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Project 6.3.4, Task 27

COMFORTABLE

(COMFORT - Advanced Benefits for Logical VTS Equipment)

Final Report

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Technical Abstract

COMFORTABLE investigated tools to improve and enrich the Vessel Traffic Management Services (VTMS) traffic image. This involved a multi-facetted approach, looking at:

- long-term and medium-term prediction tools for resource planning and traffic management;
- short-term prediction tools for navigational assistance, using AIS transponders and/or algorithms using situation-dependent criteria and values;
- the advantages and present drawbacks of ECDIS as a standard electronic chart for use in VTS traffic situation displays;
- the detailed analysis of data elements, objects and object relations in a generic VTMS system in order to facilitate links between systems;
- the involvement of the end-user (VTS operator) in the design and testing of new tools. This was achieved on the one hand by creating a user forum comprising industrial suppliers, R&D specialists and VTS operators. At the same time a situation awareness test involving simulation was developed, tested and implemented. This enabled VTS operators to take part in the development and analysis of new tools.

Recommendations are made for further studies that build on our findings.

Keywords:

Waterborne transport, VTS,

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List of Abbreviations

AIS	Automatic Identification System transponder
ARPA	Automatic Radar Plotting Aid [IMO]
ATA	Actual Time of Arrival
ATC	Air Traffic Control
ATD	Actual Time of Departure
CAM	Collision Avoidance Manoeuvre
CPA	Closest point of approach
DCPA	Distance to Closest point of approach
DF	Radio Direction Finder
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
DSC Transponder	A radio transponder making use of Digital Selective Calling, which may be a part of shipborne GMDSS equipment
ECDIS	Electronic Chart Display Information System
EDI	Electronic Data Interchange
ENC	Electronic Navigation Chart
ETA	Estimated time of arrival (see also RTA)
ETD	Estimated time of departure (see also RTD)
ETP	Estimated time of Passage
EUROREP	European Vessel Reporting System
GIS	Geographic Information System
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HMI	Human Machine Interface
IMO	International Maritime Organisation
INDRIS	Inland Navigation Demonstrator of River Information Services
ITU	International Telecommunication Union
LAN	Local Area Network
MARPOL	International Convention for the Prevention of Pollution from Vessels
OFS	Official Shipping Number
RIS	River Information Services
RTA	Requested Time of Arrival, issued by the Agent or Vessel before confirmation by the VTS
RTD	Requested Time of Departure, issued by the Agent or Vessel before confirmation from the VTS

SAR	Search and Rescue [SAR Convention]
SOLAS	Safety of Life at Sea (Convention, IMO)
TCPA	Time to closest point of approach
TSD	Traffic Situation Display
TSS	Traffic Separation Scheme
TTI	Tactical Traffic Image
UHF	Ultra High Frequency (300 - 3,000 MHz)
VHF	Very High Frequency
VTMIS	Vessel Traffic Management and Information System
VTMS	Vessel Traffic Management System / Service
VTS	Vessel Traffic Services
VTS Operator	Appropriately qualified person performing one or more tasks contributing to the services of a VTS [IMO 857(20)]
WP	Work Package

1. Introduction to the Project

Title: **COMFORT** – **A**dvanced **B**enefits for **L**ogical VTS **E**quipment

Acronym: **COMFORTABLE**

The COMFORTABLE Project has been carried out within the framework of the Waterborne Transport Programme of the European Commission's Directorate for Transport (DG VII). The broad aim of the project was to develop and evaluate enhanced tools to be used by operators of maritime Vessel Traffic Services (VTS) for the recognition and assessment of traffic situations.

1.1 Background

Vessel Traffic Services and the management of shipping traffic generated considerable research activity in Europe in the 1980's and early 90's. Building on this research, advanced technologies provide scope for new kinds of enhancement in the range of tools available to the VTS operator, with potential for increased safety and efficiency in traffic management. It is important, though, that applications using these new technologies are adapted to genuine requirements. COMFORTABLE has opened a forum for dialogue between end-users (VTS operators), researchers and suppliers in the context of prototyping new tools.

1.2 Objectives

The main objective of COMFORTABLE was to develop new tools for VTS use to help operators recognise and assess traffic situations, including the evaluation of risk. Special attention was to be paid to human factors issues when integrating these enhancements into the VTS operator's Traffic Situation Display (TSD). The goal was to provide operators with better tools without increasing workload.

1.3 Organisation of the project

1.3.1 Rationale

1.3.1.1 Technology-led initiatives

The overall approach adopted in COMFORTABLE may be described as 'technology-driven'. In other words, research institutes and industry members of the Comfort consortium developed prototype enhancements that applied new opportunities recently made available by technological advances.

Examples of these enhancements include:

- Preliminary specifications for a "VTS-ECDIS"[1] (Work Package 04)
- Integration of dynamic data from ship-borne transponders to provide VTS operators with information on grounding risks in fairways in shallow waters (Work Package 07).
- Use of the processing capacity of contemporary computers to make predictions about future traffic states and risks (Work Packages 02, 03, 05, 06, 07, 08), as well as to monitor multi-criterion changes in traffic behaviour over time (Work Package 01).
- Specification of data flows within a VTS to enable data sharing over local and regional networks (Work Package 09).

1.3.1.2 End-user-involvement

Although the VTS enhancements were technology-led, COMFORTABLE built in the involvement of end-users (VTS operators and managers) in two main ways:

⇒ Work Package 02 served as a platform to develop a 'situation awareness' test, later baptised *SATest*, to evaluate the effects of the Traffic Situation Display enhancements that were developed in conjunction with WPs 05, 06 and 07.

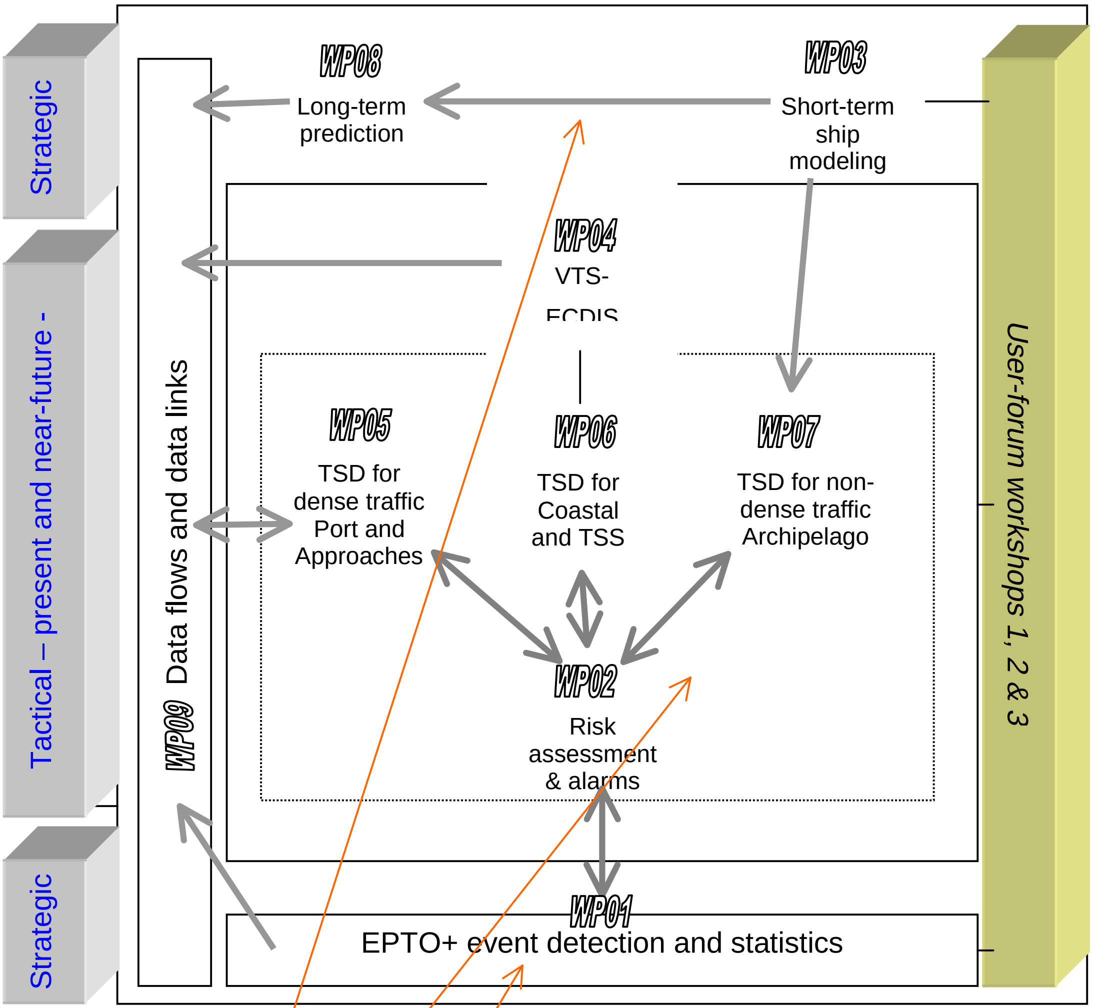
⇒ Early in the project a user-forum was set-up, comprising VTS operators from Finland, France, Germany, United Kingdom, Italy

[1] ECDIS – Electronic Chart Display and Information System. ECDIS was developed to replace paper navigation charts on board ship.

and the Netherlands. This forum met in three workshops held in Rotterdam and Lisbon, respectively. During these workshops, COMFORTABLE Work Package representatives presented their proposed enhancements. Operators and COMFORTABLE members then formed small working-groups, presenting comments for discussion in plenary sessions. This is the first example of such an international user forum of VTS operators. A full set of Workshop reports is available and has been submitted to the EC as a deliverable.

1.3.2 Organisation of Work Packages

Figure 1: Relationships of work packages in COMFORTABLE



WPs 02, 04, 05, 06, 07 all dealt with traffic situation displays. It was decided to combine these work packages as much as possible. There was considerable synergy between WPs 02, 05, 06 and 07, in particular, which dealt with risk assessment tools. Meanwhile, WPs 03, 08 and 01 dealt with the computation of traffic characteristics with particular relevance to advanced planning, while WP09 extended across all other WPs, by describing the total data flow in a generic VTS.

1.3.3 Partners involved in Work Packages

The following organisations were involved in the research conducted in the corresponding work package. Each work package was led by the organisation indicated in bold typeface.

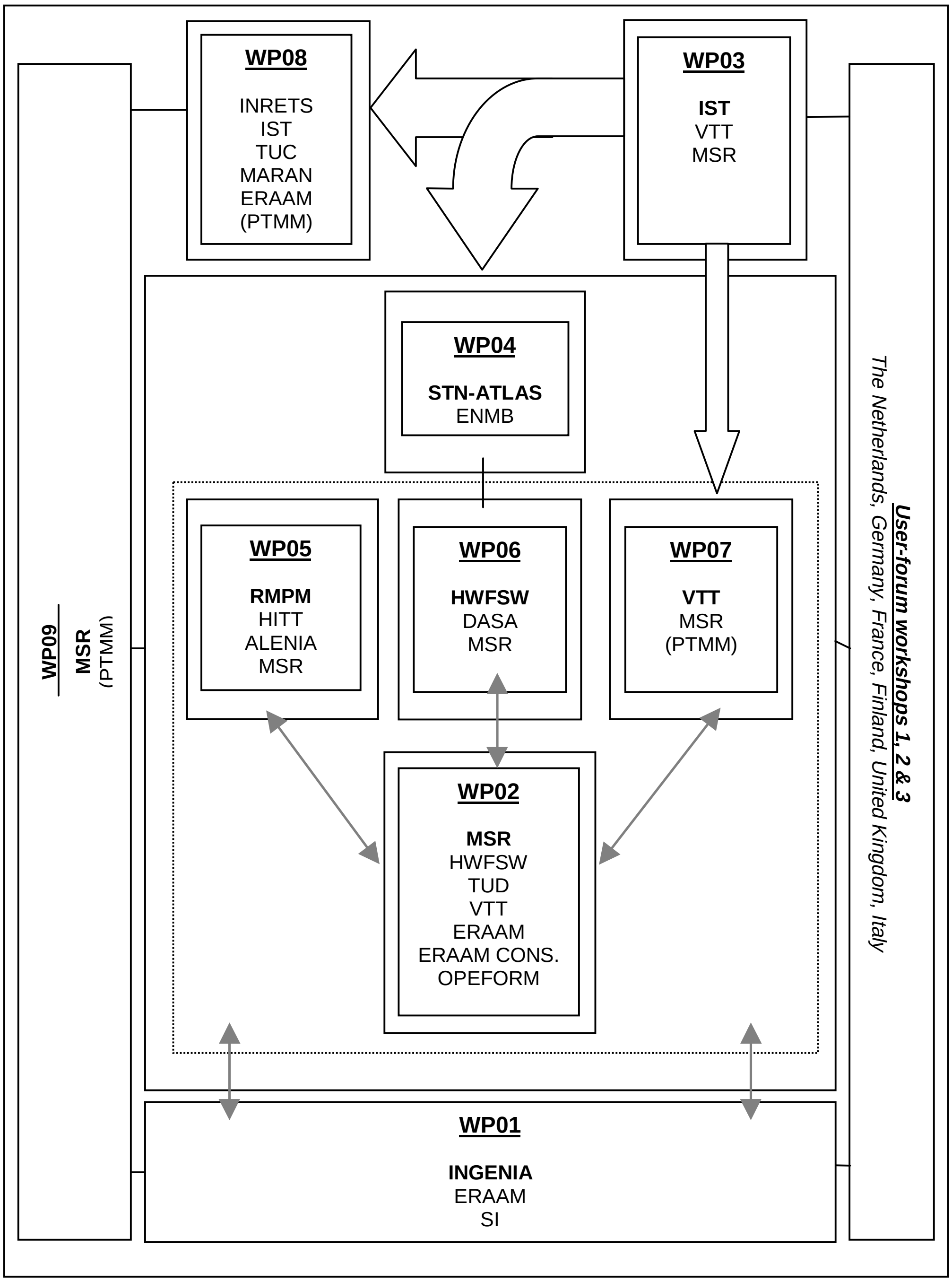
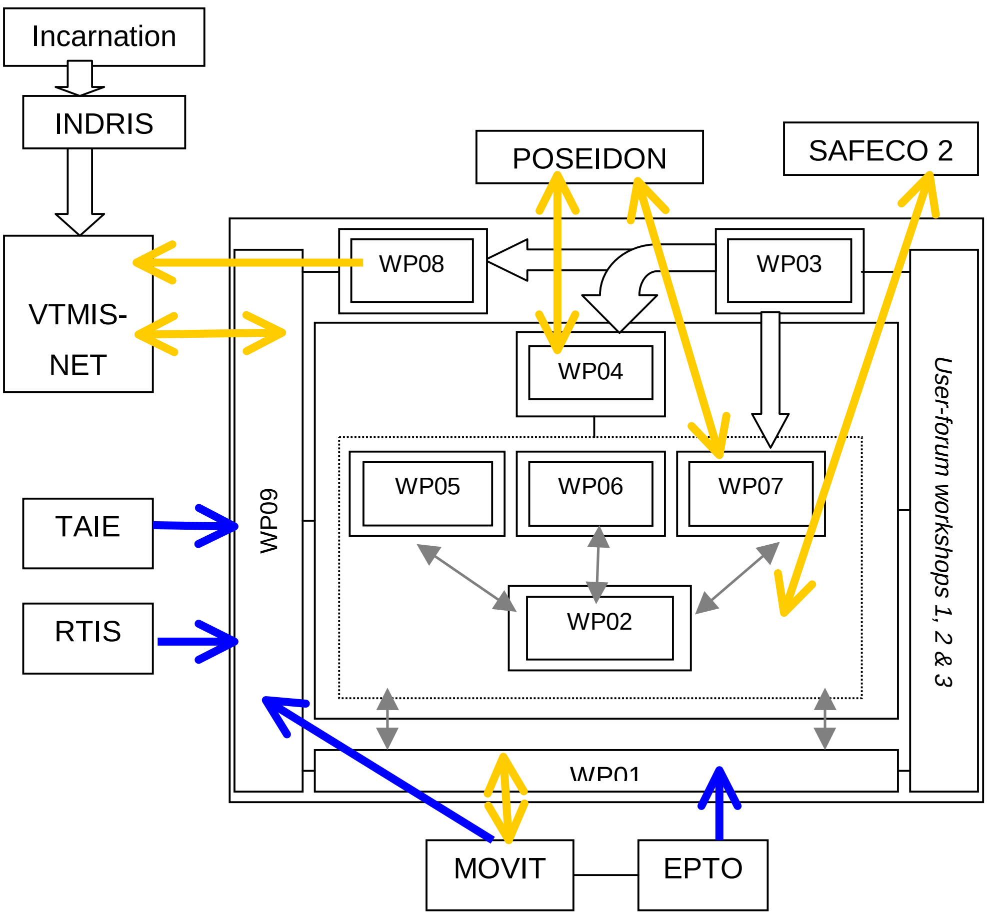


Figure 2: Partners involved in the various Work Packages.

1.3.4 Relationship of COMFORTABLE Task 27 to some other EC projects

The work packages in COMFORTABLE also have a direct or indirect relationship to other EC-funded projects concerned with Waterborne Transport (see *Figure 3*).

Figure 3: Some relationships between COMFORTABLE and other EC Waterborne Transport and Telematics projects



2. Recommendations

The following chapter contains the recommendations arising from the work carried out within the COMFORTABLE project. The supporting evidence is provided in chapters 3 and 4.

2.1 End-user involvement and human factors

The studies described here show that much can be learned by involving the end-user (VTS operators and managers) in the conception, design and testing of tools for vessel traffic management. We therefore recommend that:

- The user forum should be actively encouraged. This is a valuable, existing resource that should not be lost. The participants now have an awareness of the process of industrial design, of the European Commission's research programme, of brainstorming and the value of their opinions;
- Basic human factors research, such as the use of Situation Awareness testing (the SATest), can help in the design of tools that exploit the VTS operator's skill and experience coupled with attitude and aptitude, rather than replace it;
- The SATest is a valuable tool which should be further developed;
- SATest could be used for other purposes, such as:
  - the assessment of level of performance required and acquired by VTS operators;
  - training;
  - the study of Navigational Assistance and Shore-based Pilotage.
- A set of geographical and environmental contexts could be further developed for standardisation of awareness and could be further developed as a useful tool for training purposes for the promotion of internationally harmonised procedures and recommendations.

2.2 Prediction tools / presentation factors

The studies described here provided preliminary, encouraging results concerning both long-term (strategic) prediction and short-term (tactical) prediction. We recommend that:

2.2.1 Long-term and medium-term prediction / presentation factors

- Further investigation should be carried out, under the umbrella of VTMIS, for the use of long term predictions such as MATIAS in generating / enhancing a traffic image in non VTS covered areas;
- Further developments and on-line testing of MATIAS, are needed, especially regarding the processing of data acquired on weather and sea-state forecast from weather broadcast Services;
- Further study is required on the feasibility of looking up estimated positions and ETAs at destination, on demand, for a maximum number of identified ships sailing in the area;
- Similar information on Actual Time of Departure (ATD) should also be gathered. Not only is this information valuable for resource management within the port, but it is vital for the efficient operation of intermodal transport connections;
- The feasibility and application of a real-time (on-line) version of EPTO+ should be investigated, not only to understand the short term past but also to be able to predict the short-term future on the basis of a more complete knowledge of the past;
- Future developments of EPTO+ could include an assessment of the workload of the operator;
- Further research is needed to clarify the potential of simulation for route planning and adherence, or “Route Monitoring Systems”, especially in fairways and traffic separation schemes with junctions. Such a tool may prove useful for Shore-based Pilotage and Navigational Assistance Services.

2.2.2 Short-term prediction / presentation factors

The development and testing of enhanced automatic collision warnings showed that more efficient detection of collision dangers is possible. Using these results it is possible to reduce alarm frequency significantly, to a more realistic level:

- Taking into account defined TCPA- and distance-values, an investigation should be carried out that involves ranking simultaneously occurring warnings in terms of their different risk levels;
- Parallel to such investigations further studies are necessary to determine the best design for warning presentation so that they may be more easily distinguished from each other. VTS operators must be included in studies concerning Traffic Situation Displays and especially the design of warnings;
- The preliminary experiments involving VTS operators should be continued, to obtain more reliable data for statistical analysis of VTS interactions using enhanced collision warnings;
- Simulator experiments should be harmonised by the use of comparable scenarios, to be run on full-scale simulators;
- The situation assessment model used as a basis for enhanced collision warnings should also form the basis for the co-ordination and optimisation of encounter situations in narrow waters. By such optimisation a VTS could organise safe traffic. This should be investigated by scenario studies;
- The use of the criteria and limit values as a basis for training VTS operators - and especially the evaluation of simulator exercises - should be considered in future research and development projects;
- More research is needed on the potential for AIS transponders in terms of navigational assistance and shore-based pilotage in confined waters, ports and approaches or coastal waters. This should involve simulation studies and SATest;
- Any use of alarms should be such that the reason for that alarm, and any functional restrictions arising therewith, should be easily understood.

2.3 Standardised Electronic Chart Display

- A preliminary investigation suggested that it is not desirable to modify the IHO S52 database. A better solution would be to provide special overlays for VTS containing the appropriate VTS object sets for each area. Compared to IMO ECDIS, some of the more obvious VTS ECDIS requirements include the ability to customise the data set:
  - ⇒ A reduced background data set;
  - ⇒ A chart editor;
  - ⇒ An object editor (lines, symbols, etc);
  - ⇒ A colour editor.
- There are also some functional modifications for operational purposes, such as:
  - ⇒ VTS specific automatic alarms and alerts; the number of alarm types and their use thereby should be kept as low as possible by providing indications for information of lower importance;
  - ⇒ VTS specific new chart details, such as automatically tracked buoys;
  - ⇒ VTS specific chart details, such as additional text boxes, temporary chart objects.
- A more comprehensive study to accommodate Port, Coastal and Inland VTS on the need for standardised / harmonised VTS-ECDIS with respect to definition of the additional layers may be required;
- A similar approach as that adopted for the databases and data-links may benefit VTMIS, incorporating logistic data and links into the C_VTS database as identified;
- Assessment of the impact of AIS transponder use.

2.4 Interoperability

- By using a common system approach, a common system segmentation, and a common organisation of data and messages, it should be possible to achieve the following:

  - ⇒ *at the development stage*: to ease the development of the application system and of the Database application software;
  - ⇒ *at the operational stage*: to ease automatic data exchange and the interoperability of VTS systems with other external systems. This should relieve the VTS operators of a number of manual tasks, also assuring better data precision and reliability.
- The detailed analysis of data elements, objects and object relations carried out here should now be applied to the design of VTS and VTMIS systems that share data on the traffic image.

3. Preliminary concepts and definitions

3.1 The traffic image

The heart of VTS operations is the traffic image, which the Euret RTIS[2] project defined as follows[3].

> "The traffic image in a given regional area is a dynamic database which is composed of three layers of information related to:
>
> ⇒ the state of the traffic;
>
> ⇒ the environmental conditions"
>
> A special resource layer can be superimposed showing "the state of the resources needed by the ship."

For practical purposes, these layers may be expanded further into, for example:

The vessel traffic layer

Vessel dynamic data (e.g. positions, courses and speeds)

Vessel static data (characteristics such as length, beam, call sign)

Vessel mission data (origin/destination, sailing plan, cargo, etc)

The environment layer

Hydrographic data

Meteorological data

Data related to aids to navigation

The resource layer

In a port this may mean the availability and status of infrastructure (berths, locks, bridges, cranes)

It may include allied services, such as tugs, pilotage, linesmen, cargo-handlers, search and rescue, etc.

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[2] Regional Traffic Information Service.

[3] The traffic 'image' is not a graphic display. The graphic display is a tool to represent (part of) the traffic image.

The prediction layer

> This is a layer of calculated and anticipated situations or events, based on available data. Much of COMFORTABLE is concerned with this layer.

Work Package 09 of COMFORTABLE analysed the total data flow within a generic VTS and drew up a series of diagrams of the object-relations involved in the VTS process (see below). This is necessary for data sharing between VTSs and other information users / providers.

3.1.1 Time frames and the traffic image

One key to efficient and safe traffic management is the ability accurately to anticipate changes in the traffic image, in particular the occurrence of so-called 'symptomatic events'. These are events that trigger an action or the need to make a decision, such as a vessel waypoint report, a vessel entering a restricted zone, a collision alert, announcement of resource requirements, etc. Information can be used to anticipate these events. This information can be of either *strategic* or *tactical* use, as described below:

3.1.1.1 Strategic information

This is medium- to long-term. It includes advanced notice of a vessel's arrival in the VTS area, the vessel's sailing plan, the availability of resources, tidal windows, water depths, etc. It may also involve the identification of traffic "fingerprints" – i.e. using accumulated statistics on past traffic to predict future traffic.

Accurate ETA's[4] and ETD's[5] are important for efficient planning of port resources, as well as for the safe positioning of vessels in narrow fairways and linear systems where vessel crossing can be dangerous. Observations made in the Port Autonome du Havre at the end of 1996 showed that less than 15% of visiting container ships provided their ETA 18 to 30 hours in advance, as required.

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[4] ETA – Estimated time of arrival
[5] ETD – Estimated time of departure

Forward notification of more precise ETA's and ETD's enables more efficient matching of resources to demand. In the relatively small Mediterranean ports, for example, limited resources require careful allocation. It is in everyone's interest – both vessel owner/consignee and port – to reduce waiting times. In tidal ports such as Rotterdam, fluctuations in water depth have a significant impact on waiting times for deep draught vessels. Masters do not want to anchor because, apart from wasted time, the loss of manoeuvrability at low speed is a potential hazard. They will prefer to maintain speed (if their vessel and the weather conditions permit) or slow down at sea, rather than miss the tide on arrival.

A trend towards privatisation in some major ports is also reinforcing the need for tight resource management. In Rotterdam, for example, the number of tugs has progressively reduced by about 50% over a period of several years. Accurate ETA's and ETD's become more critical to ensure resource supply matches the demand, for all parties concerned. It is not unusual for tugs to wait over an hour at a vessel's berth because an accurate departure time was not given.

COMFORTABLE looked at the provision of strategic information in several ways:

⇒ WP08 - A study of the feasibility of constructing a regional traffic image (i.e. outside the area covered by local VTS), using MATIAS[6]. This is a tool for mathematical modelling of the dynamics of vessels known to be in the area and for which origin, destination and departure time are known, as well as data on forecast weather. MATIAS can provide up-to-date estimates of position, speed and ETA's for vessels.

⇒ WP01 – Developing and updating the EPTO2[7] software to provide off-line as well as on-line analyses of vessel traffic statistics. The

[6] MATIAS - **MA**ritime **T**raffic **I**mage **A**dvanced **S**ystem

[7] EPTO - European Permanent Traffic Observatory, EC-funded / owned software to interface with any VTS and to record and analyse vessel traffic events.

resulting EPTO+ software may be used to identify traffic patterns that can be used for better traffic management.

⇒ WP05 – Developing prototype tools to monitor traffic density and provide route-planning aids.

⇒ WP09 – Analysing data flow in a generic VTS, according to VTS functions, with a view to sharing data through networks.

3.1.1.2 Tactical information

This is short-term. It is information affecting the near future of vessels. It includes warnings of an imminent collision, grounding or similar risk. COMFORTABLE looked at the potential impact of new technology on the provision of enhanced tools for tactical purposes. These included:

⇒ WP04 – ECDIS for VTS. ECDIS charts, so far developed for on-board use, provide a high degree of precision. When combined with information from on-board AIS transponders, at least part of the uncertainty regarding vessel behaviour is reduced, opening the way to investigate further the role of VTS in tactical intervention. WP04 looked at the specifications for a VTS-ECDIS.

⇒ WP05 – knowledge of a vessel's sailing plan can be used to construct the route she is likely to follow. The vessel's adherence to this route can then be monitored. In dense traffic, particularly in fairways with junctions, this may be of value in providing advanced warning of potential encounters, to the vessels involved as well as to other fairway users.

⇒ WP06 – situation-sensitive alarms for the assessment of collision risk. Current systems use standard CPA and TCPA values to assess collision risk. In dense traffic, these provide constantly high levels of warnings. By integrating values for vessel length and sensor error, as well as the type of COLREG encounter, real-time guidance on collision risk may be much more intelligent.

⇒ WP07 - On-board AIS transponders can provide suitably-equipped VTS with accurate, real-time information on dGPS-derived position, rate of turn, heading, course, speed and, through a database, ship's characteristics. By integrating a suitable kinematic model for ship motion (WP03), more accurate short-term predictions can be made of the vessel's future trajectory.

COMFORTABLE looked at the potential application of this capacity for tactical grounding avoidance.

3.2 The traffic situation display

To a large extent, the Traffic Situation Display (TSD) provides an interface to access the traffic image data (and/or resource data) and to build a traffic image. From the VTS operator's point of view, the TSD, together with the traffic information system and communications devices, should provide all the tools needed to carry out the functions and services required[8].

3.2.1 VTS areas and traffic situation display requirements

VTS functions and services change from one area to another, with possible changes in TSD requirements. In COMFORTABLE we looked at TSD requirements and potential enhancement tools for the following VTS types:

⇒ Dense traffic in port and approach VTS (in this case the Port of Rotterdam) (WPs 02 and 05);

⇒ Dense traffic in coastal areas with traffic separation schemes (the German Bight) (WPs 02 and 06);

⇒ Non-dense traffic (fairways in the Finnish archipelago) (WPs 02, 03 and 07).

COMFORTABLE also looked at the traffic image issues raised above (3.1), in particular:

⇒ The use of ECDIS as the basic chart and database for VTS (WP04);

⇒ The integration of AIS transponder data (WP04 and WP07);

⇒ Potential enhancements for traffic evaluation and risk assessment (WPs 05, 06, 07).

[8] See IMO NAV.36/INF.8, 2 June 1990

3.2.2 Human factors considerations

Although methods for integrating human factors into interface design have existed for over 50 years, ergonomic considerations are often seen by suppliers as an “add on” to an interface designed by systems and software engineers. This is not how the client and end-user see the priorities. COMFORTABLE approached human factors considerations in TSD design in several innovative ways, paying attention to the effects the type of VTS traffic might have:

⇒ Creation of a ***user forum*** that met with the COMFORTABLE members developing new enhancements in the respective work packages. This forum gathered in three two-day workshops. End-users provided feedback on the prototypes, made their own suggestions and carried out a small-scale survey of interface features on their own initiative[9]. This showed how these VTS operators had become more aware of the issues and that they were keen to take an active part.

⇒ Creation of an interactive procedure using simulation to evaluate the effects of TSD enhancements on VTS operators’ awareness of traffic situations. This test, called ***SATest***, was developed in WP02 and applied in WPs 05, 06 and 07.

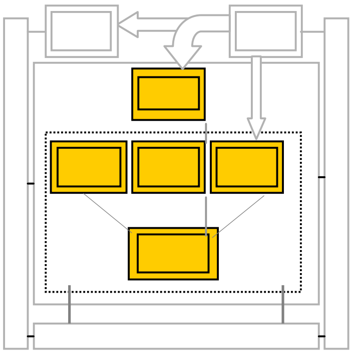
⇒ Survey of TSD requirements found in recent VTS calls for tender (WP05, 06, 07) and in available existing literature.

⇒ Survey of basic human factors principles of process control visual display design.

[9] This survey was not part of COMFORTABLE Task 27, but is reported in workshop report No. 3.

4. Overview of project achievements

4.1 Traffic situation display enhancements



The TSD serves as a primary tool for the operator to carry out the services and functions for which the VTS is responsible[10]. These services and functions overlap considerably from one type of VTS to another, but there may be significant differences. Obviously, the traffic situation display of a given VTS must be adapted to the functions / services the operators are required to perform.

4.1.1 A layered approach to TSD design

As Figure 3 shows, a convenient way to analyse TSD requirements is to consider the classes of information that are received, stored, calculated and possibly displayed. Following the example given in a previous EC DG VII project, RTIS, since the traffic image may be seen as layered, a similar approach can be used for the TSD. The traffic situation display can be imagined as built up from a blank screen, adding elements. Within each basic class of information, some data might be *static* (like coastlines), others dynamic, but relatively *slow-changing* (e.g. measured in hours), and still others dynamic and *fast changing* (e.g. measured in minutes).

This process of building up a TSD might start with the largest, most fixed elements (the geographical features of the environment) and end with the most ephemeral dynamic elements (CPA warnings, alarms, etc.).

Fundamental classes might include:

⇒ ***The environment layers***:

- hydrographic data;
- meteorological data;
- data related to aids to navigation stations/systems (buoyage, lights, radio navigation);

[10] See IMO NAV.36/INF.8, 2 June 1990

- virtual zones with special properties (anchorage, traffic separation, fairway, deep draught route, speed restriction, forbidden anchorage, trans-shipment area, etc.).

⇒ ***The resource layers***

- characteristics of the infrastructure;
- equipment and ship handling;
- goods handling;
- services and services availability;
- booking schedules for any resource requested;
- contractual and regulatory requirements associated with the allocation of resources.

⇒ ***The vessel traffic information layers:***

<u>Dynamic information</u>

- *vessel positions*, courses and speeds:

  the origin of these data (radar, AIS, VHF report, sighting, VTMIS, etc).
- vessel mission requirements and intentions:

  origin/destination, sailing plan, including reported ETA and ETD, way points, etc;

  passengers, cargoes, crews.
- vessel *status* (pilot on board, tugs assigned, equipment failures, etc).

<u>Static information</u>

- vessel fixed data (Lloyd’s data, name, call sign, length, etc.).

<u>Calculated / predicted information</u>

- course, history, TCPA, DCPA, under keel clearance, alarms, warnings, calculated ETA, etc.

⇒ ***The sensor control layer***

- The TSD is often used to control remote sensors, aids to navigation (e.g. radar settings). This may be through pop-up panels or a separate screen.

⇒ ***The display control layer***

- This consists of a number of functions that control what is seen on the TSD – the scale or range, chart offset, whether or not vectors, history trails, labels are shown, etc. This layer also allows the operator to designate the co-ordinates of areas with special characteristics, to set alarms and their parameters, perhaps to change the colours of the display, etc, (depending on the adoption of S52 in the case of ECDIS).

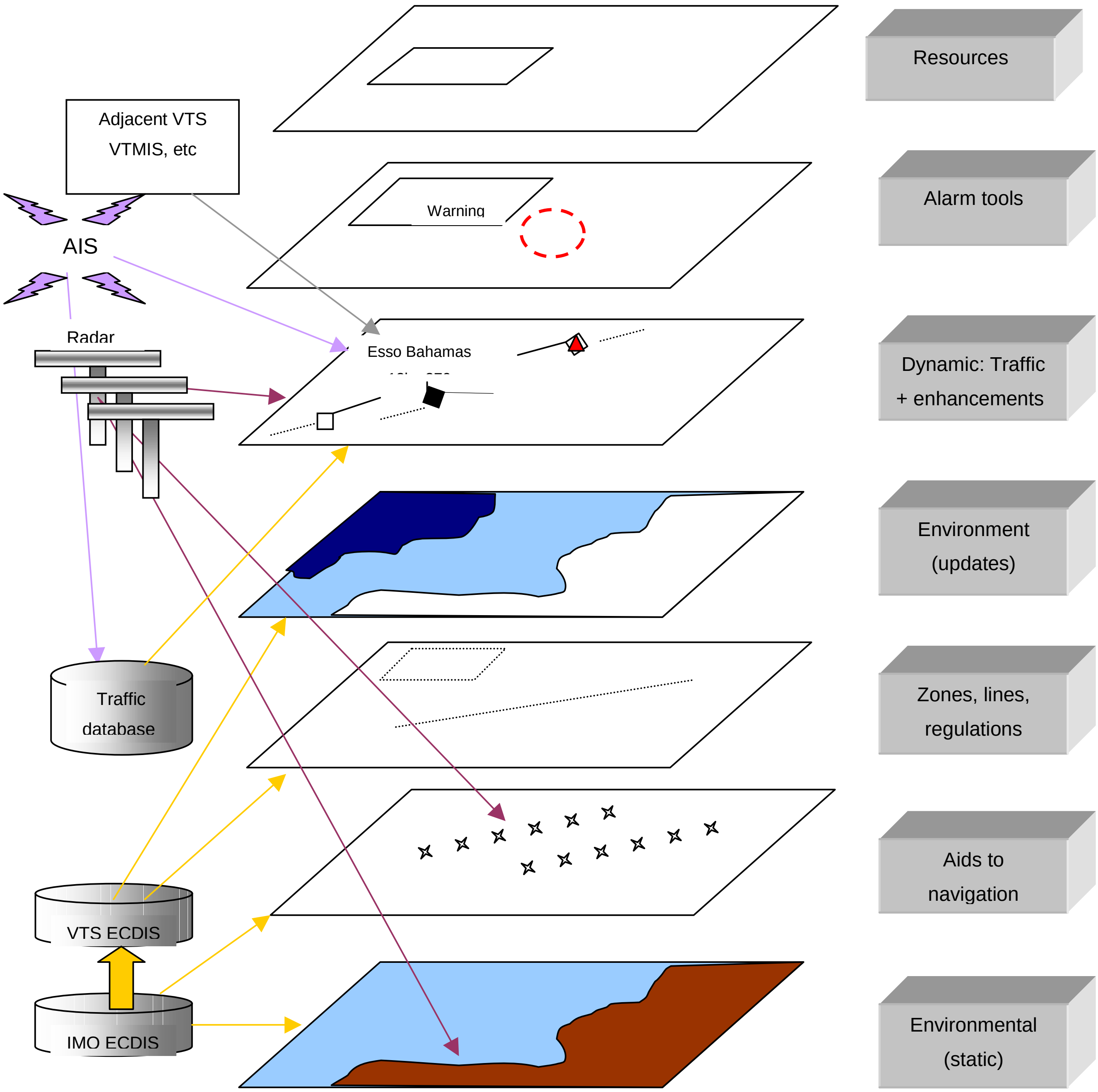
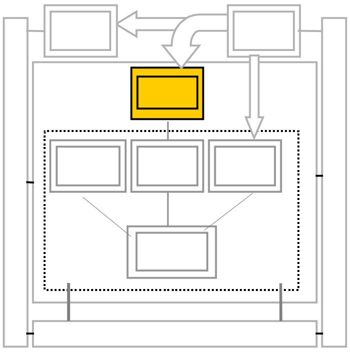


Figure 4: A layered approach to the traffic situation display



4.1.2 ECDIS for VTS

Since 1983, when the first electronic sea chart with radar overlay was demonstrated in the USA, electronic navigation charts have gradually been taking precedence over paper charts for use on the ship's bridge. In 1988 IHO published the first standards for a harmonised Electronic Chart Display and Information System (ECDIS). ECDIS uses standard S57 data content for chart presentation in the form of lines, areas and symbols. Each element has an object description (name, type, etc). The S57 chart database defines **what** is shown on the screen, while a presentation library (S52 standard) defines **how** the objects are presented.

4.1.2.1 Some advantages of ECDIS for VTS

More and more VTSs are using custom electronic vector charts with associated custom databases, although relatively few have so far adopted ECDIS. There are arguments for adopting ECDIS as a standard for VTS, although significant modifications will be needed, for example:

⇒ The same information is available on board and in the VTS. This could be especially beneficial for shore-based pilotage and navigational assistance operations;

⇒ Charts are standardised, using performance standards as agreed by IHO/ IMO;

⇒ Updates are possible;

⇒ Different VTSs would use the same chart standards and could exchange display data easily.

4.1.2.2 A need for a modified ECDIS for VTS

The standard "IMO-ECDIS" needs to be modified for use in VTS. On the one hand some items are not needed. VTS operators are familiar with their area and do not need the detailed labels available in the standard ECDIS data set. On the other hand VTS operators need information not contained in the standard IMO ECDIS, for example:

⇒ Radar target tracking acquisition zones;

⇒ Radar target tracking reporting lines;

- ⇒ Navigable space, e.g. Fairway boundaries (often differently defined for VTS purposes than in the IMO-ECDIS);
- ⇒ Fairway centre lines (in Germany also called the "Radar line");
- ⇒ Additional text notes (Temporary notes for dredging activities etc);
- ⇒ Areas of responsibility for VTS operators;
- ⇒ VTS areas limits;
- ⇒ Harbour responsibility area limits;
- ⇒ Details related to harbour management;
- ⇒ Positions of other VTS related objects;
- ⇒ Other details which still emerge with each new VTS project and in the course of technical and technological VTS development.

Meanwhile, the VTS display is designed to be watched for long periods, so the VTS ECDIS should use a palette of colours that is not tiring for the operator. VTS charts also need to integrate local information for example on water depths, which is usually more up-to-date than the data supplied by IHO for ECDIS.

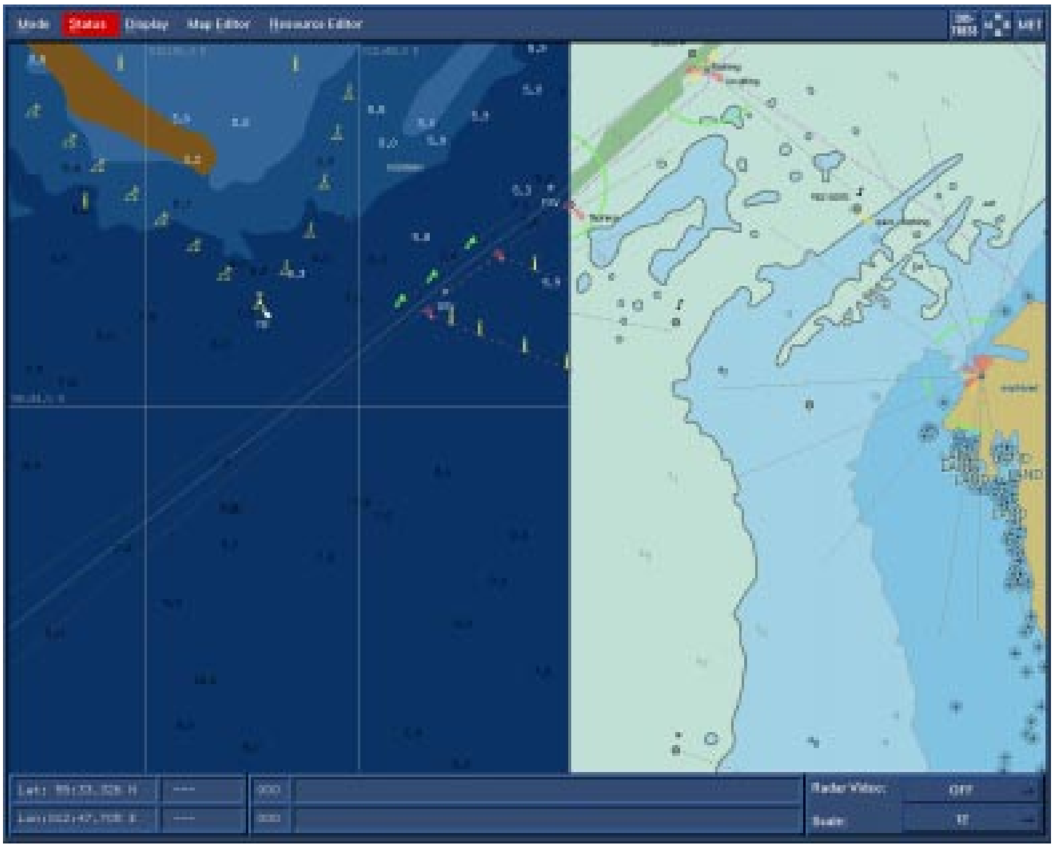


Figure 5: Example of a VTS-ECDIS (left) and IMO-ECDIS (right)

4.1.2.3 A proposed solution

A solution would be to provide special overlays for VTS containing the appropriate VTS object sets for each area. Compared to IMO ECDIS, some of the more obvious VTS ECDIS requirements include the ability to customise the data set:

⇒ A reduced background data set;
⇒ A chart editor;
⇒ An object editor (lines, symbols, etc);
⇒ A colour editor.

There are also some functional modifications for operational purposes, such as:

⇒ VTS specific automatic alarms and alerts;
⇒ VTS specific new chart details, such as automatically tracked buoys;
⇒ VTS specific chart details, such as additional text boxes, temporary chart objects.

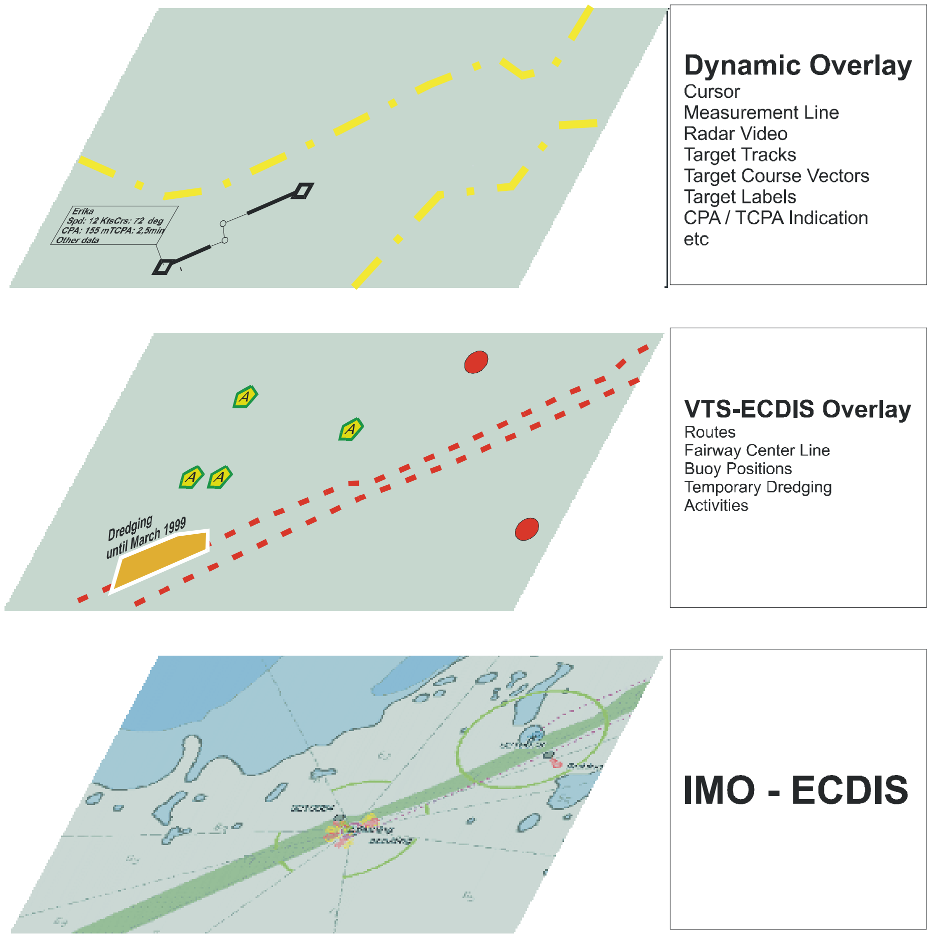
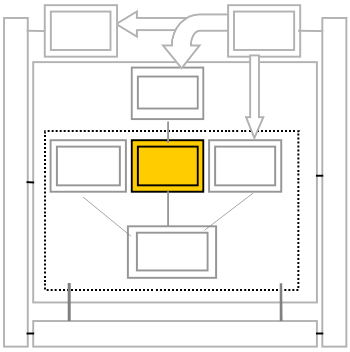


Figure 6: Proposed solution to adapt ECDIS for VTS use

Currently under discussion is the issue of the choice of symbols to represent information derived from AIS transponders, in order to distinguish it from information derived from other sources, including radar.

4.1.3 Situation-dependent collision warnings for dense traffic coastal VTSs



This prototype tool was developed for use in coastal areas with traffic separation schemes and dense traffic, although it could be adapted for other VTS areas. The German Bight was chosen as a striking example of this kind of VTS area. Here, VTS officers have an obligation to advise vessels that are in a COLREG (collision encounter) situation, when the TCPA[11] is 10 minutes (or less) and the CPA is 0.5 nautical miles (or less).

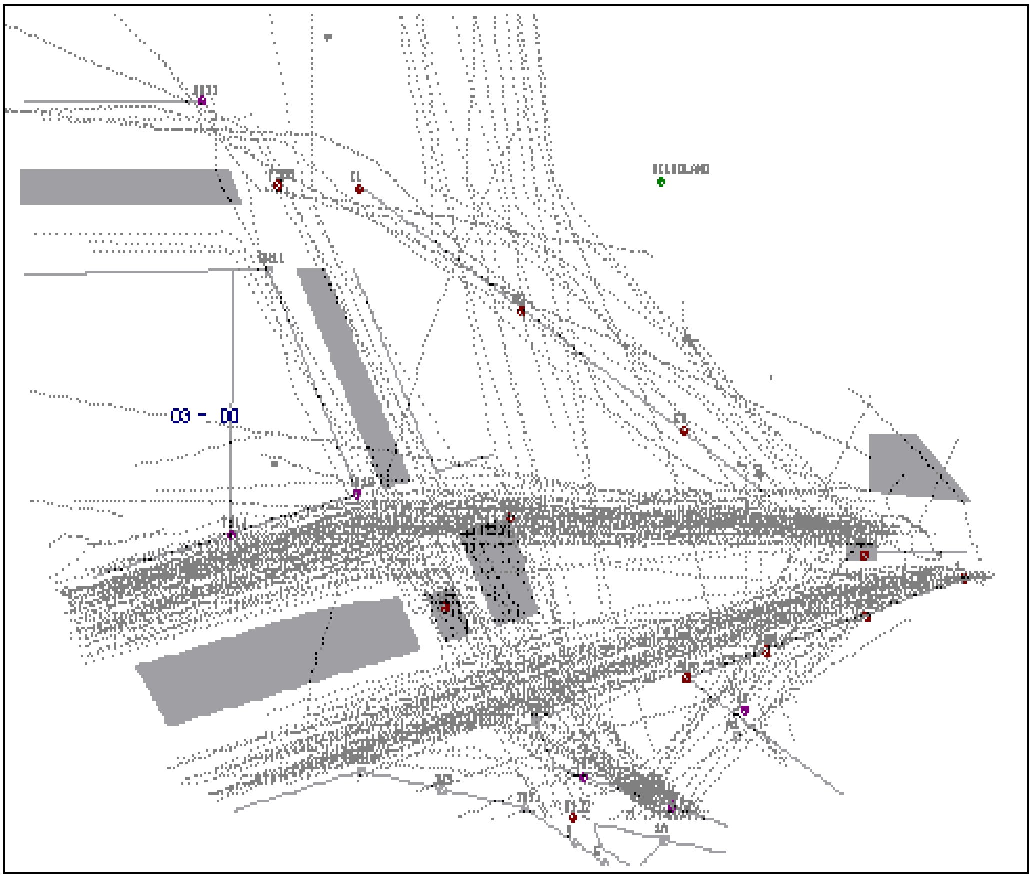


Figure 7: Recorded radar tracks of traffic in the German Bight over a 24-hour period, excluding vessels < 50m)

[11] TCPA = time to closest point of approach (CPA).

Statistical analyses of the alarm rates during normal operation were performed by replaying recorded radar data of the German Bight traffic. Applying the mandatory VTS criteria produced an almost constantly high rate of alarms. Interviews with VTS operators revealed that these alarms increased workload and were often ignored, as they usually did not represent real dangers. Furthermore, the official VTS criteria are not applied by shipmasters navigating in the area.

By applying a modified version of the risk assessment model developed by Hilgert, it was possible to reduce the alarm rate by at least 31% without increasing the risk to shipping. The reduction was achieved by introducing into threshold calculations an estimate of CPA error, due partly to inherent error in the position sensor (in this case, radar) and by taking account of the type of encounter and the concrete dimensions of the vessels involved in an encounter.

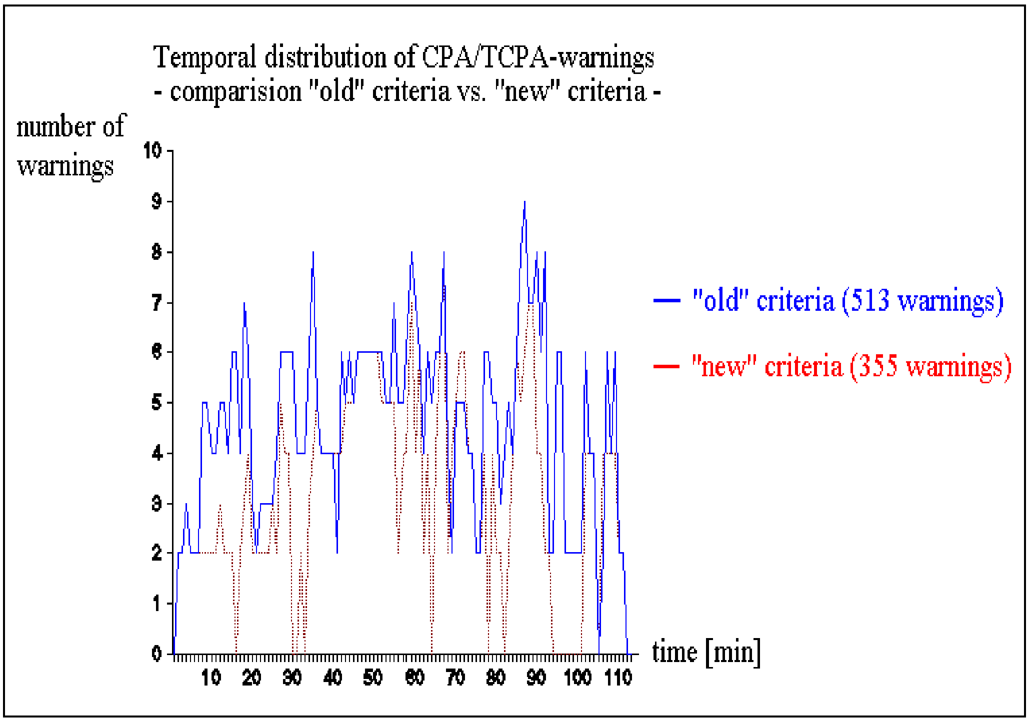


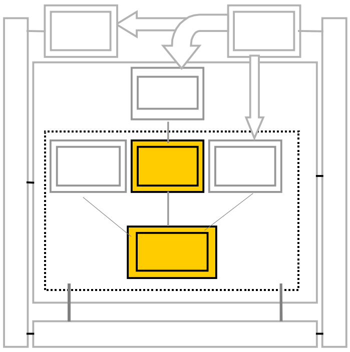
Figure 8 Effect on alarm rate of applying new criteria

According to these tests the following limit values are suggested as the most suitable thresholds for enhanced collision warnings in two-dimensional VTS areas with dense traffic.

kind of encounter situation	CPA threshold[12]
• Crossing courses and head-on encounter with passage starboard-to-starboard	$5 \cdot L_{max}$ + CPA-error
• overtaking and head-on encounter with passage port-to-port	$2 \cdot L_{max}$ + CPA-error

Table 1: Limit values as thresholds for enhanced collision warnings

4.1.3.1 Potential human factors implications



At present some minimum technical aids are available to help operators undertaking evaluation of traffic situations. These include:

- display of variable course/speed-vector length for radar tracked targets;
- display of a bearing ruler between two vessels or objects;
- alphanumerical display of CPA/TCPA values for a given encounter situation;
- lost target warning (flashing of synthetic radar symbols);
- track conflict warning (two separate tracks cannot be divided; flashing of corresponding vectors);
- collision warnings (flashing of labels concerned).

Because of the similar structure of the implemented warnings (use of elements of synthetic symbols for flashing and the same frequency of flashing for each type of warning) operators may have problems identifying alarms. But in fact the biggest problem is the high workload that arises for the operators. During the three user forum workshops, VTS operators repeated that excessive use of alarms can be a nuisance. Where they can, they often turn them off. Reducing the alarm rate without reducing safety levels is therefore a potentially significant achievement. Some other means of presenting alarms using ECDIS were discussed in WP06.

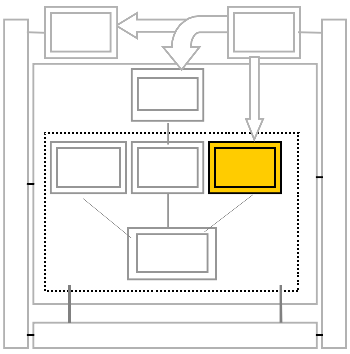
[12] L_{max} Length of the largest ship involved in an encounter situation

A simulation exercise based on SATest (developed in WP02) was run with the 'old' and the 'new' alarm thresholds and using a mixture of VTS operators who were not familiar with the test site as well as those who were. Those operators who were not familiar with the area, tended to intervene after a warning had been given, while those who were familiar with the site anticipated the warning, then used it as a confirmation of their "intuition".

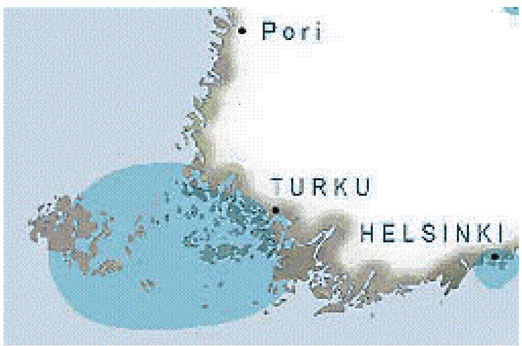
This result suggests that alarms are of most use to operators not yet completely familiar with the area they are monitoring. Experienced operators use cues based on their experience to identify potential dangers. Warnings, in this case confirm – and therefore reinforce – decisions based on their acquired skill. The new algorithm developed here could therefore form the basis for a teaching tool to train new recruits in the identification of risk.

This kind of warning could also be useful for both experienced and inexperienced operators, by confirming a hazard before the point of no return is reached.

4.1.4 Short-term path prediction in non-dense traffic VTS areas



The archipelago off the coast of Finland covers a large area, but the maximum number of vessels tracked simultaneously by the VTS is in the range of 10 to 15. In the summer period a large number of leisure craft contribute to the traffic image. Within the area there are 25 reporting points. The required report at these points includes name, reporting point, destination and route. Reports should also be given to the VTS on arrival and departure or when anchoring. Ferries operating in this area are now equipped with AIS transponders to transmit



position and other details at frequent intervals.

In non-dense traffic VTS areas such as this, the human factors challenge is one of coping with work under-load, rather than overload. The danger in areas like this is not so much of close quarters encounters with other vessels, but of going aground by leaving the narrow, winding fairway. We therefore investigated the potential for enhancing the traffic situation display by using the data on vessel position and dynamics recovered from AIS transmissions.

This involved integrating rate of turn and heading information into a new curved path prediction vector, in contrast to the conventional straight-line vector and history trail. If the ship dimensions and the exact position of the position sensor is known the prediction can be displayed as in *Figure 9*. The figure shows the ship in its current position, the predicted position and the predicted attitude.

This type of presentation is used onboard for the own ship when navigating in confined areas such as harbour basins or narrow passages.

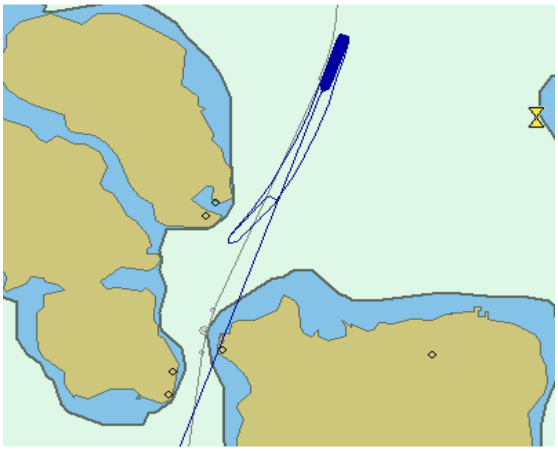
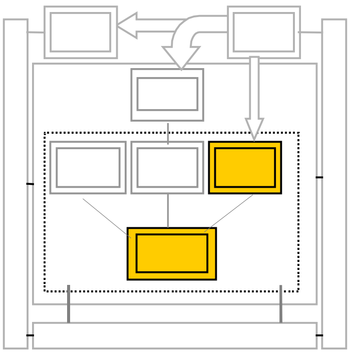


Figure 9: True scale ship symbol on electronic chart display showing heading marker and one-minute path prediction



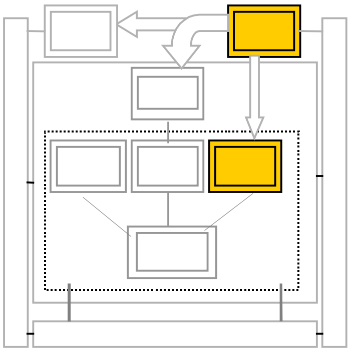
4.1.4.1 Potential human factors implications

We carried out a preliminary evaluation of the short-term path prediction tool in a SATest[13] simulation study with a number of Finnish VTS operators using the VTS simulator at VTT in Espoo. No firm conclusions can be drawn, but there was some evidence that this kind of path prediction tool could be valuable in monitoring vessel

13 Situation awareness test developed in WP02

dynamics at wheel-over points in long fairways in restricted waters with a grounding risk. If the vessel has not started to turn by a given moment, she could be contacted by the VTS. More extended prediction periods (3 to 15 minutes) would be needed than were tried here. With appropriate extensions in the look-ahead time, this tool could provide extra indications of the development of a grounding risk before the point of no return is reached.

4.1.5 Use of mathematical modelling to improve short-term path prediction accuracy



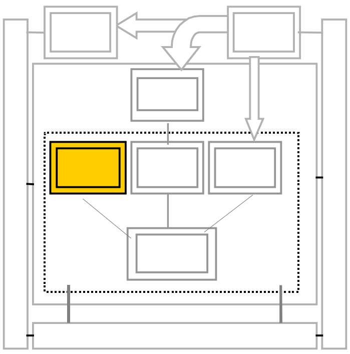
The work package concerned with a short-term path prediction tool for non-dense traffic VTS (WP07) worked closely with another work package (WP03) that was investigating mathematical modelling of ship motion for short-term prediction. A number of case studies exploring several popular practical methods for manoeuvring calculations were undertaken. These confirmed that the extreme complexity of the flow about a ship's hull in curvilinear motion means that it is impossible reliably to predict ship manoeuvring motion based exclusively on theoretical methods. An additional disadvantage of the usual methods is their need for large amounts of input data, which may be unavailable in practice.

These conclusions stimulated development of a simplified dynamic ship mathematical model enabling realistic, if not entirely accurate, simulation of any moderate manoeuvres. The model has additional advantages, including:

- ⇒ high computational speed achieved through elimination of a number of secondary effects;
- ⇒ a very small number of necessary input data;
- ⇒ a certain degree of flexibility: the degree of directional stability can be adjusted according to the properties of any given ship. It is sufficient to know the main manoeuvring performance measures required by the IMO Interim Standards for Ship Manoeuvring which have been in effect since 1994.

We proposed an advanced scheme for short-term kinematic prediction that accounts for current values of accelerations. This method permits fast short-term kinematic prediction in course changing manoeuvres. The salient feature of the method is that it accounts for the time lag due to a ship's inertia. Approximate values of this lag in terms of ship's length were computed with the help of the simplified dynamic model, using the ship's stability parameter as well as the magnitude of course change.

4.1.6 TSD considerations for dense traffic port and approach VTS



An analysis of calls for tender for port VTS confirmed that much of the operator's work involves database management, using vessel reports. The database requirements were analysed both in WP05 and WP09. The tables of these requirements are too lengthy to be included in this summary. A gradual move towards AIS will significantly reduce this part of the workload. One of the TSD issues already being addressed in some ports is to find suitable ways to distinguish vessel tracks that are derived from AIS from those based on radar return.

As we have seen above (4.1.3) dense traffic gives rise to alarm levels for encounters that can reach saturation. Strategic planning of traffic is therefore a better option, where practicable. A theoretical prototype was developed around the observation that the number of potential vessel routes within the fairway network of a busy port is limited. If the planned route of a vessel is known, then it can be simulated, using average speed estimates. Each simulated route is made up of segments of different lengths and orientation. This makes it possible to build a large number of routes from the same set of segments.

This kind of device is already used in linear systems, as a space-time graph, but has no equivalent in two-dimensional systems. The prototype route-planning model allows similar estimates and calculations to be performed, such as ETA at waypoints, CPA calculations for vessels on different branches of fairways, route adherence, speed monitoring, etc.

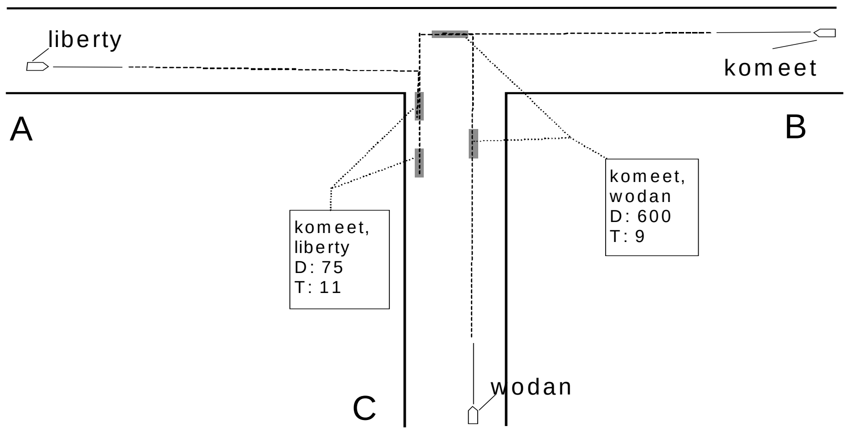
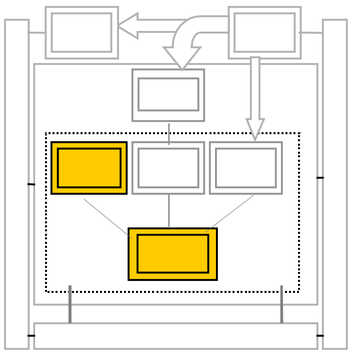


Figure 10: Example of CPA calculation using route simulation.

4.1.6.1 Human factors considerations / end-user involvement



A (fictitious) dense port and approach scenario was used in a series of simulation runs held at MarineSafety International Rotterdam with VTS operators from the Port of Rotterdam.

The aim was to provide baseline data with which to evaluate TSD enhancements. The simulations were part of *SATest*, a test developed by TU Delft in COMFORTABLE to measure *situation awareness* – i.e. the 'mental picture' of operators concerning the traffic and its evolution over time.

The procedure involved creating an exercise scenario with, for example, known conflicts or dangers at certain moments. The simulation exercise was interrupted at pre-determined moments and operators were asked to draw their recollection of the traffic on special forms. These forms were later analysed. A baseline situation was set for the geographical and environmental context (see figure 11).

The results showed that experience had an effect on the operators' ability to anticipate incidents, with less experienced operators detecting potential incidents later than their more experienced colleagues. This could suggest that some TSD enhancements might be of particular value to relatively inexperienced operators and for training purposes.

The SATest results also revealed that operators tend to "chunk" vessels together, if they have some important dynamic aspect in common (e.g. at anchor, approaching a bend, etc). This is a way of simplifying the visual exploration of the TSD for new information. Interestingly, the drawings showed that VTS operators view vessels in terms of their paths, not as points in space. In other words their 'mental image' of the traffic integrates time as a dimension inseparable from the spatial dimension.

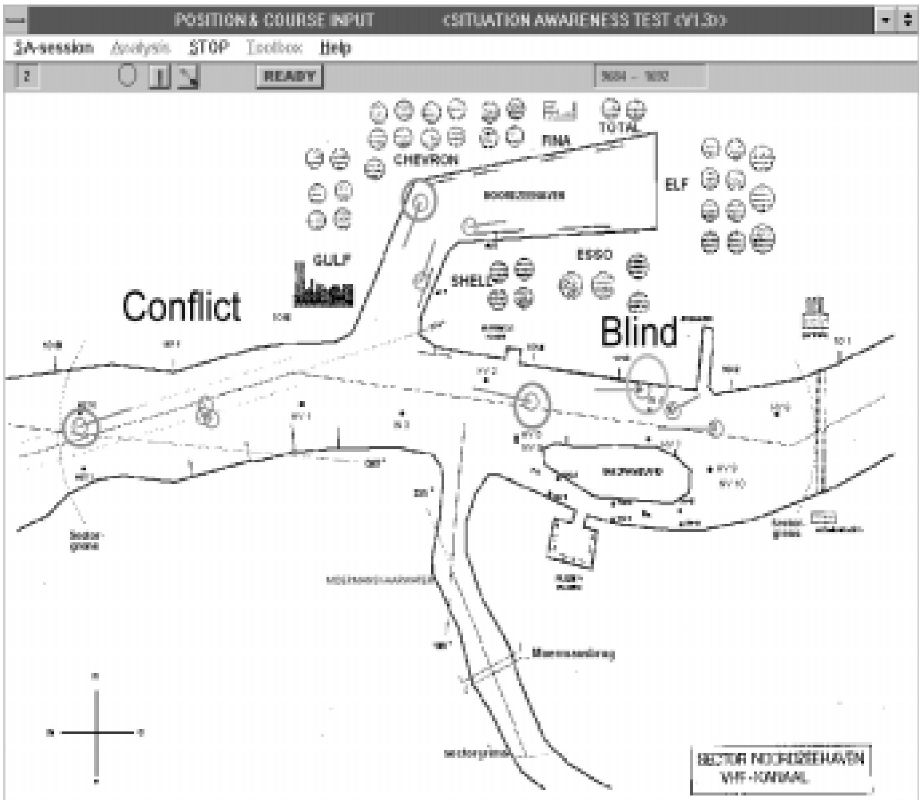
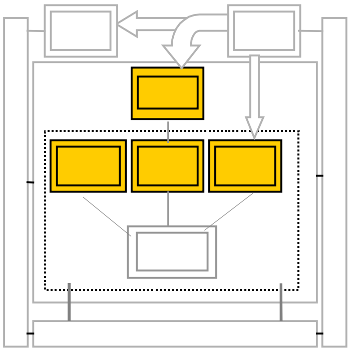


Figure 11: Fictitious port and approach site used for SATest

The SATest also revealed that VTS operators use a wide variety of cues based upon accumulated experience in order to structure their image of the traffic. The name of a vessel that calls regularly may be sufficient to evoke its destination, route, length, draught, etc. Indeed, in the Port of Rotterdam, about 6000 vessels account for all the 30,000 port calls each year. “Keep it simple” has been the take-home message from all three of the user-forum workshops, as far as TSDs are concerned.

4.1.7 General human machine interface considerations for Traffic situation displays



COMFORTABLE was able to provide some guidance on HMI considerations for different types of VTS. In particular, some fundamental ergonomic principles were summarised concerning readability, colour combinations for figure and background, the use of screen areas for different types of information, etc. One noteworthy consideration is the need to minimise response times for changes of scale or area in TSDs. Between one and three seconds is a maximum. This could have implications for the design of ECDIS for VTS, since the detailed vector charts may take longer to redraw after a view change.

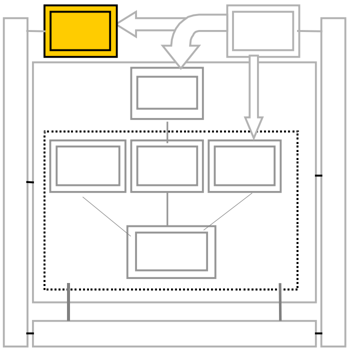
We felt that it is not wise to try to lay down universal guidelines for VTS traffic situation displays, even classified according to the type of VTS (e.g. port, coastal, linear, etc). Two coastal areas are not alike and national regulations are still not harmonised. The kind of intervention of VTS operators in the German Bight in case of encounters is not required in UK coastal VTS, for example.

Some clients like to use windows for different views or types of data, others prefer to have a separate screen for special applications, such as a way-time graph, tidal water-depth map, traffic simulation and replay, etc. Not all VTSs use CCTV, or radio direction finders, or AIS.

Our feeling is that further research into human factors, using simulation exercises and tests such as SATest are essential when new TSD enhancements are being developed. Basic human factors research, such as situation awareness, can also help in the design of tools that exploit the VTS operator's skill and experience, rather than replace it.

4.2 Towards a regional traffic image

4.2.1 Long-range ETA estimation using mathematical modelling of ship motion



At present the services provided by VTS are usually local (limited to the VTS area of coverage). The VTS '96 Symposium highlighted:

⇒ A demand to monitor traffic in areas without VTS coverage

⇒ The growing need for an interactive exchange of information between VTS centres, both for vessel management and logistics purposes. The development of a traffic image in areas where VTS has not been established is a cost-effective alternative to monitoring traffic. It may also enable a quick and direct response in the case of an incident or accident.

The value-added services of Vessel Traffic Management and Information Services (VTMIS) are mainly based on the possibility of constructing an accurate traffic image of the area under consideration, especially regarding the state of the traffic. Port authorities, pilotage organisations, tugs companies, stevedores and other actors involved in the management of maritime transport are increasingly interested in improving the accuracy of information on the approaching traffic.

Of particular interest would be the facility to look up estimated positions and ETAs at destination, on demand, for a maximum number of identified ships sailing in the area. Similar information on Actual Time of Departure (ATD) would also be valuable. Not only is this information valuable for resource management within the port, but it is vital for the efficient operation of intermodal transport connections. Deep draught vessels calling at tidal ports have a narrow time window to reach berth. Port authorities and private cargo-handling companies cannot afford to have heavy plant and manpower idle.

The MATIAS project (Maritime Traffic Image Advanced System) within COMFORTABLE aimed to design, implement, assess and demonstrate processing methods to construct the traffic state of the Traffic Image of any regional sea area. The purpose was to support the services of VTMIS, with the aim of improving the management of maritime transport, especially the logistics aspects.

MATIAS was a feasibility study of the future system, aimed at providing a VTMIS with data on:

- ⇒ the vessels sailing in the area of interest and their estimated positions at any given time;
- ⇒ predictions of future positions at specified times;
- ⇒ the Estimated Times of Passage [ETPs] of vessels at any specified location (e.g. a given VTS area);
- ⇒ ETAs at port of destination.

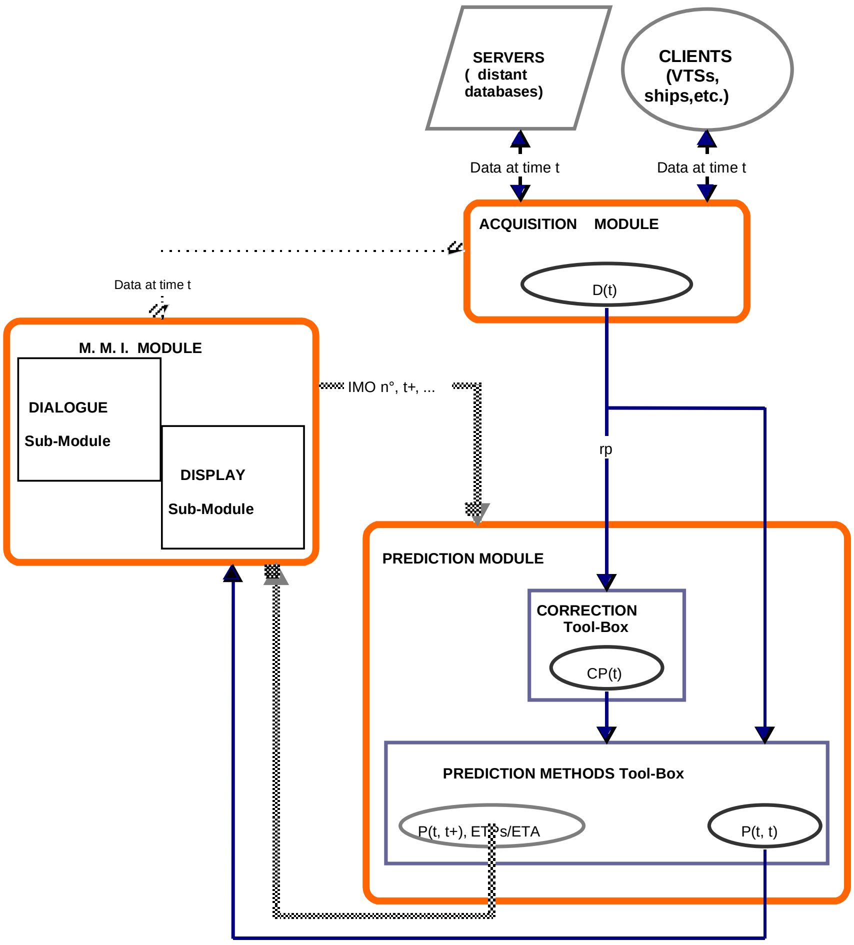


Figure 12 MATIAS architecture

The system was designed in such a way that various prediction methods can be selected and activated for a given ship throughout her voyage, depending on:

⇒ the nature, quality and value of the data related to this ship and to the environmental conditions acquired by MATIAS;

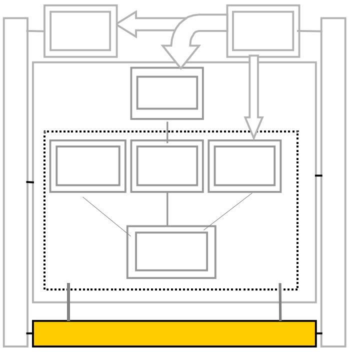
⇒ possible corrections made by the system once new information has been acquired.

The greater the accuracy of information acquired on a given vessel, the less complex the prediction method selected. When a shipmaster has reported his planned route, a simple extrapolation technique based on this reported route and on estimated speed values, provides excellent results, so long as the vessel actually follows this route.

An experiment was carried out with the co-operation of a container ship, the Nedlloyd Korrigan. The Master was asked to report his sailing plan before departing and to report the vessel’s positions during her voyage from Damietta to La Spezia. The vessel made 25 position reports in total. After a sailed distance of 289 nm, which is about 20% of the total sailed distance, MATIAS estimated her ETA with an error of only 2%.

In good weather the service speed is usually a good estimate of the ship's speed values. But in bad weather conditions, the use of a ship hydrodynamic model seems unavoidable. Here again, to apply this model, it is important to have accurate information on the environmental conditions and on the ship's characteristics and status. This is not often the case, so the model has to perform below its optimum. Details of the mathematical models and their evaluation in on-line tests are given in the annexe on WP08.

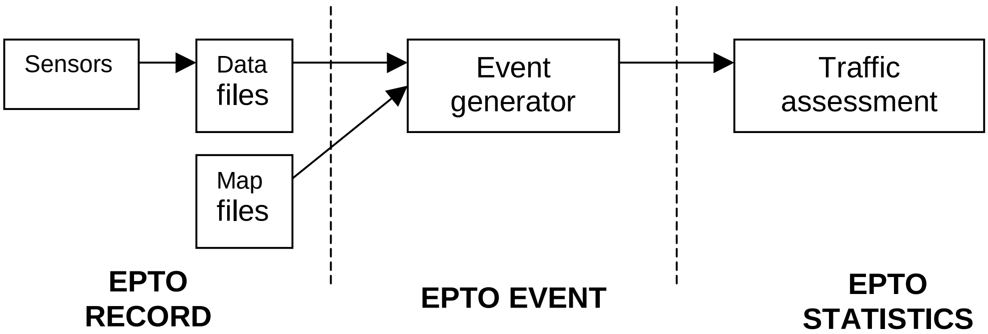
Further developments and on-line testing of MATIAS, are needed, especially regarding the processing of data acquired on weather and sea-state forecast from weather broadcast Services.



4.3 The use of the short-term past to predict the short-term future

The EPTO (European Permanent Traffic Observatory) project was launched to support the work carried out by IALA toward harmonisation of maritime traffic management procedures throughout Europe. Within this context, the EPTO tool is used for recognition and assessment of traffic situations that provide the user with statistics on traffic events.

Until now the EPTO tool has only been used off-line by management staff with recorded VTS data. In COMFORTABLE, our objective was to produce EPTO+, a tool for the VTS operator based on the last version of EPTO tool, EPTO2. To achieve this objective, the work was specified using the results of intensive operational use of EPTO2, in September 1996 in the Port of Le Havre (VTO experiment[14]) and the first COMFORTABLE user-forum workshop.



These specifications included the following requirements:

⇒ It should be possible to study not only basic events but also dependent events (a set of two basic events linked together because they occurred on the same ship, at same time);

⇒ Radio communications between ships and VTS should be recorded and taken into account for event interpretation;

[14] The VTO (Vessel Traffic Observatory) program was initiated and co-financed by the European Commission to promote EPTO use inside and outside Europe.

⇒ It should be easier to modify the thresholds for event detection and statistics;

⇒ The EPTO graph generator needed to be more flexible, especially during exploratory phases.

These requirements were the basis of the specification phase of EPTO+. According to these specifications, the partners focused their design on the following topics:

⇒ a more intelligent and parametrisable event detection module;

⇒ a more powerful, flexible and easy-to-use statistics interface;

⇒ an on-line version of EPTO+.

The scheduled work essentially concerned two of the three modules of EPTO: *EPTO Events* which is devoted to event detection and *EPTO Statistics* which computes statistics on the basis of the detected events. EPTO+ needed to be designed around a SQL database and should be able to generate Excel compliant data. For portability reasons, it was decided to use Java as the programming language for *EPTO Stat*.

New kinds of function and data structure were generated:

⇒ *Scripts* These are key features of EPTO+ which contain the requests to database definitions. They may be created interactively by the user and then saved, to be reused later for off-line or on-line extraction.

⇒ *Containers* to collect scripts that have to be executed together while in on-line mode.

⇒ A completely new *graphics tool* was generated in Excel. As a result it is possible for the user automatically to build graphs and then interactively to modify them within this powerful environment.

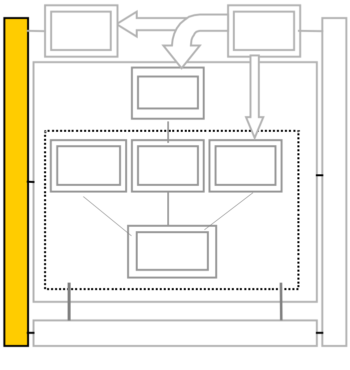
⇒ There is now an *automatic mode*. It consists of periodically acquiring newly detected events, storing them in an events database, applying selected containers and then automatically producing updated versions of the generated graphs.

The developments in the *EPTO2 Events* module were improvements rather than complete re-engineering. Some event detection processes were improved. For example, collision risk detection can now depend on context (zone, ship characteristics and environment). Some event structures were also updated in the light of specifications following the VTO experiment.

EPTO+ now integrates some results of the EC's MOVIT project (Task 31) concerning connectivity. It is now possible easily to connect EPTO+ to any VTS compliant with the MOVIT Communication Standard (MCS). This standard is based on the CORBA[15] norm that facilitates integration of heterogeneous hardware and software. It defines objects (track, ship characteristics, environment, etc) to be exchanged between EPTO+ and a VTS.
A real-time version of EPTO+ could be of great interest, not only to understand the short term past but also to be able to predict the short-term future on the basis of a more complete knowledge of the past. We believe that it could be the basis for a tool to help VTS operators in planning short-term traffic.

Future developments of EPTO+ could include an assessment of the workload of the operator by defining categories of events:
⇒ Events which are system driven;
⇒ Events which are procedure driven;
⇒ Events which are related to risk due to the errors of other parties.

4.4 Data flows and data links within and between VTSs



Work Package 09 ran in parallel to all others. It aimed to provide a framework for the system-level database design of a general VTS, either a port VTS or a coastal VTS. As such, it constitutes a reference point for the design and implementation of future VTS Database systems. The resulting "C_VTS Database" is in compliance with the

[15] Common Object Request Broker Architecture. Object oriented norm for data exchange on an heterogeneous network.

former requirements as defined by RTIS and TAIE, and with the new requirements of AIS-*Automatic Identification System* and ECDIS-*Electronic Chart Display Information System*, providing also a technical solution for the correct handling of ECDIS standard database and VTS database.

This should hopefully contribute to the further development and harmonisation of VTS in Europe, as well as to their integration with the emerging realities of River Information Systems and VTMIS networks. By using a common system approach, a common system segmentation, and a common organisation of data and messages, it should be possible to achieve the following:

⇒ *at the development stage*: to ease the development of the application system and of the Database application software;

⇒ *at the operational stage*: to ease automatic data exchange and the interoperability of VTS systems with other external systems. This should relieve the VTS operators of a number of manual tasks, also assuring better data precision and reliability.

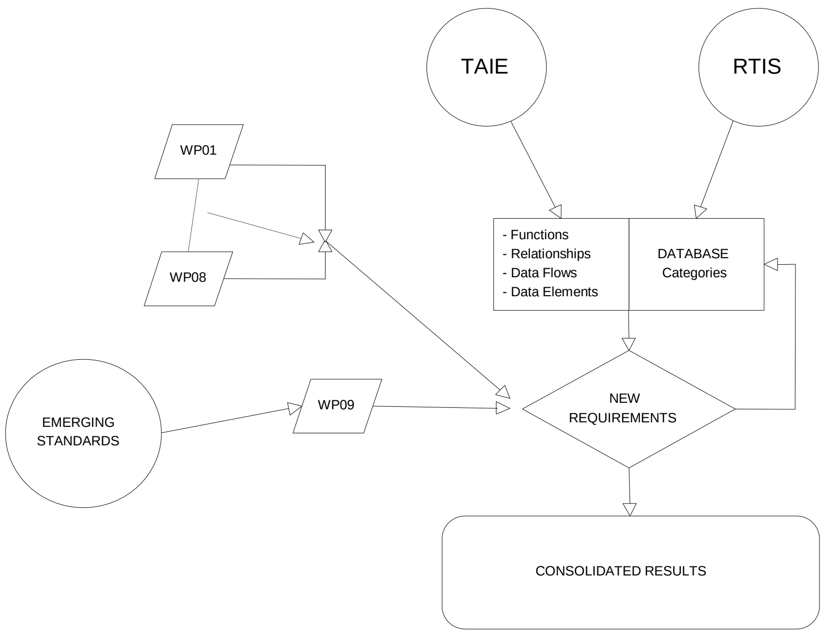


Figure 13: Logical links among WP09 and other WPs

The methodology used to derive the data elements is summarised in *Figure 13*. Essentially, this involved an exhaustive, iterative construction of the final set of elements from a wide variety of sources, including previous and ongoing EC projects, as well as other work packages in COMFORTABLE.

4.4.1.1 - Functional description of the system

For the overall description of the system two common formal modelling methodologies were adopted:

⇒ *Data Flow Diagrams*: to describe the functional interrelationship between VTS Functions and the respective data exchange: these are the *transformational aspects* of the system.

⇒ *Object Modelling*: to describe the *static structural data aspects* of the system.

At the end of the design work the following results were obtained:

⇒ A full set of *Data Flow Diagrams*;

⇒ A full set of *Input/Output Messages* and related Symptomatic Events;

⇒ A comprehensive *Data Elements Table* of the C_VTS Database (more than 1500 items);

⇒ A set of top-level *Object Model Diagrams*: a proposed model for the conceptual organisation and aggregation of the many Data Elements, developed with the Object Modelling Technique.

5. Historical review and acknowledgements

5.1 Objectives

As stated in chapter 1.2 the main objective of COMFORTABLE was to develop new tools for VTS use in order to help operators recognise and assess traffic situations, including the evaluation of risk.

Taking into consideration the ever increasing advances in technology, a need was identified for research into the way in which state-of-the-art communications and surveillance techniques, along with the latest in presentation techniques, could be best utilised by the VTS operator. Keeping the improvement to safety, efficiency and the protection of the environment at a level of utmost importance, ways were sought to develop and fine-tune the technology available.

5.2 User- or Technology-driven approach

By studying any “Call for Tender”, for example, it is possible to identify a number of state-of-the-art user requirements based on the latest technology. It might be said that some technology was not yet proven within the field of VTS. COMFORTABLE aimed at not only developing new tools for VTS operators but also to evaluate their usefulness and relevance in various situations. From this it can be said that, for a short time, the beginnings of COMFORTABLE were **‘User-driven’**, the direct influence coming from what the market was asking for.

Following this manufacturers and researchers took hold of the technology available and attempted to exploit it to the maximum. The manufacturers and researchers considered, and developed, a number of applications, leading to the conclusion that COMFORTABLE could be said to be **‘Technology-driven’**, which it remained for the majority of the project.

The last phase of COMFORTABLE grew out of a need to evaluate the tools developed. SATest, developed within COMFORTABLE as a method to evaluate and analyse the new tools regarding the effect on operator performance, dealt with the situational awareness changes on the VTS operator. However, the project management wanted to consider whether the manufacturers and researchers had developed the tools that the VTS operators, of different levels, really wanted. A vehicle was needed whereby the VTS operators and managers could meet and provide input for the manufacturers and researchers, providing opinion on the usefulness and suitability on a wide range of tools, and representing a diverse field of operation.

Not until COMFORTABLE was there a "VTS Operator Forum" established, whereby VTS operators and managers from various European countries could exchange knowledge and experience with the manufacturers and researchers. COMFORTABLE provided the perfect platform for this leading to a series of three interactive workshops being organised. From the interaction that took place it could be said that COMFORTABLE became **'Joint expert-driven'**, with respect to the further development and enhancement of the tools.

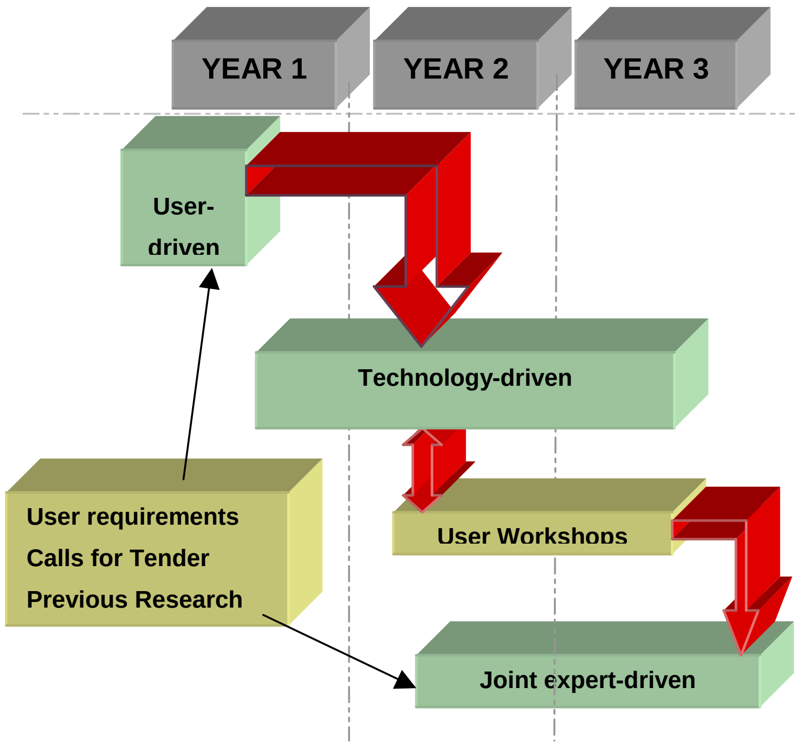


Figure 14: Evolution of user-driven vs. technology-driven approach

5.3 Acknowledgements

Throughout the duration of COMFORTABLE there was a high turn-over of persons involved. Through this we can say that the transfer of knowledge and awareness of the topics considered within COMFORTABLE was conducted at a premium.

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[16] MSR later contracted Peter Coles, under the umbrella of “consistency of reporting”, utilizing his scientific journalism expertise.

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