroit.

Articles and publications

Published and planned articles in scientific, industrial or other publications

Successes and spin-offs

InPort

For InPort’s part, there have been many positive spin-offs. The company has cooperated with several partners that our customers collaborate with today. This gives us all a better understanding of the various stakeholders in this industry. The proximity to SMA has given InPort very good channels into the correct competence and the knowledge that our collaboration has been strengthened, which has pleased our customers that are port authorities. As a project manager, Viktoria Swedish ICT has handled this project with verve and constantly made sure that the mood and motivation are kept high. This has led to InPort contributing, unfunded, more hours than it has received coverage for thanks to a well-run project with an interesting future. The project has opened up channels to all the partners, which InPort is very pleased about. Since we are linked to authorities across the north, we can take this experience with us across borders, which brings benefits for this business. Our goal has been to show that InPort is a good player in this business, and we feel that this has strengthened InPort as a company and that the project has created great opportunities for our future development.

It is hoped that InPort will to find further collaboration with like-minded projects. We have today received an offer to be involved in another project, MONALISA PORTCMD. We believe this will also create new opportunities for us. InPort has much and broad expertise in Port & Terminal and this kind of collaboration will help us to market our expertise in Sweden and abroad. InPort has recently won a contract with the Port of Gothenburg. We believe that this type of project and the demonstrated results are factors that make us a leader in Port & Terminal in Scandinavia. New collaboration has already been established by the SMA with the EU Directive Single Window. This was done without collaboration with GOTRIS, but thanks GOTRIS we are already familiar with SMA

Knowledge transfer: information hubs for traffic management

The application of research ideas such as the information hub for co-modal integration has been proven to generate useful experience and models for future work in the traffic management area. Viktoria Swedish ICT has used the GOTRIS project as an example in its assignment to finalise the Swedish roadmap for traffic management (Färdplan trafiksälgsövergripande trafikledning, Forum för innovation i transportsektorn, 2014). The idea of information hubs is also used as a model in the development of the Sea Traffic Management concept in the European Union (MONALISA 2, TEN-T).

Research on predictability measurements in co-modal transport chains

GOTRIS has generated useful data for verifying research topics concerning predictability in co-modal transport chains. The data generated will become useful in describing some of the effects sometimes called the funnel effect.

Further research on RIS and inland waterways

The GOTRIS project has initiated several possibilities to further research and development within the area of RIS and inland waterways. In the interreg project EMMA, coordinated by Hamburg Hafen AG, Viktoria Swedish ICT participates with background from the GOTRIS-project in order to further strengthen IWW as a efficient transport mode. The project has also gained interest from the European Comission, encoarageing to furthere development within the European Union.
**Introduction to GOTRIS project report – Part two**

The document contains a second part that describes the technical view of GOTRIS. This description is openly available and can serve as a blueprint for future development of collaborative federated management platforms.

**Project partners and organisation**

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Role in the project</th>
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<tbody>
<tr>
<td>Industry actors</td>
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<tr>
<td>Ahlmarks Line</td>
<td>Ahlmarks Line AB is a transport company with regular services and contract trading between Lake Vänern/the Norrland coast and Great Britain, Germany, the Netherlands and France. The fleet transports approx. 1.3 million tons of goods annually.</td>
<td>Takes part in setting the requirements and in field trials (vessels, staff)</td>
</tr>
<tr>
<td>Thunbolaget</td>
<td>Thunbolaget Erik Thun AB operates 34 vessels most of which are wholly/partly owned. The business areas are conventional dry-cargo vessels, self-discharging vessels, product tankers and some charter.</td>
<td>Takes part in setting the requirements and in field trials (vessels, staff)</td>
</tr>
<tr>
<td>Port of Gothenburg</td>
<td>The Port of Gothenburg is the leading port in Scandinavia, with extensive container handling.</td>
<td>Takes part in setting the requirements and contributes reference knowledge</td>
</tr>
<tr>
<td>Authorities and infrastructure managers, Financers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>Region Värmland is responsible</td>
<td>Contributes reference knowledge,</td>
</tr>
<tr>
<td>Organization</td>
<td>Description</td>
<td>Role</td>
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<tr>
<td>City of Gothenburg</td>
<td>The city of Gothenburg has a turnover of 34 billion SEK and 48,600 staff. It consists of city district administrations, about 20 labour administrations and about 25 companies.</td>
<td>Represents public transport, pedestrian and road traffic and city planning perspectives in the project. Contributes API. Financer.</td>
</tr>
<tr>
<td>Swedish Maritime Administration</td>
<td>The Swedish Maritime Administration is a service-producing public enterprise whose main task is to promote good conditions for shipping in Sweden and for Swedish shipping.</td>
<td>The Swedish Maritime Administration contributes pilotage and channel knowledge and the pilots as primary users in the pilot trials in the project. The Channel Office will also receive information from GOTRIS.</td>
</tr>
<tr>
<td>Swedish Transport Administration</td>
<td>The Swedish Transport Administration is responsible for the long-term planning of the transport system for road traffic, rail services, shipping and air traffic. It is responsible for building, running and maintaining national roads and railways.</td>
<td>In the project, the Swedish Transport Administration represents the authority perspective in GOTRIS. It is seen as a plausible neutral administrator of infrastructure and regulations. It also represents rail infrastructure and the operators that use the train network. It contributes an API for train information and road information. Financer.</td>
</tr>
<tr>
<td>Municipality of Karlstad, Municipality of Kristinehamn</td>
<td>Municipalities in Region Vänern with important shipping interests</td>
<td>Contribute reference knowledge and contacts with train operators in the Lake Vänern area, Financers</td>
</tr>
<tr>
<td>Region Västra Götaland</td>
<td>Region Västra Götaland acts as a county council and shall promote growth and sustainable development.</td>
<td>Contribute reference knowledge, Financer</td>
</tr>
<tr>
<td>Vinnova</td>
<td>Swedish Innovation Agency</td>
<td>Main financial contributor</td>
</tr>
<tr>
<td>Service developers</td>
<td>InPort, Intelligent Port Systems AB, develops and sells IT systems for port, terminal and train operations.</td>
<td>InPort contributes knowledge on information requirements to the transport chain for ports, shipowners and other actors. It also contributes systems and products needed for the project. In the project, InPort is responsible for the development of, among other things, the on-board interface.</td>
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<tr>
<td><strong>InPort</strong></td>
<td>The Swedish Transport Administration ICT is a company that is wholly owned by the Swedish Transport Administration. It delivers network capacity and everything from complete solutions to simple services for intelligent transport systems, offices, networks and operation.</td>
<td>Contributes to the project with IT infrastructure and a base platform (hardware, software) to run GOTRIS. Contributes expertise on SOA and IT architecture. Develops the GOTRIS service platform in the project.</td>
</tr>
<tr>
<td><strong>Swedish Transport Administration ICT</strong></td>
<td>Chalmers University of Technology is one of two university foundations in Sweden. Chalmers offers education of ship’s officers.</td>
<td>Contributes to the project with simulation and visualisation tools. It is responsible for field trials, evaluation and verifications in the project.</td>
</tr>
<tr>
<td><strong>Chalmers, Shipping and Marine Technology/Lighthouse</strong></td>
<td>SSPA Sweden AB is owned by Chalmers University of Technology Foundation and operates in vessel design, energy efficiency, seaworthiness, decision support systems, risk and environmental analysis, and logistics and infrastructure.</td>
<td>In the project, SSPA contributes the model and simulation knowledge and API for vessel positions (AIS). Develops forecasting methods and models for these.</td>
</tr>
<tr>
<td><strong>SSPA</strong></td>
<td>Viktoria Swedish ICT is part of Swedish ICT and is a research institute focusing on vehicle and transport ICT.</td>
<td>Contributes knowledge on ITS solutions and transport ITS. In the project, it is responsible for project management and technical issues.</td>
</tr>
<tr>
<td><strong>Viktoria Swedish ICT</strong></td>
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Appendix

- Appendix A – Gotris Tablet services.
- Appendix B – GOTRIS use case specifications
- Appendix C – Marine Traffic Analysis tool.
- Appendix D – GOTRIS environmental effects.
- Appendix E – User experience report
- Appendix F - Coverage Analysis Göta Älv

The GOTRIS animation: https://www.youtube.com/watch?v=JyjVIEKQAY