

Sanna Sonninen, Maaria Nuutinen &  
Tony Rosqvist

# Development Process of the Gulf of Finland Mandatory Ship Reporting System

| Reflections on the Methods





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## Abstract

This research report describes the development of the IMO- adopted mandatory ship reporting system in the Gulf of Finland (GOFREP) and the methods used. The main aim of this publication was to document the development process of the GOFREP system in such a manner that it can be utilised and further developed by others in the construction of a multilateral maritime traffic monitoring and information system. Furthermore, the description of the GOFREP development history aimed to reflect the system in order to guide its further development.

The GOFREP system was jointly developed by Finland, Estonia and Russia and has been operative since July 2004. In this publication the events of the actual GOFREP development are abstracted into five phases. The main objectives of the phases and the main results of each phase are summarised and discussed. The applied methods are also briefly described and the supporting studies reported.

The focus of the publication is on the development of the operation, whereas the other objects of the development get less attention. Particularly, the technical development is described rather superficially.

The development of the GOFREP system is a good example of a time-pressured complex design task that has remarkable constraints. The six guiding principles of the development identified during the process and the practical methods used are suggested also for other design of maritime systems. This publication clearly indicates the need of comprehensive expert influence and commitment in the process of evolving a traffic management system. The process also highlighted the utmost importance of implementing research as an essential part of developing safety-critical systems.

## Preface

The idea of enhancing maritime safety in the Gulf of Finland with a ship reporting system originates from the late 1990s when a significant future increase in the vessel traffic could be foreseen. Especially the obvious growth in oil transportation and the risk induced on the highly sensitive environment of the Gulf raised concern among the authorities of the three shoreline countries. In the summer of 2000, the Finnish Maritime Administration, VTT Technical Research Centre of Finland and Saint Petersburg Business Contact Centre started a joint preliminary survey on the advantages of implementing a joint VTMS (Vessel Traffic Management and Information System) for the Gulf of Finland. Encouraged by the results of the study, the Finnish Maritime Administration started preparations to develop the VTMS system for the Gulf of Finland together with the Estonian and Russian Maritime Administrations. A VTMS is a kind of an umbrella for relevant activities of which the mandatory ship reporting system for the Gulf was decided to be the first new activity to be developed. The goal of this publication is to describe and reflect the development process of this system.

The development of an IMO (International Maritime Organisation) approved mandatory ship reporting system, later named as the GOFREP system and the amending of the existing traffic separation scheme (TSS) were engaged as parts of VTMS development. The first milestone of this development was the signing of a Memorandum of Understanding (MoU) between the Ministry of Transport and Communications of Estonia, the Ministry of Transport and Communications of Finland and the Ministry of Transport of the Russian Federation. This MoU on strengthening the cooperation to further enhance maritime safety in the Gulf of Finland came into force (with the last signature) on October 30, 2001. After the MoU was signed, the realisation of the Gulf of Finland VTMS became a part of the Finnish Cabinet Platform in 2002.

The main points of the MoU were the need to amend the traffic separation schemes in the Gulf and to launch the development of a joint VTMS. The work was started immediately. As a result (the first steps of the VTMS), the amended traffic separation schemes and the mandatory ship reporting system were submitted for approval to the IMO Sub-Committee on Safety of Navigation

(NAV) at its 48th session. The adoption by IMO at its Maritime Safety Committee meeting in 2002 set in motion a versatile development process that this publication focuses on.

After several phases of development, research, surveys and meetings, the GOFREP system was ready for operation in July 2004. The development process lasted more than five years as a whole with a stronger effort and investment during the last three years. The work was mainly financed by the national authorities of the cooperating countries with the Finnish Maritime Administration paying for the operational development. Part of the work was financed by the Safety and Reliability Technology Theme at VTT.

This development work became a success story with the help of several organisations that are not all mentioned here. I would like to express my gratitude to the representatives of the cooperating countries Estonia and Russia for the work done. Especially I would like to thank colleagues at the Estonian Maritime Administration, the Russian Maritime Administration, Rosmorport and its predecessor, the Port Authority of Saint Petersburg and the Russian Central Marine Research and Design Institute (CNIIMF). Their work and commitment to the development has made the realisation of the GOFREP system possible. I would also like to thank all the national parties that have cooperated, all the operational personnel at the VTS and GOFREP Centres as well as the VTT research personnel for their efforts. In addition to these resources from Estonia, Finland and Russia, I would like to acknowledge the close cooperation with the Channel Navigation and Information System (CNIS) in Dover.

Helsinki

Matti Aaltonen

Director, Traffic Department

Finnish Maritime Administration

## **Acknowledgements**

The effective and successful cooperation of the key organisations, the Finnish Maritime Administration, Estonian Maritime Administration, Port Authority of Saint Petersburg and Rosmorport was essential for the success of the GOFREP development process described in this publication.

Several organisations deserve acknowledgement for their contribution to the development process. Some of these are named by Director Aaltonen in the foreword and others appear on the pages of this publication. We hope that we have remembered to mention everybody since in our opinion the development process was a success story thanks to the knowledge of these numerous participating experts and their willingness to contribute.

We would also like to thank The Finnish Maritime Administration and The Ministry of Transport and Communications for their commitment to the development and for the opportunity to be a part of this development process. Thanks are extended to Deputy Director Kari Kosonen from the Finnish Maritime Administration who cooperated closely during the writing process.

Helsinki, May 2006

Authors



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## List of acronyms

AIS	Automatic Identification System
CAWP	Contextual Assessment of Working Practises
CNIS	Channel Navigation Information System
COLREGS	Regulations for Preventing Collisions at Sea
CTA	Core Task Analysis
DCU	Dynamic, Complex and Uncertain
DJP	Document of Joint Procedures
FSA	Formal Safety Assessment
GDSS	Group Decision Support System
GOFREP	The mandatory ship reporting system in the Gulf of Finland
IALA	The International Association of Marine Aids to Navigation and Lighthouse Authorities
ICT	Information and Communication Technology
ITS	Intelligent Transportation Systems
HCD	Human-Centred Design
HSC	High Speed Craft
IMO	International Maritime Organization
MCA	Maritime and Coastguard Agency

RCO	Risk Control Option
R&D	Research and Development
SAR	Search and Rescue
SAT	Site Acceptance Test
SRS	Ship Reporting System
TSS	Traffic Separation Scheme
VHF	Very High Frequency
VTM	Vessel Traffic Management
VTSS	Vessel Traffic Service
VTMIS	Vessel Traffic Management and Information Services
WG	Working Group
XML	Extensible Markup Language

# 1. Introduction

## 1.1 Aims and structure of the publication

This publication describes and reflects the development process of the mandatory ship reporting system (SRS) in the Gulf of Finland (GOFREP). The focus of this publication is on the development of the operation, “the human part of the system”, whereas the technical development is only described superficially. The Finnish Maritime Administration (FMA) occupied a leading role in the described development process of the Finnish-Estonian-Russian system. The FMA managed the progress of the process as well as funded a significant part of the work. VTT Technical Research Centre of Finland acted as a facilitator, largely of the actual coordination of the development process in co-operation with the FMA. VTT also conducted the majority of the necessary research during the process. In part the research concentrated on the actual operation of the system and in part it was supportive research. Several reports and articles on the development and the conducted research already exist but they do not offer a comprehensive description of the whole process. The FMA trusted the conducting of this task to VTT.

The main aim of this publication is to document the development process in such a manner that it can be utilised and further developed by other stakeholders meeting similar challenges to those experienced in the construction of a multilateral maritime traffic monitoring and information system. The process included a variety of activities and methods deemed necessary for successful development. This publication focuses on the assessment of the impact of the system on the safety and efficiency of vessel traffic and on human-related methods. During the development work it became obvious that the existing guidance may not give adequate support for developing the various systems. It was seen that if processes like the development of GOFREP were systematically documented, they would form a valuable source of material for enhancing the present guidance and for supporting the people responsible for the development of similar systems. This was our motive in describing the development history and the methods used, and in reflecting those. At the same time we also acknowledge that requirements and challenges vary and are individual making it impossible for the guidance to ever be comprehensive to the detail. Therefore,

the publication includes what was done, by which methods, why it was done as it was and what proposals for improvement or issues to be perceived we found important to take into account in developing similar systems.

The publication also documents a part of the national SRS history and it can be used in guiding future development. During the development work 7 research reports and dozens of other publications were written in Finland as well as in the cooperating countries. A more detailed description of the development activities, their progress and the methods applied can be found in these various existing documents (FMA, 2004a; 2004b; 2004c; Nyman et al., 2002; Sukselainen & Rytönen, 2001; Rytönen et al., 2002; Rosqvist et al., 2002; Sonninen, 2002; 2004; Sonninen et al., 2004a; 2004b; Sonninen & Savioja, 2005; Nuutinen et al., in press).

This publication starts with the description of the background of the GOFREP development. In Chapter 2 we shortly summarise the way we abstracted the development as a phased process. In Chapter 3 the result of the development work, GOFREP, is briefly described together with the summation of the main events of the development. In Chapters 4 to 8 the GOFREP development process is reported in more detail as five separate phases. In the last section we summarise and discuss the emerged system and the development process.

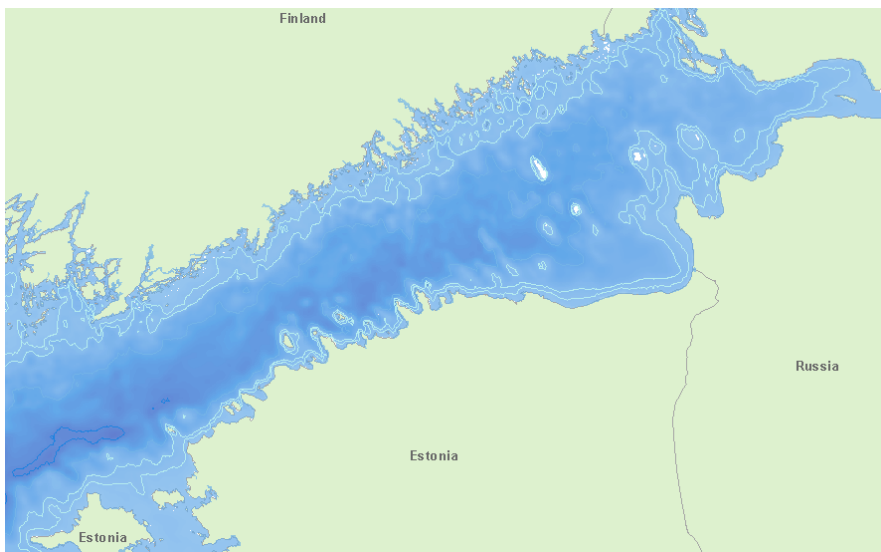
## **1.2 Background**

### **1.2.1 Operational environment**

The coastline of the Gulf of Finland is an environmentally rich ecosystem with natural beauty. It is also economically extremely important to the societies of the shoreline countries but also to the individual citizens to whom the Gulf provides living and recreation. In the same way the shoreline countries had strong national needs for the protection of this gulf but they also had common concerns and goals to be achieved.

The Baltic Sea is the largest brackish body of water in the world and has always been an important sea route connecting the Nordic countries and Russia to continental Europe and beyond. The Gulf of Finland is situated in the north-

easternmost part of the Baltic Sea. It is approximately 400 km long and from 58 to 135 kilometres wide and surrounded by the three shore states: Estonia, Finland and Russian Federation. The average depth of the shallow Gulf is 37 metres, the eastern part and the coastal areas being even shallower. Only the central part of the Gulf is relatively deep, on average 60 meters. There are numerous environmentally sensitive areas along the coastline of the gulf that have the status of protected area or conservation area. In 2005 nearly the entire Baltic Sea and the Gulf of Finland as a part of it was adopted by IMO as a Particularly Sensitive Sea Area (PSSA). This unique sea area provides income to many and serves as a recreational area to even more. (See Figure 1.)



*Figure 1. Depth relief map of the Gulf of Finland (picture: HELCOM, MARIS-system, online: [www.helcom.fi/gis/maris/en\\_GB/main/](http://www.helcom.fi/gis/maris/en_GB/main/)).*

Navigation is difficult in the Gulf as its narrow entrance fairways wind to ports between islands, shoals, rocks and grounds. Pilotage is compulsory in territorial sea. In the wintertime navigation is further impeded by ice. The Gulf is typically partly frozen from December to March making it necessary to ensure the safety and efficiency of maritime transportations by ice breaker assistance during this time.

The Gulf of Finland is an important transport corridor to all of the three shoreline countries. There are more than 20 ports handling goods in foreign



traffic. In addition, several minor ports operate in the area. The major ports such as Helsinki and Sköldvik in Finland, St. Petersburg and Primorsk in Russia and Tallinn and Muuga in Estonia handle a significant amount of each of the countries' total waterborne transport. Approximately 80 percent of Finnish foreign trade is transported by sea.

Today the Gulf of Finland is among the densest maritime traffic areas in the world; nearly 300 vessels pass through the Gulf daily and on a busy summer day this figure exceeds 400 transits. A characterising feature in the diversity of the vessel traffic is the crossroads between Helsinki and Tallinn: heavy north-south direction passenger traffic between these cities including high speed crafts (HSCs') and ferries crosses with the east-west direction tanker traffic in the centre of the Gulf. Six million passengers travel between these cities annually. A variety of cruise vessels, RoRo Passenger vessels and other cargo vessels navigate in this same area. In addition there is a busy passenger traffic route between Helsinki and Stockholm and a high traffic density of recreational traffic (in the summer time).

### **1.2.2 Identification of a need for system implementation**

The development of society and the growth of trade are reflected to the development of transportation in the Gulf of Finland. Furthermore, the strong economic growth of Russia and Estonia has made the increase substantially bigger than the average rate of growth in the Baltic Sea area. Russia lost many of its important ports with the disintegration of the Soviet Union and consequently started the work to build new ports and terminals and to improve the existing facilities. Particularly the efficient construction of oil harbours has resulted in an unforeseen and rapid increase of oil transportation in the Gulf of Finland. The development in Estonian ports has also been strong and it became even more rapid when Estonia joined the EU. The number of vessels presently transiting the Gulf of Finland has doubled in less than a decade. When the present development plans are realised, the vessel traffic will continue to increase.

There are three major causes for the increasing and diversifying of vessel traffic flows in the Gulf: passenger traffic between Helsinki and Tallinn, tanker traffic to the Russian oil terminals and general increase of waterborne transportation

due to a strong economic growth and EU membership. The number of passenger vessel transits between Helsinki and Tallinn increased rapidly from the mid 1990s to the beginning of the millennium. The volume of oil transportation was 50 million tonnes in 2001 and 128 million tonnes in 2005 (Figure 2). According to Finnish Environment Institute (SYKE) the amount is expected to increase from 200 up to 250 million tonnes by 2015 (SYKE, 2006). These two traffic flows of tankers and passenger vessels, along with the numerous other vessels and recreational boat traffic, cross one another in the narrow part of the Gulf between Helsinki and Tallinn. Though it is not the only high risk area in the Gulf, this area in particular is seen to cause a potential threat to the safety of navigation and to the marine environment.

The risk induced by the heavy vessel traffic is especially highlighted in the Gulf since the marine environment is so sensitive. The main safety concern related to the increasing ship traffic in the Gulf of Finland is the increase of the risk of collisions between different types of vessels, and environmental damage due to subsequent oil spills.

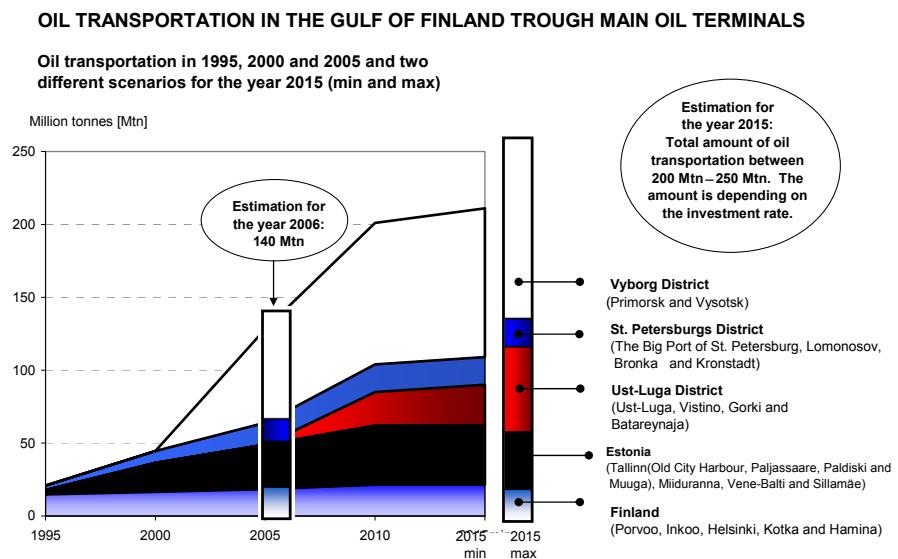


Figure 2. Oil transportation in the Gulf of Finland through main oil terminals (picture: Finnish Environment Institute SYKE).

### **1.2.3 Visions and challenges of the new system**

An accurate reconstruction of the original vision(s) of the new system and its objectives afterwards is difficult. The starting point for the development was to ensure that the safety level of the Gulf would not decrease. Therefore, the foreseen growth in the accident risk needed to be controlled. In practise, this meant that the developed system should be able to mitigate the increasing risks, especially the risks of collision and grounding by upholding a comprehensive sea traffic image and by gathering and providing relevant information to the ships navigating in the area.

This objective was ambitious for a “mere” mandatory ship reporting system since its task would grow from being just the information collector to the responsibility of intervening into potential hazard situations. The original definition of the system, VTMIS can be seen to have influenced the developers’ understanding of the general objective. This general objective had an impact on the technical objective that was shaped into being the creation of a vessel traffic information database and exchange system where accurate, high quality traffic information could be collected and stored. Furthermore, the definition of what information is essential to be exchanged between the national SRS Traffic Centres needed to be decided. Thus, the developing of these technical means became one of the main objectives. The implementation of Automatic Identification System (AIS) was in progress at the time of the GOFREP development and the utilisation of it to the largest possible extent was self-evident through the process.

Three important aspects in the visions of the system can be recognised retrospectively: the aimed system should actively and efficiently operate in such a way that the risk of accidents can be reduced; the service provided to vessels should be identical in spite of the fact that it is offered by three different countries and the operation should be high- quality from the first day that the system operates.

The projects funded by the EU during the 80s and the 90s, such as COST-304, VTMIS-NET, VTMIS-Compendium and POSEIDON were among the strong contributors to the early shaping of the use of VTMIS as a risk control measure for the Gulf, to name just a few. Both the authorities and research institutes

participated in these projects and the results of the projects were considered to be highly beneficial for the development of new measures to enhance maritime safety in the Gulf. The definition of VT MIS and VTM (Vessel Traffic Management) were developed by the “Concerted Action on VT MIS”. This was a group of representatives from Member States of the European Community, involved in research and development (R&D) on VT MIS within the European Fourth Framework Programme. These definitions were adopted as the guidance for the system to be pursued for the Gulf of Finland in the initial discussions. A quotation from the definition:

*Vessel Traffic Management: the set of efforts (measures, provisions, services and related functions) which, within a given area and under specified circumstances, intended to minimise risks for safety and the environment, whilst maximising the efficiency of waterborne and connecting modes of transport.*

*Vessel Traffic Management and Information Services intend to respond to public and private demand for facilitating Vessel Traffic Management. VT MIS include services distributing in given areas (at regional, national or transnational level) the pertinent information to be used both in real time and in retrieval modes by actors involved.*

The Concentrated action further complemented the definition:

*VT MIS are not (existing) systems or services. It is a concept, a kind of umbrella, for all activities improving the exchange of information for the services relating to movements of vessels or the cargo. The shortest possible description would be: “VT MIS are improving vessel traffic information.”*

It was clear from the early steps of development, that there is a need to implement a system that actively assesses navigational situations, detects the developing hazardous situations and provides the relevant parties with proper information accordingly. This is the task of a VTS but since the risk area is on international waters and in accordance with international law, a VTS could not be implemented.

Several challenges on the operational development of the new system requiring careful consideration were recognised from the very beginning of the development. First, the involvement of three countries with the development created obvious challenges relating to cultural differences, different resources and a different history and state of the vessel traffic surveillance. Russia is not a member of the EU and in the beginning of the planning the situation of Estonia was the same.

The second main challenge was the strict time limit: after IMO accepted the submitted proposal for the mandatory ship reporting system in the Gulf of Finland and the amending of the TSSs in the area, the date for the commencing of operation was set, which created time pressure for the development.

The third challenge was the result of ambitious general objectives for the new system: the risk of accidents should be reduced; the service provided to vessels should be identical and the service should be high-quality from the first day that the system operates. Together with the others the objective of high quality directed the focus of the development efforts into the human part of the system: on operations, operational procedures, training and common agreements on the nature of the system. The development of operational procedures for a new system is always challenging, but because of the above recognised challenges common investment of time and energy into the development was considered necessary. An important prerequisite for the strong Finnish contribution to this development was the already existing VTS infrastructure and VTS system.

#### **1.2.4 Theoretical approach**

The challenging development task required an interdisciplinary approach and flexible interaction between practical development and theoretical and empirical research. In addition the methods applied should be used efficiently and with careful consideration of their applicability for the particular question in hand. Since the aim of GOFREP is to enhance safety the broad tradition of safety research served as a point of departure with particular emphasis on approaches and methods presented in human factors, cognitive ergonomics and risk analysis literature. The terms human factors and cognitive ergonomics are used commonly when referring to the research area in psychology, which is

characterised e.g. by a systemic notion of human-environment (or technology) interaction and aimed to improve the performance of the whole system (Norros & Leppänen, 2000; Leppänen & Norros, 2002). A further reason for adopting safety research as a starting point was that the important role of human performance has become very palpable in the form of accidents and thus human performance has gained lots of attention in the safety critical domains (see e.g. Dekker & Hollnagel, 2004; Dekker & Woods, 1999; Hollnagel, 2004; Perrow, 1984; Reason, 1990; Turner & Pidgeon, 1997; Vicente, 2004). We aimed to integration of disciplines (Kontogiannis, 1999), different theoretical frameworks (Jackobsson Kecklund, 1998), lowering of the boundaries between different domains and approaching human performance from a multidimensional perspective (integrating different sub- and disciplines and views of researchers and practitioners) (Morphew, 2001) that are suggested in order to improve understanding of human performance, and especially to find efficient countermeasures against stress (see also Nuutinen, 2006).

GOFREP was considered as a complex socio-technical system characterised by: large problem space, social, heterogeneous perspectives and values, geographical and cultural distribution, dynamic and delayed control, potential hazard, coupling with other systems, automation, uncertainty and defectiveness of data, mediated interactions, disturbances and unexpected events (Vicente, 1999 pp. 14–17). The term socio-technical system refers to a set of interrelated technical, psychological and social elements that share a common goal or purpose (see Vicente, 1999 p. 9). The triple aim of the truly efficient complex socio-technical system as safe, productive and health promoting according to Vicente (1999) was adopted as the frame in which the operator performance should always contribute.

Operational procedures have been and are one of the most important means to ensure adequate level of human performance in safety critical domains. This can be considered as an example of standardisation, a development strategy or philosophy that is strong in the complex socio-technical systems in safety-critical domains (Norros & Nuutinen, 2002). There are also different other ways of promoting human performance e.g. by choosing an adequate automation strategy, human-centred design (HCD) of technology and training all of which can acquire different form and content according the background philosophy. The recognised need of adaptation of operator performance both situationally

(e.g. Norros, 2004) and over time (e.g. Gauthereau, 2003; 2004; Hollnagel, 2002) in reaching safety has challenged the idea of standardisation (see e.g. Vicente, 1999 p. 22; Dekker, 2003; Norros & Nuutinen, 2002; Norros, 2004 pp. 217–218) as a main strategy to ensure a high level of operator performance (Nuutinen, 2005b; Nuutinen & Norros, in press). Because of the complexity of these systems, the aimed outcome (e.g. enhancing traffic safety and efficiency) cannot be achieved by doing things always in the same way. The situational factors should be taken into account. Further, there has to be possibility to change practises and develop new skills and knowledge when the operative environment changes (Nuutinen, 2006). Strict proceduralisation can also restrict the possibilities for learning through daily work (Norros & Nuutinen, 2002; Nuutinen, 2005a). There was still room for other choices of development strategy in this early phase of the construction of the new activity. For example McCarthy et al. (2004) emphasise the active role of the workers making sense of their activity, creating goals and adapting artefacts beyond the task descriptions and official definitions of the goals.

For above reasons, we utilised the Core-Task Analysis (CTA) framework, which rests on over 20 years of interest in understanding adaptive human action and sense-making in dynamic, uncertain and complex work environments and careful theoretical and methodical integration (Norros, 2004; see also Section 6.4). The concept of *core task* means “the shared objectives and the outcome-critical content of work that should be taken into account by the actors in their task performances for maintaining an appropriate interaction with the environment” (Norros, 2004 p. 17). The approach has been developed at VTT for analysing the work demands and the construction of the work activity and competence in order to support design and development of complex socio-technical systems. CTA draws from several theoretical approaches. It exploits ideas of the cultural-historical theory of activity (Engeström, 1987; 1999a; Leont’ev, 1978; Vygotsky, 1978), and the functionally oriented cognitive task analysis tradition (e.g. Rasmussen, 1986; Vicente, 1999; for more detail, see Norros, 2004). The framework has been utilised for different purposes in process control and supervising work (e.g. Norros & Nuutinen, 2002; Hukki & Norros, 1998; Klemola & Norros, 1997; 2001; Norros & Klemola, 1999; 2005; Nuutinen, 2005b; 2006; Nuutinen et al., in press), in organisational culture studies (e.g. Reiman & Norros, 2002; Oedewald & Reiman, 2003; Reiman &

Oedewald, 2002a; 2002b; 2004) and in accident investigation (Norros & Nuutinen, 1999; Nuutinen & Norros, 2001; in press).

Thus, GOFREP was approached within the above general framework as a complex socio-technical system, bound by constraints and enabled by possibilities (Vicente, 1999) of the current and historical constituents of the activity system (Engeström, 1999; see also Section 8.3.2). From this perspective e.g. the general aim of the operative design of the new system was that the core task demands of the GOFREP operators remains reasonable and they have adequate resources and competence to cope with the demands in the changing operative environment.

### 1.3 Guiding principles

The development work should realise the envisaged system. The ambitious objectives, the recognised prerequisites and identified challenges created the basis framed by the chosen theoretical approach. The development work was guided by several principles that were:

1. international cooperation in order to promote the harmonisation of maritime systems
2. utilising of scientific methods and research for system development and for supporting decision making
3. user-centred development
4. trilateral development
5. utilisation of existing constructions and systems
6. learning from the operation of existing systems also other than maritime systems.

One of the starting points was a serious concern for the accelerating growth of introducing new systems to the mariners. The aim was that the required system knowledge and the additional requirements imposed to the mariners would have to be kept to a minimum. The mariners' possibilities to focus on their *core task*, navigation of the vessel, should not be compromised by introducing complicated



and unique systems. The mariners should not have to adjust to variable demands and confusing differences between systems that are categorised under the same label. Thus, the systems all over the world under the same category should be as similar as possible in spite of their location and their demands should be unambiguous. The necessary local and other contextual instances should be carefully considered and the way they are brought to attention should be planned specially. **Active involvement in international cooperation** was seen as a precondition for the development but also as a possibility to have an impact on how the systems are defined and understood internationally.

Another guiding principle was to **utilise scientific methods and research** during the development process. Conducting studies with a narrowed focus can produce valuable information supporting the decision making and directing the development efforts. The results of the studies can also be used to show the benefits of the decisions. The different methods originating from the research can be utilised both for special purposes (e.g. Formal Safety Assessment [FSA]) or for creating frameworks structuring the practical development. These ensure that the development processes cover all important objects and factors. Recognising the need of studies and applying the available methods for purposes they can best serve is essential. The applied and modified methods can also create a basis for the practical methods needed for different purposes in the operative system. Adopting this principle was considered important for ensuring high quality and cost-effectiveness of the development process – and the aimed system.

**Commitment to the principles of user-centred design** was one of the main starting points of the development. This, for example, meant that the need of the new technological systems was critically evaluated and the objects of the investments carefully chosen from the perspective of the expected benefits for the actual operation. The operational development cannot be done without the effort and knowledge of the experts on the various related subjects. The expertise required included: vessel traffic management and information systems, navigation and vessel traffic in the Gulf of Finland, winter navigation, hardware and software development, Search and Rescue (SAR), Navy, Coast Guard, psychology, human-technology interaction and risk analysis etc. The strong emphasis on the real end users and the new system operators' prerequisites for working in every country guided the whole development. The commitment of the key persons of the aimed system organisation and the persons owning

executive power to the development was considered important already at an early phase of the development. Thus, the development work pursued the interaction of the bottom-up construction and top-down standardisation through the development (see e.g. Nuutinen et al., in press; Nuutinen, 2006). By a bottom-up construction we mean the development achieved with participation of the different experts and their efforts to create a common understanding of the system to be. On the other hand, top-down standardisation includes activities and decisions that restrict, define and enable the development by ensuring that the socially constructed conceptions and agreements gained by the people participating in the development become documented and accredited.

**Creation of a common goal and genuine cooperation between the participating countries** was considered essential for the success of this user-centred development. The development of a ship reporting system in international waters requires commitment and agreement of all the shoreline countries.

**Utilisation of existing constructions and systems** in the participating countries and **learning from the operation of the existing ship reporting systems and other systems** around the world were principles the adoption of which aimed at cost-effectiveness of the development process but also at ensuring the high quality of the new system. For example, guidance from available sources was sought to advance the developers' knowledge on the development. Though the services provided at the Gulf of Finland outside the national VTS areas are not VTS services, the aims and modes of operation in the aimed system were very comparable with the VTS operations. Thus in addition to the relevant guidance for SRS operation (IHO/IMO, 1998; IMO, 1972; 1974; 1977; 1989; 1994; 2000; 2001) the guidance given in the IALA VTS Manual (IALA, 2002) for the development of VTS, the IALA Recommendation (V-119) on the Implementation of Vessel Traffic Services (IALA, 2000a) and IMO resolutions (IMO, 1974; 1997) were seen as the main source of reference when planning the development process.

## 2. Description of the development as a phased process

### 2.1 Development phases and their objectives

In this publication the course of the actual GOFREP development is abstracted as a phased process. The phases of the development were:

1. preconditions for the development process
2. definition of the aimed system
3. design of common operations and provision of resources
4. validation and implementation of the new system
5. establishment of continuous development.

To ensure that all relevant aspects of development should be considered the development task was divided into three foci: normative constraints, resources and operations.

**Normative constraints** refer to e.g. international and national laws, rules and regulations and responsibilities that restrict and enable the development and the operation of the system.

**Resources** refer to the technical and other facilities and human resources e.g. in terms of ensuring the availability of necessary personnel by recruitment and training. In addition, the development work had to ensure that also operations would be ready from the first day of the activation of the system.

By **Operations** we mean everything that is strongly based on people working, knowing, using the available resources, conceptualising their work and identifying themselves as part of the system and organising the work.

On the basis of these the objective for the development could be defined as *a creation of sufficient normative conditions, adequate resources and operation in order to ensure that the aimed system is operative when started.*

Table 1 describes the phases, their objectives, the aimed main results of every phase and the main focus or foci of the development that the phase contributed to. The general objectives described in Table 1 and repeated in the beginning of the description of each of the phases list the objectives that are new to the development process or very important for the phase in question. However, these objectives are not limited to only one phase but some of them are present in more than one phase.

*Table 1. The phases of the development, their objectives, the aimed main results and the main focus or foci of the development which the phase contributed to.*

PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5
<p><b>Preconditions for the development process:</b> Definition of vision, objectives and prerequisites</p> <p><b>OBJECTIVES:</b></p> <ul style="list-style-type: none"> <li>- a common understanding on the need for the system</li> <li>- identification of system prerequisites: <ul style="list-style-type: none"> <li>▪ existing resources: infrastructure, technical systems and applications, facilities, etc.</li> <li>▪ required resources</li> </ul> </li> <li>- high level national and multilateral (participating governments) acceptance and support to the development</li> <li>- organising the relevant people to start the work</li> </ul>	<p><b>Definition of the aimed system:</b> Metalevel system description, international adoption, formation of development organisation</p> <p><b>OBJECTIVES:</b></p> <ul style="list-style-type: none"> <li>- establishment of the development organisation</li> <li>- creation of commonly agreed metalevel system description</li> <li>- conducting a Formal Safety Assessment for cost-effectiveness</li> <li>- getting an international adoption for the system (IMO)</li> <li>- learning from the existing SRS systems</li> <li>- ensuring financial resources for the system construction</li> <li>- presenting the metalevel description to system users for improving the aimed operation</li> <li>- national co-operation with allied services</li> </ul>	<p><b>Design of common operations and provision of resources:</b> Procedures and tools</p> <p><b>OBJECTIVES:</b></p> <ul style="list-style-type: none"> <li>- development of commonly agreed operational procedures to be followed identically in each of the countries</li> <li>- development of user-friendly technical means for ensuring system performance</li> <li>- comparing and harmonising the emerging system and the existing systems</li> <li>- definition of the operators' competence level</li> <li>- production of training material and exercises</li> <li>- amendment of the development organisation</li> <li>- establishment of an operational GOFREP organisation</li> <li>- testing the appropriateness of the procedures and technical facilities</li> </ul>	<p><b>Validation and implementation</b></p> <p><b>OBJECTIVES:</b></p> <ul style="list-style-type: none"> <li>- validation of the functionality of the procedures and technical facilities as an operational entity</li> <li>- system start-up</li> <li>- identification of the risk that the system presents to the national organisation</li> <li>- amendment of the operational GOFREP organisation</li> <li>- checking system operability</li> <li>- creation of conditions for further development by analysing the present organisation, working practices, organisational culture and conceptions</li> <li>- informing the system users</li> </ul>	<p><b>Establishment of continuous development</b></p> <p><b>OBJECTIVES:</b></p> <ul style="list-style-type: none"> <li>- defining and applying a strategy of continuous development</li> <li>- ensuring continuous development by <ul style="list-style-type: none"> <li>▪ applying the used design method for continuous development of the existing system</li> <li>▪ identification of methods</li> <li>▪ establishment of a virtual development organisation</li> </ul> </li> </ul>
<p><b>AIMED RESULT: Mandate to start development</b></p> <p><b>Contributes to</b></p> <p>sufficient normative conditions</p>	<p><b>AIMED RESULT: Metalevel description (general objective for the system) and international adoption</b></p> <p><b>Contributes to</b></p> <p>sufficient normative conditions</p>	<p><b>AIMED RESULT: Common procedures, GOFREP system (technical tools and systems), facilities, recruitment and training, etc.</b></p> <p><b>Contributes to</b></p> <p>sufficient normative conditions, adequate resources and the aimed system being operative</p>	<p><b>AIMED RESULT: Operative system, adequate resources</b></p> <p><b>Contributes to</b></p> <p>sufficient normative conditions and the aimed system being operative</p>	<p><b>AIMED RESULT: Strategy, methods and organisation for continuous development</b></p> <p><b>Contributes to</b></p> <p>the aimed system being operative</p>

## 2.2 The GOFREP development process

The development process was also divided into sub-processes. The development abstraction consists of two main interacting sub-processes: a decision making process and the R&D process. Throughout the development these main processes were extended and sustained with supporting activities. Many of the activities continued through the entire development and thus the placement of activities into phases was somewhat artificial. The applicable methods for every phase were recognised and adapted according to the particular needs of the development, if needed. The main results and documentation of each phase were also described. The description of every phase starts with the figure describing the activities of the phase.

The following subjects are described in each of the phases: Objectives of the phase, main actions of decision making, R&D and supporting processes. The studies conducted and methods applied in the R&D process are briefly described. Also the participating actors and their role are included in the description. The results and documentation of the phase are summarised at the end of each chapter and the recognised needs for the following phases and observations for development of the process are discussed. In the VTS Manual IALA refers to the development process of planning a VTS or enhancing an existing VTS as a Feasibility Study. In the case of GOFREP, most of the tasks listed under the IALA Feasibility Study Phases were conducted, but not necessarily in the same phases, order or extent. The main differences are reflected in some of the discussion chapters but the comparison is not extensive. Thus, for the purpose of this publication and for reasons of not using confusing terms, the IALA Feasibility Study is referred to as the IALA framework and the framework used in the GOFREP development simply as the (GOFREP) development process.

Before moving on to the phases in more detail, a short summation of GOFREP and the main events of the development is presented.

### **3. A summation of the development history**

#### **3.1 GOFREP – Mandatory Ship Reporting System in the Gulf of Finland**

The operation of the Gulf of Finland Mandatory Ship Reporting System is jointly managed by the Finnish Maritime Administration, by the Estonian Maritime Administration in Estonia and by Rosmorport in Russia. Three Traffic Centres operate the Gulf of Finland Mandatory Ship Reporting System: Tallinn Traffic in Estonia, Helsinki Traffic in Finland and Saint Petersburg Traffic in Russia. GOFREP operates in the international sea area of the Gulf of Finland under the guidelines and criteria for ship reporting systems issued by IMO. The operational area of the system covers nearly the entire international water area of the Gulf (Figure 3). All ships of 300 gross tonnage and upwards entering the Gulf are required to participate.

The GOFREP area is divided into two areas of monitoring responsibility with a borderline drawn through the midpoints of the traffic separation schemes off Kõpu, Hankoniemi, Porkkala and Kalbådagrund. Helsinki Traffic in Finland monitors the GOFREP area north of this borderline and respectively, south of the borderline is the monitoring responsibility area of Tallinn Traffic. Since GOFREP operates in the international water area the official language is English.

The aims of GOFREP are to enhance the safety of navigation and to increase the protection of the marine environment. An important means for achieving this is the monitoring of compliance with the Regulations for Preventing Collisions at Sea (COLREGS). GOFREP operation is based on surveillance of vessel traffic (radar and Automatic Identification System, AIS) and navigational marks in the operational area, and of course radio communication. The three Traffic Centres in the coastal countries also exchange information they receive from the vessels reporting to GOFREP through a common database. In addition to the database, other reports such as reports on neglects of the reporting requirements, contraventions, accidents etc. are exchanged.

The Traffic Centres provide information to shipping about specific and urgent situations which could cause conflicting traffic movements and other information

concerning the safety of navigation, such as information about weather, ice, water level, navigational problems or other hazards. A characteristic feature of this northern sea area is the formation of an ice cover during the winter months. During this period the traffic separation schemes may be declared invalid. The Traffic Centres assist vessels navigating in the GOFREP area by informing them of the recommended routes through the ice and of the contact information for the icebreakers.

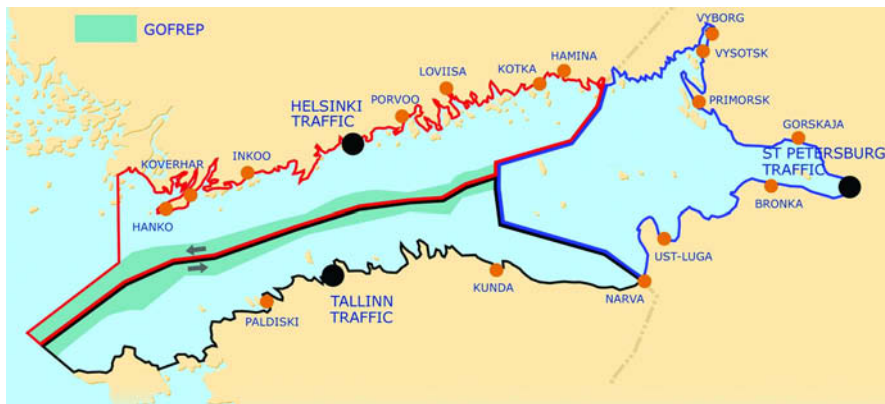


Figure 3. Area of GOFREP, the Mandatory Ship reporting System in the Gulf of Finland.

### 3.2 Main events of development

The idea of enhancing maritime safety of the Gulf of Finland with a VTMIS originates from the late 1990s when a significant future increase in vessel traffic could be foreseen. When comparing the predictions of that time to the realised figures, neither the speed nor the extent of this growth could be estimated at that time. The speed of the construction of Russian oil terminals and other harbours and terminals has been more rapid than the analysts predicted. In addition, efficient development in Estonia has contributed to the total increase of vessel traffic. Based on the indications for future increase of risk for maritime accidents and the number of subsequent oil spills, the Finnish Maritime Administration, VTT Technical Research Centre of Finland and Saint Petersburg Business Contact Centre launched a joint preliminary survey on the advantages of implementing a joint VTMIS for the Gulf of Finland in 2000.



The identification of future change is seen as the starting point of the development process of GOFREP. An important aim of the joint preliminary survey was also to identify the bodies in Finland, Estonia and Russia that are responsible for the development of the VTS environment and to start discussions on the possibility of a joint effort in building a tripartite system for the Gulf. The aims of the preliminary survey also included discussions and outlining of a general level description of the future national vessel service and information systems, strategies and system development. Already at this time it was seen that in the future one of the most challenging aims would be to introduce the Gulf of Finland as a particularly sensitive sea area where special requirements for maritime traffic can be implemented.

The first milestone of the development was reached based on the results of the preliminary survey: a Memorandum of Understanding (MoU) between the Ministry of Transport and Communications of Estonia, the Ministry of Transport and Communications of Finland and the Ministry of Transport of the Russian Federation was signed. This MoU on strengthening the cooperation to further enhance maritime safety in the Gulf of Finland came into force on October 30, 2001. Next year the realisation of the Gulf of Finland VTMS became a part of the Finnish Cabinet Platform and together with the Estonian and Russian Maritime Administrations and the Port Authority of St. Petersburg, the Finnish Maritime Administration started preparations to develop the VTMS system for the Gulf of Finland. The most significant part of VTMS that was to be developed was considered to be an IMO adopted mandatory ship reporting system for the Gulf.

The main points of the MoU were the need to amend the traffic separation schemes (TSS) on the Gulf and to launch the development of a joint VTMS. The work for the implementation of the mandatory SRS, GOFREP, was started immediately. From the beginning to the end of the development work the Finnish Maritime Administration was in a key role in managing and controlling the progress. Two national working groups (WG) were established by the FMA to plan the TSSs and the GOFREP operation: Operational and preplanning WG and Technical WG. In addition, a national co-operation group for the Gulf of Finland VTMS-project was organised among the relevant authorities. The mandate for the work was issued by the Ministry of Transport and Communications. Part of the decision-making organisation in Development

Phase 1 was the tripartite co-operative WG of Finland, Estonia and Russia to whom the results of the national work was submitted for final approval.

The next step of the R&D process was the statistical analysis on the Baltic Sea maritime traffic that produced base material for the evaluation of the operational requirements of GOFREP. This analysis was conducted by VTT and the aim was to obtain accurate information both on the prevailing traffic volumes and future trends (Rytkönen et al., 2002). The work was funded by the Finnish Environment Institute and the Finnish Ministry of Transport and Communications. This analysis gathered information on the volumes of transported goods and the number of ship calls at Baltic Sea ports with a focus on the oil transportation and the forecast of its future development. The main Baltic ports and their basic development plans were also studied. Geographically the survey gathered information from the whole Baltic basin but the emphasis was put on the Gulf of Finland vessel traffic. These base statistics for GOFREP were later twice redefined more accurately to meet the demands of the FSA study (Phase 2) and then the needs of the operational procedure development (Phase 3).

IMO recommends that a Formal Safety Assessment should be conducted to support decision-making. The Finnish Ministry of Transport and Communications decided together with the FMA that an FSA study shall be conducted and submitted to IMO with the proposal for GOFREP and amended TSS. The FSA was conducted by VTT in cooperation with the Helsinki University of Technology during 2001–2002 (Nyman et al., 2002). The economic feasibility of implementing the proposed system as risk control options was the prime assessment problem motivating the FSA study. The outcome of the FSA study clearly indicates that the implementation of the proposed system is highly recommendable and the operation of the system significantly reduces the risk of collision. It was concluded that the positive effect of the system extends to the control of the consequences of maritime accidents.

Based on the work done by the decision making process i.e. FMA and the national and tripartite working groups and the results of the R&D process, i.e. the preliminary survey, statistical analysis and the FSA study, the FMA and VTT prepared documents to IMO for the adoption of TSS and GOFREP. Russian and Estonian representatives participated in the development work actively and the final decision on the description of TSS and GOFREP was made

in a tripartite VTMS working group with representatives from all three cooperating countries.

The amended TSS and the mandatory ship reporting system proposals were submitted for approval to the IMO Sub-Committee on Safety of Navigation (NAV) at its 48th session (IMO, 2002a). It supported the approval of the proposal and the IMO Maritime Safety Committee approved it in its December 2002 meeting (IMO, 2002b; 2003). This set in motion the versatile development process of GOFREP.

When the IMO documents were ready there was no longer a need for national working groups and the whole organisation that was established for the preparative work needed to be rearranged to start the operational development of the now IMO-adopted SRS. The responsibility of the new organisation could not be underestimated. After the positive decision from IMO a development organisation containing three levels was built: an executive level, a preparatory level and an operational level. It was formed by Estonian, Finnish and Russian maritime authorities. The highest decision making bodies outside this organisation were the ministries of the contracting states.

The GOFREP joint operational procedures for the three countries were developed cooperatively in 2002–2004 in accordance with IMO recommendations on systems jointly managed by more than one country. The FMA and VTT considered that the development of joint procedures and evaluation of the correctness and functionality of the procedures could be accomplished in design workshops (Operational Exercises) attended by experts from all three countries. These workshops consisted of planning and selection of potential procedures for assessment, evaluation of their functionality by using simulations and decisions on the best procedures in the debriefing sessions. Simulation was used as a user-centred design (UCD) method for procedure development and it enabled the participants from the GOFREP countries to take part in the development-comparison-judgement process that resulted in solutions that could be accepted by all countries. Four design workshops (Operational Exercises I–IV) were arranged for this purpose.

As a result of the work done in the design workshops and in the Operational Sub-Committee, a Document of Joint Procedures (DJP) was accepted by the

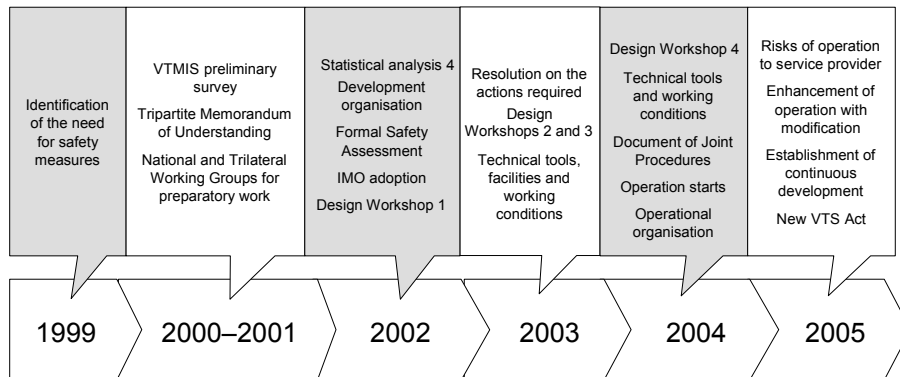
GOFREP countries in June 2004 before the operation started. The DJP describes the external common operational procedures of GOFREP. It is a handbook of procedures and as such an integral part of the daily work in the Traffic Centres and of the regular training exercises. Information on the operation of similar systems was also studied during the development of GOFREP. As a result of excellent co-operation with the Channel Navigation Information System (CNIS), some of the information and details in the DJP were reproduced with the permission of the Maritime and Coastguard Agency (MCA) UK and are congruent with the CNIS Joint Operating Manual. The aim of this was to make the participation into different SRSs around the world easier for mariners by developing similar maritime systems to different parts of the world.

To ensure safe and effective operation of GOFREP more than the common operational procedures for the three cooperating countries were needed. The development of technical solutions and especially the construction of a common information exchange and database system for the national Traffic Centres for storing the information on vessels transiting the Gulf was a necessity. In addition to the database, means to utilise other relevant systems were developed. One of these is the Helcom AIS system, a technical system for mutual exchange and deliveries of AIS (Automatic Identification System) information. This system has been fully operational since 2005 in all Baltic Sea countries and Norway.

On the national level each country ensured that the available sources of information are utilised and that the practical and usable software for the GOFREP operation is available for the operators. In Finland a new module for GOFREP operation was added to the VTS system. This module was developed in close cooperation between the FMA personnel, the VTS-system manufacturer and VTT. Also the building of state-of-the-art premises was undertaken. The premises were built to accommodate all the necessary VTS working positions as well as GOFREP working positions.

The operational level responsible for procedure development was added to the organisation when the decision on the arranging of the design workshops for Expert Working Group was made during this phase. This organisation was later amended when after the system start-up the Expert Working Group was replaced with the Traffic Centre Personnel WG.

After five phases of development, research, surveys and meetings, the GOFREP system was ready for operation in July 2004 (Figure 4). The development process took more than five years as a whole with a stronger effort and investment placed during the last three years – and it is still going on. The process of development should continue throughout the lifecycle of the system.



*Figure 4. Main events of GOFREP development from 1999 to 2005.*

## 4. Phase 1: Preconditions for the development process

Main activities of Phase 1 are presented in Figure 5 below.

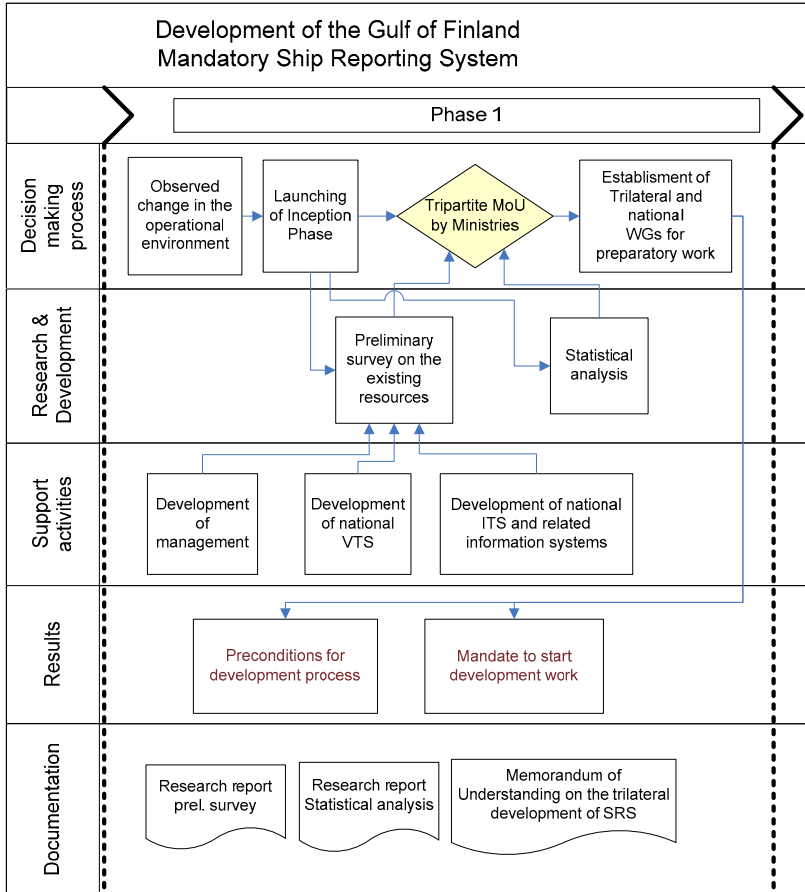


Figure 5. Main activities of Phase 1.

### 4.1 Objectives

During the first development phase the responsible authorities, i.e. the maritime administrations of the GOFREP countries created the necessary foundation for

successful development. This included the structuring of preconditions for the development process i.e. definition of the vision, objectives and prerequisites. The goal of this phase was to obtain a full mandate for starting the development of a VTMISS entity for the Gulf and more concretely the development of GOFREP.

To achieve this goal, the prerequisites for the new system, such as the required infrastructure, technical systems and applications, facilities, etc. needed to be identified and defined. This was realised by conducting a preliminary survey (4.4) on the state-of-the-art in the three shoreline countries and a statistical analysis (4.5) on the Gulf of Finland maritime traffic. The objective of the preliminary survey was to list both the existing and the required resources. A part of this survey was the determination of the existence of a common will for the development and implementation of the VTMISS. With these results the other main objectives of this phase i.e. obtaining of high-level national and multilateral (participating governments') acceptance and support to the development and organising of the relevant people to start the development work were to be achieved. As presented in Table 1, the general objectives of the phase were:

- a common understanding of the need for the system
- identification of system prerequisites:
  - existing resources: infrastructure, technical systems and applications, facilities, etc.
  - required resources
- high level national and multilateral (participating governments') acceptance and support to the development
- organising of the relevant people to start the work.

Of the identified higher level focuses of development (Resources, Normative constraints and Operation) this phase aimed at ensuring sufficient normative constraints (Table 1). In this early stage of the development it is important to recognise the relevant laws, rules and regulations and possible needs for their modification. Furthermore, it is important to define and agree on the responsibilities and authorisations of the different parties.

## **4.2 Main activities of the decision making and R&D processes**

The main activities of Phase 1 included launching of the Inception Phase in the Decision making process resulting in the execution of the needed research in the R&D process to support the decision making process.

The whole process of GOFREP development started when the general need for safety measures for the Gulf was identified in a bilateral Finnish-Russian expert group (Memorandum, 2000). The same group identified the need for conducting the above mentioned preliminary survey. This task was carried out by FMA, Finnish-Russian Business Center and VTT and participated by various experts from Estonia, Finland and Russia. The main findings of the survey showed that there was a considerable difference in the preparedness of coastal countries. However, all countries believed that there is an undisputable need for the system and the will for the development and construction work was strong. The development of VTMISS was strongly supported by maritime authorities, frontier guards and port authorities. Based on expert opinions, the system as it was defined at that time was deemed to be able to reduce risks induced by the growing traffic (Sukselainen & Rytönen, 2001). Also the winter navigation i.e. the operation of ice breakers in their work assisting vessels was seen to be one of the beneficiaries of the VTMISS. Moreover, additional benefits for industry, ship owners and ports were perceived but were not accurately identified and listed during the study. To fulfil the expectations it was necessary to provide a comprehensive traffic image of the Gulf for the authorities responsible for the operation of the main element of the VTMISS, the GOFREP system.

Encouraged by the results of the first R&D process step, the preliminary survey affirmed the identified need for VTMISS and the Ministries of Estonia, Finland and Russia signed a Memorandum of Understanding (MoU) on Strengthening the Cooperation to Further Enhance Maritime Safety in the Gulf of Finland in 2001 (Memorandum, 2001). The main points of the MoU were the need to amend the traffic separation schemes (TSS) in the Gulf and to launch the development of a joint VTMISS. The national maritime authorities were now able to establish a steering group to develop and to coordinate the VTMISS cooperation. Thus the main goal was achieved with the MoU as the basis for the



development work and for the definition of the organisation responsible for this work was created.

Even though no statistical analysis or forecasts on traffic volumes was made during the preliminary survey, it gave indications that the abnormal increase in maritime traffic figures compared to the average increase boosted by economy, had already started and the future increase could be unexpectedly fast in the Gulf of Finland area. This was then verified in the *statistical analysis* (Section 4.5). Based on resulting traffic development scenarios, the main results concluded that the total transportation rate in the Baltic Sea will become two-fold, and the amount of oil transported was predicted to grow three times higher already by the year 2010. At the time of the study the global increase in maritime traffic had been significant for a couple of decades, especially in container vessel traffic. The traffic in the Baltic area had not only increased, but the nature of the traffic had started to change rapidly with the increasing number of liner traffic and the introduction of RoPax vessels and high speed crafts. Perhaps the most interesting development, however, was the very fast development of Baltic and Russian seaport and the tendency of increase in oil transportation, especially in the Gulf of Finland.

### **4.3 Supporting activities**

The supporting activities of Phase 1 included the identification and development of national management organisations (organisation responsible for development), the development of national VTS systems and the development of Intelligent Transportation Systems (ITS) and related information systems (Figure 5).

The national VTS-systems started operation in Russia already in the 1960s and in Finland in the 1990s. When the GOFREP development commenced there was no operative VTSs in Estonia but the first VTS, Tallinn VTS started its operation in autumn 2003. From 1995 until 2001 during the time when the Finnish national VTS network was built to cover all of the main fairways along the Finnish coastline, strong effort was put to both technical and operational development in Finland. The first Finnish VTS Centre, Helsinki VTS, started operation in 1996. The work was completed in 2002 when the only Finnish inland VTS, Saimaa VTS started its operation. Altogether there are six VTS

centres in Finland (starting from the north): Bothnia, West Coast, Archipelago, Helsinki, Kotka and Saimaa VTS. At the same time when the understanding of VTS operations grew in Finland, the need for a similar system was considered and recognised for the whole Gulf of Finland.

In Finland the time of raising concern for the future of the Gulf of Finland was also the time of continuous development and implementation of automatic information exchange and management systems for information related to maritime transportation, i.e. the Finnish maritime ITS architecture (Figure 6). These systems included in the architecture have mostly been developed by the FMA and are very progressive and comparable. No corresponding systems have been implemented even today in most countries. In addition to equipment required for efficient monitoring of vessel traffic i.e. AIS, radar and VTS systems, the ITS architecture includes ICT (Information and Communication Technology) systems such as the PortNet and the Intermodal Portal, the icebreaker management system IBNet, the PilotNet system for pilotage, augmented satellite navigation systems and various registers and databases. All of these, except PilotNet, are used and managed by FMA. Systems like PortNet integrate information obtained from its users among the authorities and commercial stakeholders. The development of the above mentioned systems enabled comprehensive national development of maritime information and monitoring systems. The need for further expanding the role of VTS and GOFREP in Finland into a data management centre supporting incident management was also identified during the supporting process of ITS architecture development (Hautala et al., 2004; Mäkinen et al., 2004; Sonninen et al., 2005). It was concluded that as the operation of the GOFREP and VTS is to a large extent based on national ICT systems they poses a great deal of the information required for maritime incident management. Both the mode of operation and resources enabled GOFREP and VTS to take a role also in the maritime incident management.

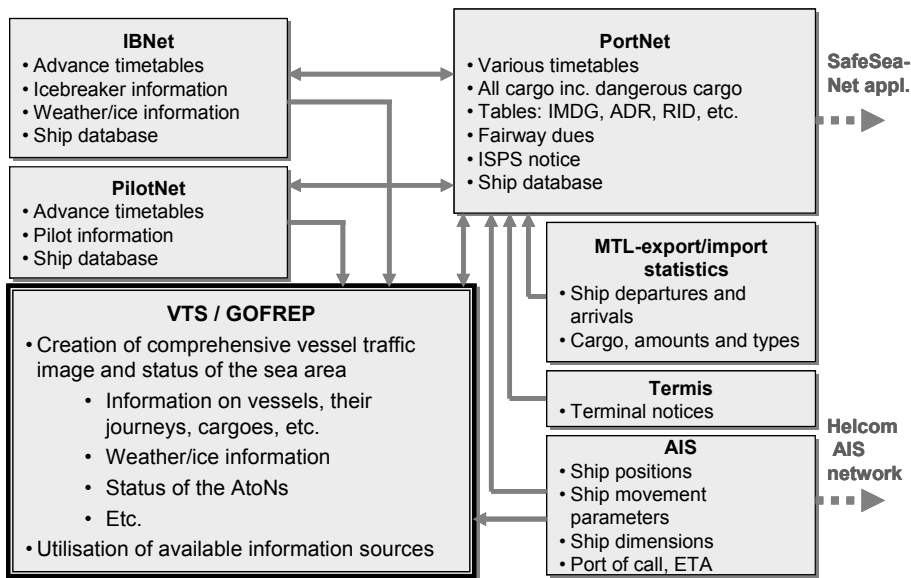


Figure 6. Finnish maritime ITS architecture. PortNet = maritime ITS service portal; PilotNet = vessel pilot management system; IBNet = Ice Breaker information and control system.

During this phase the development idea of a VTMISS was focused on the development of a mandatory SRS. Together with the amended TSSs, these were seen as the first steps towards a VTMISS entity.

## 4.4 VTMISS preliminary survey

### 4.4.1 Background and focus

The concern for future development of vessel traffic in the Gulf of Finland was discussed in a Finnish-Russian Shipbuilding Association seminar in 1999. As a result of these discussions the association gave a statement on the Finnish-Russian Co-operation in Shipbuilding and Environmental Protection in Navigation. After studying this statement the Finnish Maritime Administration, the Technical Research Centre of Finland and Saint Petersburg Business Contact Centre started a preliminary survey on the advantages of implementing a joint VTMISS for the Gulf of Finland in the summer of 2000. The aim of this

preliminary survey was to study the feasibility of a trilateral VTMS from the point of view of the existing equipment, systems and views of the shoreline countries. (Sukselainen & Rytönen, 2001.)

The preliminary survey focused on identification of the present state of affairs and future development. Much of the discussions and evaluations took place in various meetings that were arranged with the Estonian, Russian and Finnish specialists. Visits were also made to the Ports of St. Petersburg, Tallinn (Muuga) and Helsinki to obtain comprehensive insight. In addition, the local VTS centres in the Gulf were visited to create an extensive description of the resources.

#### **4.4.2 Data, methods and participants**

The preliminary survey on the feasibility was based on expert interviews, negotiations in tripartite meetings, information gathering on the available systems and equipment and a literature survey on VTS and VTMS. In addition a restricted study on future development of the ports and terminals in the Gulf of Finland was made by interviewing the representatives of ports and terminals.

The delegation that participated in the preliminary survey from Russia included representatives from the Port of St. Petersburg, VTS experts both from the Russian regional VTS organisation RASKAT and the St. Petersburg traffic control in Petrodvorets centre and from the Ministry of Transport. The Estonian participants represented corresponding organisations including the port authorities, Estonian National Maritime Board and the local Traffic Centre in Pirita Bay and Tallinn. The main representatives of the Finnish delegation were from the Finnish Maritime Administration and its many departments including Helsinki VTS, VTT Technical Research Centre of Finland and the Saint Petersburg Business Contact Centre. Also organisations such as the Ports of Helsinki, Kotka and Hamina and several other experts of the maritime field, ship owners and terminal enterprises provided their expertise to the survey.

### **4.4.3 Findings**

The aim of the preliminary survey was to clarify the feasibility of a regional VTMS system for the Gulf of Finland. The findings showed that there was a considerable difference in the VTS development level and in the national technical preparedness. To construct a VTMS all three countries were required to acquire new systems, equipment, develop training and hire personnel, but the magnitude of the needed measures varied from country to country.

## **4.5 Statistical analysis on the Baltic Sea vessel traffic**

### **4.5.1 Background and focus**

After the preliminary survey had been concluded, VTT conducted a statistical analysis to obtain more accurate information both on the prevailing traffic volumes and the future trends (Rytönen et al., 2002). The work was funded by the Finnish Environment Institute and the Finnish Ministry of Transport and Communications. This analysis gathered information on the volumes of transported goods and the number of ship calls in Baltic Sea ports with a focus on the oil transportation and the forecast of its future development. The main Baltic ports and their basic development plans were also studied. Geographically the survey gathered information from the entire Baltic but the emphasis was put on the Gulf of Finland vessel traffic.

### **4.5.2 Data and methods**

The statistical analysis focused on collecting and analysing seaborne transportation data including all the main groups of cargo and ports in the Baltic Sea. Information was collected under the following topics:

- oil transportation figures and capacities of the ports and terminals
- transportation modes
- transportation units, especially the size and age of tankers and other relevant parameters such as single/double hull, need for ice classification, propulsion system, redundancy

- other main transportation figures
- main routes
- features and navigational difficulty of the port approaches
- defined wind limits for tanker manoeuvres.

Information was collected from the literature and directly from the ports and terminal operators especially for the analysis of the terminal development, forecasts for realigning of supply chains or reconstruction of the logistic systems. In addition to the information obtained from statistical resources such as national statistical offices, Lloyds' database was utilised as a significant source of information for the definition of vessel traffic volumes and cargo flows. Information from the database on the traffic season in May 2000 was selected as a baseline for the study. This information was then analysed using standard statistical applications and the results were verified by comparing them to the existing national statistics representing annual figures. Special attention had to be paid to the overlapping information from vessel traffic that had several ports in the rotation in the Gulf of Finland area to avoid the results being biased due to heavy liner traffic. The statistical analysis was mainly conducted by VTT but the Finnish Environmental Institute also contributed to the study.

### **4.5.3 Findings**

According to the prognoses made in the statistical analysis on the development for the year 2010, the growth in the vessel traffic volumes will be even more rapid than was ever previously foreseen. In addition to the traffic volume prognoses the analyses also included the definition of both present and future main vessel traffic routes.

## **4.6 Results and documentation**

The decision making process (Figure 5) of Phase 1 included the identification of the state of economical development, its future impacts and the resulting needs for actions. The main R&D process of the first development phase included two separate studies: a preliminary survey focusing on the prevailing technical status of national vessel traffic services systems in the shoreline countries and a

statistical analysis on the Baltic Sea vessel traffic volumes. The decision making process included naturally the launching of the R&D process but also the engaging of the whole development process after the preliminary survey was conducted and a resulting Memorandum of Understanding signed. This created an important normative condition. An essential part of the first phase was the naming of the organisation having the mandate for decision-making in matters related to the new system, Gulf of Finland VTMS and its main element, the GOFREP system, in this phase of the development. This organisation included the national Ministries giving the decision-making mandate (MoU) to a Tripartite Working Group and authorising it to establish trilateral sub-committees and working groups to solve any technical, operational, economical or legislative questions and problems that should arise. This organisation was a fundamental precondition for Phase 2, creation of metalevel system description. This development organisation was amended during phases two and three.

## **4.7 Discussion**

If this method of proceeding is compared to the IALA framework (IALA, 2000a; 2002), it only included the parts of the possible initial investigation or the Inception Phase that focus on the questions “what is the present status of the object i.e. the vessel traffic, what is the identified need for implementing any system and what are the available resources in each of the shoreline countries and among the numerous stakeholders relevant to the system”.

The IALA Recommendation V-119 (IALA, 2000a) lists to what the local problems could be related. Of this list the interaction of maritime traffic and volume and mix of traffic were studied. The other listed items were analysed in the FSA conducted during Phase 2. The recommendation also gives a comprehensive list on matters that should be studied during the Inception phase. In the case of GOFREP development, most of these matters were preliminarily studied during Phase 1 and then analysed with more detail during the FSA in Phase 2. The purpose of this practice was to optimise the use of resources that were needed to obtain the necessary information for decision-making. When and if the decision for the implementation is made, resources will be used to conduct more comprehensive analyses.

With the experience gained from the GOFREP development process, the first phase of a such process should focus on the existing state of system prerequisites and the definition of the aims of the measures to be implemented. The accuracy at which Recommendation V-119 and the VTS Manual (IALA, 2002) propose that the matter be studied before decision-making can be argued. This is unless the aim of the Inception Phase is purely to define the problems in hand, and if the implementation of a VTS is not considered appropriate, to choose any risk control measure that is considered suitable.

If the content of the Feasibility Study is compared to the content of a FSA study (IMO, 2002c), two of the Feasibility Study phases are included in the FSA methodology: risk assessment and cost/benefit including the decision-making. The five steps of FSA also include some tasks of the Inception Phase, identification of hazards and description of the operational environment. The use of FSA is recommended but the overlap with the recommended progress of the Feasibility Study should be noted.



## 5. Phase 2: Definition of the aimed system

Main activities of Phase 2 are presented in Figure 7 below.

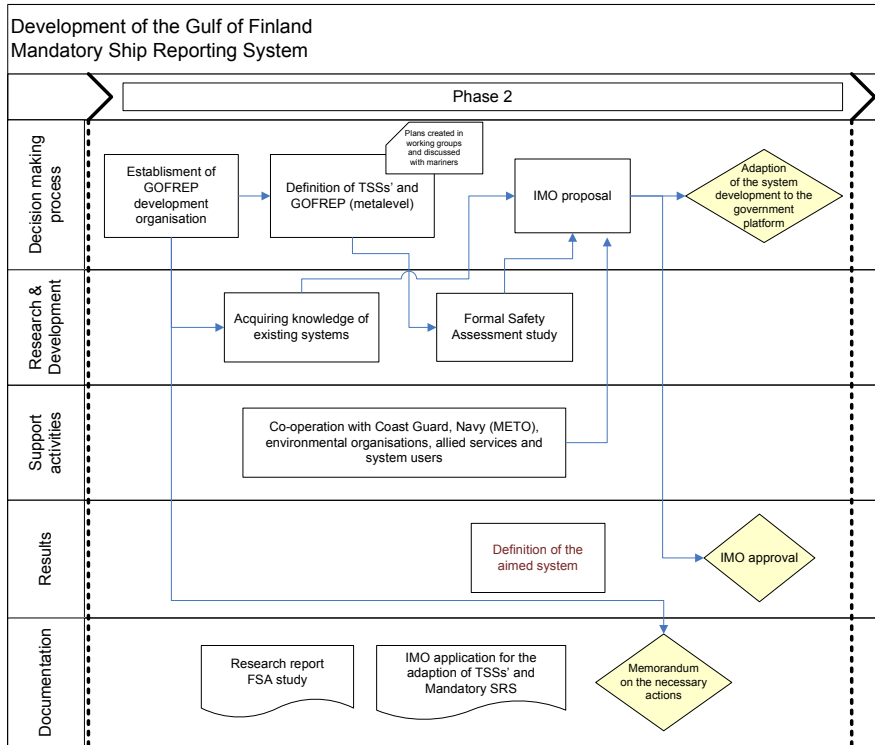


Figure 7. Main activities of Phase 2.

### 5.1 Objectives

The main objective of this phase was to obtain sufficient amount of knowledge and a multilateral agreement for creating and accepting a metalevel description of the aimed system.

The general objectives of the phase were:

- establishment of development organisation based on the preparatory working groups (Phase 1)
- creation of a commonly agreed metalevel system description
- conducting a Formal Safety Assessment for cost-effectiveness
- getting an international adoption for the system (IMO)
- learning from existing SRS systems
- ensuring financial resources for the system construction
- presenting the metalevel description to the system users for improving the aimed operation
- national cooperation with allied services.

The structuring of a preparatory decision-making organisation that enabled both the use of operational expertise in the development and effective decision-making in the wheels of bureaucracy was of utmost importance at this phase of the development. It would further the solving of one major challenge in the GOFREP development: the requirement of fulfilling the needs and standards of three different countries with different cultures and reaching a common understanding on the general objectives and operational aspects.

The most significant objectives of this phase included the obtaining of IMO adoption for the system granting the implementation of GOFREP. When the main operational objectives of the developed system were agreed by the contracting governments it was possible to reach a common understanding of the main functions with which these objectives could be reached. The system was planned to fulfil the requirements set to SRS operation by IMO and all relevant IMO and IALA documentation were naturally followed or used as guidance. Again, though GOFREP is not a VTS, a lot can be learned from IMO and IALA VTS guidance also with regard to SRS operation. In addition to the knowledge obtained from the resolutions, guidelines and recommendations, learning from existing systems was selected as an effective way to improve the development process. Of the contacts to the different traffic centres, cooperation with the Channel Navigation Information System (CNIS) was the most extensive.

## 5.2 Main activities in the decision making and R&D processes

The Ministry of Traffic and Communications in Finland engaged the official national development work on April 11, 2001. At the same time, the GOFREP development organisation also started to take shape, since *the national working groups were established* to fulfil the national responsibilities. In Finland three national working groups, operational and preliminary planning WG, technical WG and a national cooperation group for the Gulf of Finland VTMS-project started their work in 2001. These two first mentioned WGs included participants from the FMA, Charting and fairways department, Maritime department and the Gulf of Finland Maritime District. In addition representatives from the Naval Headquarters, Headquarters of the Frontier Guard and the Gulf of Finland Coast Guard District had participants in all three WGs and VTT participated in the work of the operational WG. These organisations were evaluated to hold sufficient competence for the creation of a metalevel description of the aimed system.

The formation of the basic knowledge for the development started at a national level. In addition to the national tasks, the FMA took the responsibility of compiling the required facts and forming the documents to be submitted to IMO. This division of tasks was agreed in the Tripartite WG. The three above-mentioned national working groups started their work for a metalevel system description. The operational and preliminary planning WG was responsible for the compiling of information from the work of the three national WGs.

Producing the *metalevel system description of TSS and GOFREP* included several tasks, many of which are the same as the objectives of the whole development Phase 2: planning of the amendments to TSS, ensuring that the international requirements are met, learning from existing SRS systems, national cooperation with allied services and system users, etc. The *acquisition of knowledge of existing systems* was mainly based on the literature survey during this Phase. The work done resulted in an improved understanding of the system requirements and good ground for the operational development. Although the tasks included in the production of the metalevel description were mainly fulfilled during this phase, they were tasks that needed to continue throughout the development process.

The cost-effectiveness of the aimed system was assessed simultaneously to the production of the system description. It was necessary to assess the effectiveness of the aimed system or different variants of the system before making the decision on which variant of the system is chosen for implementation. The final choice between the last two potential variants was verified with the *Formal Safety Assessment study* (5.4). The use of FSA methodology is recommended by IMO to support decision-making (IMO, 2002c). This recommendation is also repeated in IALA recommendation V-119 and IALA VTS Manual (IALA, 2000a; 2002). If thoroughly conducted the benefit of utilising the FSA approach for system development is the amount of information it produces to the decision makers: accurate description of the geographical area, comprehensive traffic image, high risk areas, identified environmentally sensitive areas, etc. This is needed not only to evaluate the cost-effectiveness of the system but also for the development of the operation in more detail. The results of the FSA were the starting point of the development tasks in Phase 3.

The Finnish Ministry of Transport and Communication together with the FMA decided that an FSA study shall be conducted and submitted to IMO with the documents concerning the adoption of GOFREP and the amended TSS. The FSA was conducted by VTT in cooperation with the Helsinki University of Technology and the economic feasibility of implementing the proposed system as risk control options was the prime assessment problem motivating the FSA study. The outcome of the FSA study clearly indicated that the implementation of the proposed system is highly recommendable (Nyman et al., 2002; Rosqvist et al., 2002). The operation of the system significantly reduces the risk of collision. It was concluded that the positive effect of the system extends even further, to the control of the consequences of maritime accidents. The system can provide information for many purposes including search and rescue and the prevention of marine pollution. In addition, during the period of winter when the Gulf of Finland is partly or wholly covered with ice GOFREP can relay information between the icebreaker fleet and the vessel traffic assisting the icebreaker fleet in ensuring safe and effective navigation also in ice.

The execution and outcome of the FSA were summarised and appended to the documents to be submitted to IMO. These documents were then forwarded for approval to Russia and Estonia and the information they provided was included. The IMO documents were finalised at a high-level trilateral meeting in March,

2002. As a result of these efforts, the amended traffic separation scheme and GOFREP, the mandatory ship reporting system in the Gulf of Finland were submitted for approval to the IMO Sub-Committee on Safety of Navigation (NAV) at its 48th session (IMO, 2002a). After the NAV approval the proposal was forwarded to the Maritime Safety Committee (MSC) that adopted the mandatory ship reporting system in the Gulf of Finland in December 2002 (IMO, 2002b; 2003). Previously during the same year the realisation of the Gulf of Finland VTMS had become a part of the Finnish Cabinet platform. The work done during the development process had convinced the highest decision-making level that there is need to secure financially the developing and implementation of this system.

When the IMO documents were ready, the national working groups were no longer needed. Now the common system development was challenged by the fact that development tasks were carried out simultaneously in more than one country and the decisions made concerning nearly every detail needed also to be accepted by these countries. To maintain efficient working and decision-making in order to keep the tight timetable, a very functional development organisation was needed. Also in every process a responsible leader is needed and in the case of GOFREP development it was the Finnish Maritime Administration. The mandate to operate for the development organisation was given by the MoU in Phase 1. The MoU e.g. authorised the work of the Tripartite Working Group and gave it the right to appoint sub-committees or sub-working groups to solve any problems arising during the development.

The trilateral development organisation had already started to evolve and was finalised in winter 2003 when the Trilateral Operational and Technical Sub-Committees started their work. The organisation was formed by the Estonian, Finnish and Russian maritime authorities and contained three levels: an executive level, a preparatory level and an operational level (Figure 8). The highest decision-making bodies outside this organisation were the ministries of the contracting governments. The authorities' representation in the different levels of the organisation was nearly always supplemented by representatives of research organisations from the contracting governments: VTT from Finland, Cybernetica from Estonia and Central Marine Research and Design Institute (CNIIMF) from Russia.

The operational level responsible for procedure development was added to the organisation when the decision on the arranging the design workshops (Operational Exercises) for the Expert Working Group was made during this phase.

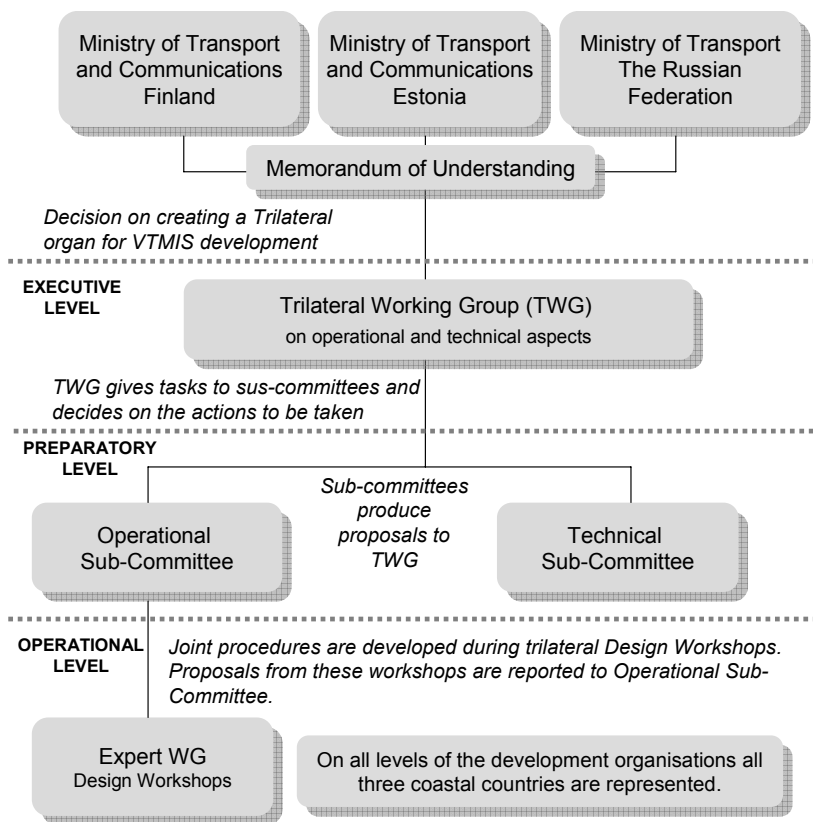


Figure 8. The GOFREP development organisation formed during the second phase.

### 5.3 Supporting activities

Phase 2 aimed to start the cooperation between the system (GOFREP) developers, users and allied services to ensure a continuous discussion throughout the development process. The allied services and system users can provide valuable information for the development and thus the discussions with all relevant parties was started in good time when the system description was

still forming. This enabled the input from these parties to be fully acknowledged in the development.

## 5.4 Formal Safety Assessment

The aim of the FSA study was to assess the effectiveness of the proposed routing, monitoring and mandatory reporting systems as measures to improve maritime safety in the Gulf of Finland by reducing the risk of casualties and increasing the protection of the marine environment (Nyman et al., 2002; Rosqvist et al., 2002). The economic feasibility of implementing the proposed system as risk control options was the prime assessment problem motivating the FSA study. There is a cost to be prevented in every averted collision of vessels that would lead to an oil spill. How much is it worth paying for? This was the underlying question related to the economic feasibility of the implementation of either of the two system options assessed in the FSA.

The FSA was performed in the Gulf of Finland VTMIS – project and it is outlined according to the sub-analyses of the FSA (Figure 9).

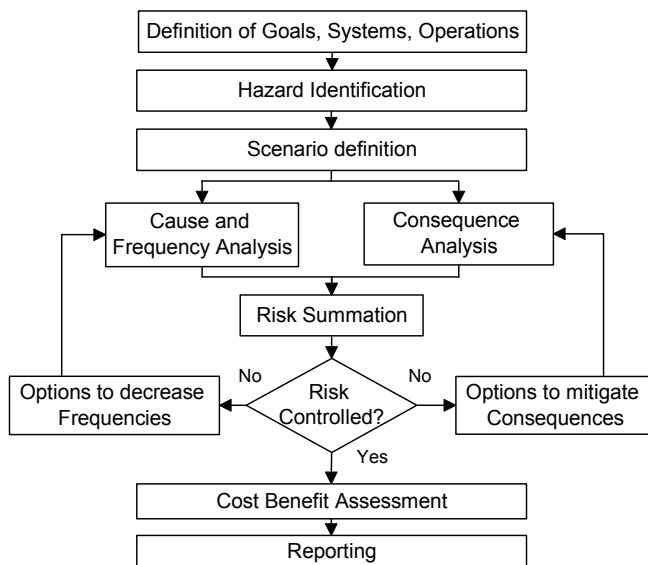


Figure 9. Definition of system and the evaluation criteria.

### **5.4.1 Definition of goals, systems, operations**

Essential limitations of the scope of the FSA were decided in the inception stage of the Gulf of Finland VTMS -project: risk control options based on a modification of a previously adopted traffic separation scheme combined with a mandatory reporting system or a mandatory reporting system including a radar-based traffic monitoring system were considered the only feasible options. Two risk control options (RCO) were thus defined, called ‘System1’ and ‘System2’.

#### **System 1:**

‘System1’ includes the amended traffic separation schemes and the mandatory ship reporting system for the international waters of the Gulf of Finland. This option does not include the radar-based traffic monitoring system.

#### **System 2:**

‘System2’ includes the amended traffic separation schemes, the mandatory ship reporting system and both a radar and AIS-based traffic monitoring system.

The evaluation criterion to be used in the cost-benefit analysis phase was decided to be the Total Return on investment. The cost categories to be included were the damage costs saved by introducing an optional risk control measure (‘benefit’ side) and the implementation costs (‘cost’ side). This presupposed the definition of a baseline risk. The baseline risk was defined to be the risk level represented by ship-to-ship collisions with oil spills with the traffic projection at year 2010.

The FSA study of the above RCOs was constrained to the open sea period. Wintertime risks were evaluated by the Helsinki University of Technology with a similar procedure as described in the following paragraphs.

### **5.4.2 Hazard identification**

The hazard identification was performed in a expert workshop using the group decision support system GroupSystemV as facilitated by a risk analyst and a technical support person. The risk identification was very general: each participating expert was allowed to freely formulate risk scenarios that were



subsequently commented by the other experts. The risk scenarios were grouped into 'technical', 'communicative', 'human error' and 'external'. The hazard identification phase was supported by key words defined for each group. About fifty risk scenarios were produced and ranked by an impact scale from 1 to 10, 10 representing an extremely likely and very severe hazard. Hazards, the ranking of which exceeded five were selected for further analyses, and to direct the risk modelling tasks comprising cause and frequency analysis, and consequence analysis.

The expert workshop was attended by the following representatives of the named organisations:

- Helsinki pilot station, Senior Pilot, Master Mariner
- Finnish Environment Institute (SYKE), Inspector
- Maritime Safety Training Centre, Head of Ship Simulation Unit
- Naval Forces, Commander
- Finnish Maritime Administration, Helsinki VTS, Supervisor
- Accident Investigation Board, Chief Accident Investigator, maritime accidents
- Finnish Environment Institute (SYKE), Senior Inspector
- Finnish Maritime Administration, Senior Inspector
- CHL Consulting Oy, expert in brainstorm methodology, group decision support system (GDSS)
- Silja line Oy, Marine Manager, Master Mariner
- Fortum Shipping, Head of Operational Division, Master Mariner
- Finnish Maritime Administration, Captain of icebreaker Apu
- Finnish Maritime Administration, Chart and Fairway Department, Fairway Designs
- Coast Guard, Sea Rescue Operator.

### **5.4.3 Risk estimation: hazard frequencies and consequences**

The frequency analysis module of the GRACAT software (ISESO, 2000) makes it possible to estimate an annual grounding or collision frequency or probability for a specific vessel operating on a specific route. The specification of the risk calculations includes the fairways and the waypoints, the location of shoals and grounds and other fixed obstacles in the vicinity of the fairways, the flow of traffic on all different fairways and legs, the types and sizes of vessels on the different legs, the velocity of vessels on the different legs, and the ship deviation off the mid-fairway on the different legs. The definition is done separately for both directions of traffic. The fairways are defined by waypoints using true values of latitudes and longitudes. The locations of grounds and shoals are defined similarly by latitudes and longitudes. Furthermore, the depth below the water level, the surface type (hard or soft) and the shape of the shoal/ground are defined. With the waypoints and the shoal/ground information the program then creates a graphical map of the sea area under examination to ease the specification of the calculation cases. The program thus offers the possibility to systematically compare vessels and/or routes regarding the accident risk they represent.

The computational framework applied in GRACAT for the frequency estimations is based on a model developed by Fuji in the year 1974 (ISESO, 2000). In this model, the number of theoretically possible 'latent' collisions per unit time is first determined. Vessels are assumed to navigate their route basically 'blind' and placed on the fairways according to the distributions representing the vessel deviation from the mid-fairway. The estimation of the expected number of collisions per unit time is then obtained simply by multiplying the theoretically possible number of collisions by a (conditional) probability that represents the incapability of the vessel (or vessels) to notice the dangerous situation in sufficient time and to react to it properly by carrying out the corrective manoeuvres necessary to avoid the collision. The 'Causation Factor' used to specify the conditional collision probability takes into consideration, for example, the weather conditions of the area, visibility, manning at the bridge, vigilance and training level of the navigators, quality of the navigation aids, manoeuvrability of the vessels, and the operation practices of the vessels (for example, decreasing the velocity in poor visibility).

In the FSA study, risk estimations were limited to ship-to-ship collision, as the consequences were assumed significantly more severe for these compared to grounding. Regarding ship-to-ship collisions the GRACAT software examines three different types of collision types:

1. Two vessels colliding on a straight leg of the fairway as a result of two-way traffic in the leg and thus the possibility of a head-on collision.
2. Two vessels colliding head-on at a turn of the fairway as a result of one vessel neglecting or missing the turn (i.e., error of omission) and due to that colliding with another vessel moving on the same fairway in the opposite direction (intersection collision).
3. Two vessels using different fairways colliding at the fairway crossing (crossing collision).

At this point it should be noted that the collision type ‘overtaking collision’ is not addressed by GRACAT. ‘Overtaking collision’ refers to a situation where a faster vessel overtakes a slower one on the lane causing a risk situation.

In order to obtain the expected values of the causation factors for each of the above collision type the Fault Tree technique was utilised. The underlying dynamics of the functions related to the causation factor were decomposed into two phases: functions related to escalation of the collision situation and functions related to evasive action (critical collision hazard). Especially, the functions, or more specifically, the functional failures leading to the escalation of a collision situation were structured in more detail, as the anticipated benefits of the pre-defined risk control measures are realised in this phase (Rosqvist et al, 2002). The probability values of the basic events of the Collision Fault Tree were elicited from four experts separately for each of the decision options ‘Baseline2010’ (= ‘do nothing’), ‘System1’ and ‘System2’. It was assumed that the VTS functions were performed exactly as designed with no ‘human error’ on the VTS operators’ side.

For the purposes of using the GRACAT software in the risk estimation, all relevant vessel types in the Gulf of Finland were grouped into generic vessel classes defined as tankers, passenger ships and others. Each of these vessel types

was further divided into two size groups: large and small. Traffic flow statistics were collected and projections for 2010 calculated for the above vessel types.

The main assumptions related to the ship-to-ship collision frequency analysis in GRACAT are 1) a normal distribution of trajectories around the mid-line on the lane – the scatter parameter has to be specified by vessel position data or expert judgement; 2) the inter-arrival times are exponentially distributed – the ‘rate’ parameter has to be specified by vessel traffic data or expert judgement; 3) vessels are moving along the lanes with their average speed; 4) the probability of intersection collision is fixed to 0.01 per turn given the simultaneous presence of two vessels at the turn; 5) a common causation factor for head-on and crossing type (with any angle) of ship encounter; 6) VTS operation to prevent collision situations is limited to the so-called escalation stage of ship encounter, not the critical collision stage which is characterised by evasive actions by the navigators only.

The frequency analysis results indicated a significant reduction in ship-to-ship collision frequencies involving a tanker (large or small) for RCO ‘System2’.

In the consequence assessment the following assumptions were made: 1) the amount of oil spilled given a rupture in the hull of a tanker after a collision is 1/48 of the average amount of oil carried; 2) the amount of oil spilled given a rupture in another type of vessel corresponds to a single bunker oil tank; the marginal and joint probabilities for rupture in one vessel, both vessels, or neither vessel, are derived from the MEHRA-report (Safetec, 1999).

The VTS operation does not affect the amount of oil spilled given a collision (or grounding). The effects are seen as changes in the expected annual costs through the changes in the collision frequencies leading to oil spills.

It is important to note that the evaluation criteria did not include absolute non-tolerability limit values as prescribed in the ALARP-principle. Thus, the results of the risk estimation phase were not used to prescribe the adoption of one or the other RCO per se.

#### **5.4.4 Cost-benefit assessment**

In the FSA study, the assessment of the consequences of ship-to-ship collisions was limited to oil spills and the costs thereof. The environmental damage costs as well as overhead and cleaning costs were assumed to be linearly dependent on the oil spill volume in tonnes. The oil spill volumes are dependent on the ship types involved in the collision. The probabilities of oil spill given a ship-to-ship collision were obtained from the MEHRA report (Safetec, 1999). The savings related to avoided oil spills were referred to as the expected reduced societal cost.

#### **5.4.5 Findings based on the FSA**

In the performed FSA study, the ‘benefit’ of implementing the risk control means (system 1 or system 2) was measured in terms of the expected reduced societal cost due to a decrease in the number of collisions and the associated oil spills after the implementation of either of the risk control options. The cost-benefit assessment indicates that the total return of an investment in ‘system2’ is significant and can be justified despite the uncertainties involved in the assessment.

Based on retrospection of the Gulf of Finland VTMS -project some improvement ideas can be presented. Some of these ideas concerning the method and development from a more general point of view are presented in Chapter 8. The ideas strongly related to the conduct of FSA are described in Section 5.6, Discussion.

### **5.5 Results and documentation**

The main objectives of Phase 2 were the creation of a metalevel definition of the GOFREP system, getting the definition commonly agreed by the GOFREP countries Finland, Estonia and Russia and getting the system approved and adopted by IMO. To achieve this a development organisation was formed and proved in practise to be highly functional. During this phase most of the work was done by the FMA. The FSA was conducted to evaluate the cost-effectiveness of the aimed expensive system, but it also served as a framework

for understanding the object area and its problems. Moreover, the system definition was discussed with the relevant organisations and services at the brainstorming sessions arranged during the study. The wishes and needs of these organisations were also considered to the extent possible.

With the definition of both the risks of the object sea area, the Gulf of Finland, and the operation of the GOFREP system as a risk control measure, the development process became a part of the platform of the Finnish Cabinet. This was a clear indication of the importance of the developed system and ensured the financial resources for the development. The development was considered to be of utmost importance in all three GOFREP countries.

The progress and the events of the development process during Phase 2 have been documented in the protocols and minutes of the meetings, in the research report and in other articles written about the FSA study (Rosqvist & Tuominen, 2004; Rosqvist, 2003) and in the proposal submitted to IMO.

With the results gained during Phase 2, the prerequisites created during Phase 1 were further enforced and the bases for operational development were created.

## **5.6 Discussion**

The tasks listed under the phases of the IALA framework were conducted but not necessarily by the same phases or in the same order in GOFREP. For example the Feasibility Study in the IALA framework starts with the investigation to support the decision on whether the intended measures are the appropriate means to address the identified problems. In the case of GOFREP this was not investigated, but the decision on implementing a VTMS was made by the Ministries of the three countries based on the common opinion of the experts in these three countries. The preliminary survey conducted before the decision was already focused on investigating the bases for VTMS development in the shoreline countries, and the opinions on the feasibility of the trilateral system in the three countries.

Learning from the operation of comparable existing systems enables the implementing of procedures found good in other systems and to avoid the same

operational flaws and pitfalls that have already been identified during the development of these systems. The available documentation of existing systems such as the United Kingdom systems CALDOVREP, MAREP/POSREP, QUESSREP and CNIS was studied. The operation of these systems was used as an example and as a model from the first steps of the development in the Gulf of Finland.

Several minor notes on the application of FSA may be listed:

#### **Note 0: The role of the system definition -step in the FSA**

As can be inferred from the above, the first step of the FSA: Definition of goals, systems, operations, is essentially dependent on the outcome of the inception period where political work and argumentation play a central role for what is deemed relevant in a decision process where the scientific analysis plays a supplementary role. The starting point for the FSA in the Gulf of Finland VTMISS -project may seem constrained with two pre-defined RCOs to be assessed. This reflects the good work in the inception period rather than a poorly limited FSA. Instead, resources could be allocated for the development of well-formulated and relatively detailed risk models for the assessment of the defined RCOs.

#### **Note 1: Hazard Identification based on GDSS**

The use of GDSS to generate hazards and develop scenarios supports efficient use of experts' time and elicitation of their know-how during the FSA Hazard Identification phase. The development of approximately fifty risk scenarios within a few hours cannot be performed by any traditional group techniques. The challenge for the facilitation is the determination of the degree of freedom allowed in the formulation of the hazards. Experience suggests that hazard generation that does not specify hazardous events at a level of rather technical detail renders the risk scenarios very general with the cost of losing specific information of the system under study. This also renders the risk scenarios difficult to assess in terms of likelihood and consequence. For the Gulf of Finland VTMISS -project specific hazardous events should have been defined as starting points for the hazard identification. For instance, 'ship-to-tanker collision', 'tanker-to-tanker collision', 'difficult crossing', 'difficult

overtaking' -events would have better forced specific information to be elicited from the experts compared to a free generation of hazards that was allowed in the hazard identification phase.

One observation is that field expertise should represent a majority of the experts in the workshop. Only those people who are involved with vessel operations on a regular basis have the specific experience that is needed to formulate realistic and credible hazards and risk scenarios.

## **Note 2: Risk estimation based on the GRACAT software**

The risk estimation approach was based on the GRACAT software. Modelling assumptions coupled with the latest version of the software had to be assumed.

The validity of some of the assumptions made in the Gulf of Finland VTMIS -project can be checked in, at least, the following ways: 1) updating of traffic projections for the year 2010; 2) utilisation of AIS-tracks to validate the spread of trajectories in the lanes; 3) utilisation of AIS-tracks to follow the behaviour at intersection points and validate the intersection collision probability parameter.

A GRACAT-update would be needed to take into account the risk related to overtaking.

The experience feedback from operators on successful interference to prevent foreseen incidents would be needed to check the validity of the assumption of operation to interfere in situations where a collision hazard is developing. This is a broader topic related to the quality of operator work, work definitions and performance.

The basic limitation of the underlying method of the GRACAT software is the traffic flow model which assumes time independence of the ship-to ship collision frequency / probability, i.e. the inter-arrival times are independently and exponentially distributed. Maritime transportation between harbours in a smaller sea area follows schedules implying that the risk profile differs from the 'memoryless' traffic flow model of GRACAT: the risks are likely to be 'peaked' on certain days of the week and/or hours of the day. Discrete event simulation is



perhaps the only credible way to model the traffic in sea areas like the Gulf of Finland or the Baltic Sea.

Regarding the consequence analysis, the main assumption relates to the fraction of oil spilled given a rupture in a tanker with an average oil load (= 1/48). A review of the justifications of this value may be motivated.

### **Note 3: Cost-benefit assessment based on Total Return of an investment**

The basic approach in the cost-benefit analysis was to look at the RCOs as investment objects and to evaluate them according to established financial metrics. The metric utilised was Total Return which is a random variable due to many uncertainties related to the cost factors. Therefore, the expected value of the total return was defined as the measure for the cost-benefit ratio.

The costs related to the implementation of the RCOs 'system1' and 'system2' were considered fairly accurate even though the installation, the annual maintenance and operational costs are different between Russia, Estonia and Finland. The cost figures were obtained from the authorities of the respective countries.

The expected cost related to the oil spill is coupled with many uncertainties. The probabilities of the average oil spill volumes were obtained from general statistics that do not necessarily represent the conditions on the Gulf of Finland. The oil recovery costs and the environmental damage costs depend on the location, weather conditions and time of year of the oil spill event. The parameters of the linear cost function utilised should be checked by regression analysis of carefully selected oil spill and oil recovery cost data available for the Baltic Sea. The linear relationship is also disputable in the light of recent studies conducted at the Technical University of Denmark. Thus, a comparison with cost estimates obtained by alternative cost functions reported in the literature should be performed for validating the reported total return values.

## 6. Phase 3: Design of common operations and provision of resources

Main activities of Phase 3 are presented in Figure 10 below.

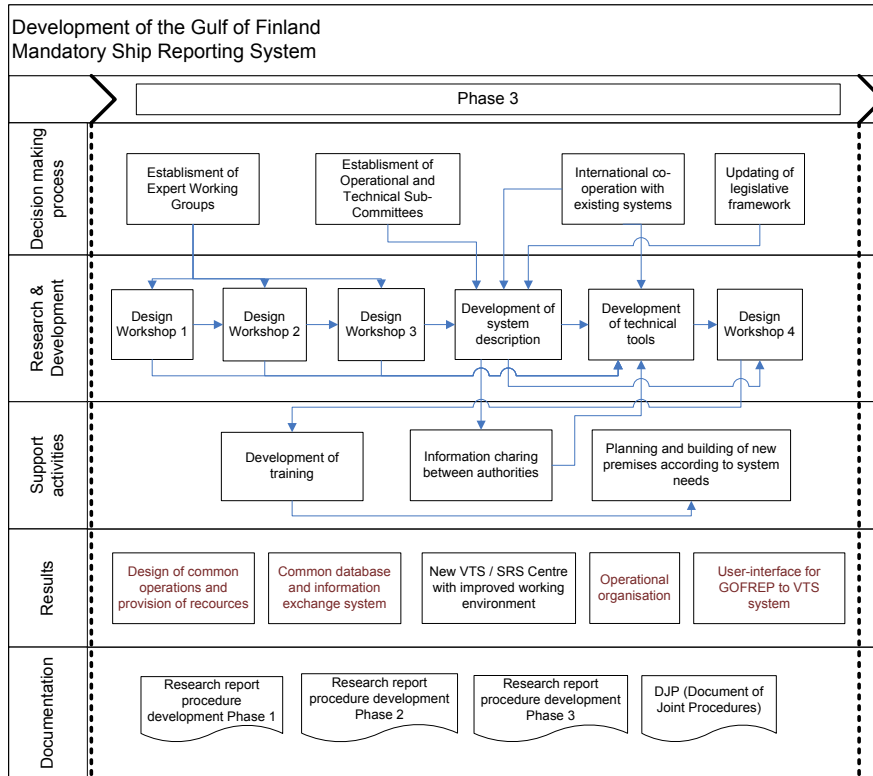


Figure 10. Main activities of Phase 3.

### 6.1 Objectives

This phase aimed at creating a commonly agreed description of the system that is more detailed than the metalevel description produced in Phase 2. Also development on the aspects related to the three foci of development i.e. Operation, Resources and Normative Constrains was pursued in order to reach the level of readiness required for trial use of the system. During this phase a

majority of the concrete design work enabling the system start-up was done. The general objectives of the phase were:

- developing of commonly agreed operational procedures to be followed identically in each of the countries
- development of “user-friendly” technical means for ensuring the system performance
- comparison and harmonisation of the emerging system and existing systems
- definition of the operators’ competence level
- production of training material and exercises
- amendment of the development organisation
- establishment of an operational GOFREP organisation
- testing of the appropriateness of the procedures and technical facilities.

The ensuring of high quality and effective operation required development of both technical solutions and common operational procedures. IMO recommends cooperation in the development of operational procedures for systems jointly managed by more than one country. All countries had their own means for information exchange between the relevant national maritime authorities. However, a separate, common database and information exchange system was seen as a necessity for the purposes of GOFREP.

The development organisation formed during the previous phases was especially important during Phase 3 when the time pressure had increased and numerous decisions on multiple alternatives had to be made in the procedure development.

## **6.2 Main activities of decision making and R&D processes**

During this phase the *development organisation was amended* when the Expert Working Group started its operation. The GOFREP operational and technical development including the development of joint procedures was mainly done on

two levels of the organisation (Figure 8): in the Expert Working Groups and in the Operational and Technical sub-committees. The high importance of their role and effective working was unquestionable.

Most of the operation design was made during the preparations for the design workshops and in the actual workshops, i.e. Operational Exercises. During Phase 3, as during the whole development process, the FMA maintained continuous work for preparing meetings and workshops for different levels of the development organisation, compiling information required for the development and preparing a variety of documents.

For reasons of operational reliability and efficiency the GOFREP area was divided into two monitoring responsibility areas making the northern part Finnish monitoring area and the southern part Estonian monitoring area. However, from the beginning of the procedure development it was clear that GOFREP operation shall be uniform regardless of the area: a vessel shall receive the same services with the procedures wherever in the GOFREP area it should navigate. This demand guided the procedure development in the R&D process of this phase.

During the previous stage it was decided that design workshops called Operational Exercises (OE) shall be used for the development of the GOFREP operation and the development of joint procedures. The FMA and VTT considered that the development of joint procedures could be best accomplished in *design workshops* (6.5). The benefit of these workshops was that they could be attended by the experts from all three countries. One of the aims of these meetings was to create a sense of common effort and commitment for the development of a joint system. During 2002–2004 four workshops (OE I–IV) were arranged and they were participated by subject matter experts, human factors specialists and representatives of the relevant authorities (FMA, 2004a; 2004b; 2004c; Sonninen, 2002; 2004; Sonninen et al., 2004a; 2004b). The Core Task Analysis approach (CTA; Norros, 2004) served as the scientific framework for the workshops and use of simulations in the design (6.4). In accordance with IMO recommendations, joint operational procedures were developed with the aim to offer guidance to the daily work of the GOFREP operators.

The workshops consisted of planning sessions that were based on predefined materials. The participants then planned and selected potential procedures for assessment. When a limited number of potential procedures was chosen, they were evaluated for their functionality by using simulations. The number of preplanned simulation exercises with a duration of 15–50 minutes varied depending on the type of and number of procedures being evaluated. After simulations all participants gathered into debriefing sessions where the best procedures were decided. In this way, simulation was used as a user-centred design (UCD) method for the procedure development. Its greatest benefit in addition to that it enabled the participants from the GOFREP countries to participate in the development-comparison-judgement process was that the resulting solutions, i.e. the chosen procedures, could be accepted by all countries.

The utilisation of simulations in the workshops started with small-scale, low fidelity simulations, proceeding to the use of large-scale real-time simulations and was finalised with operational trials in the traffic centre with the real GOFREP system but with dummy targets.

The procedure development aimed at documented, commonly agreed GOFREP procedures for three countries. Each decision made in the workshops was documented with justifications and forwarded to the Operational Sub-Committee. The Sub-Committee then prepared the workshop proposals to a Document of Joint Procedures (DJP) that was forwarded for adoption on the Tripartite WG. Various operational matters were defined in the Operational Sub-Committee and then forwarded for approval to the Tripartite WG. The Tripartite WG also named the development tasks that the Operational Sub-Committee and the Expert WG should undertake and defined the schedules for the development tasks.

The need for a common information exchange system between the GOFREP traffic centres in Finland, Estonia and Russia was identified already in OE I. The development and specification of this information exchange system was a significant part of the GOFREP development. This task was undertaken by the Technical Sub-Committee. The main task was the creation of a GOFREP data exchange standard, that defined the communication protocol, the interface and the message structure. The messages are based on XML (Extensible Markup Language). The GOFREP system is based upon a fully distributed database model with independent GOFREP databases in all three countries, automatically

exchanging data between them. On national level, each country ensured that available sources of information were made available and utilised, and that the practical and usable software for the GOFREP operation was made available for the operators. In Finland a new module for the GOFREP operation was added to the VTS system. This module was developed in close cooperation between the FMA personnel, the VTS-system manufacturer and VTT.

As a result of the work done in the Design workshops (the OEs) and by the Operational and Technical Sub-Committees, a Document of Joint Procedures (DJP) was accepted by the GOFREP countries in June 2004 before the operation started. The DJP describes the external common operational procedures of GOFREP. It is a handbook of procedures and as such an integral part of the daily work in the Traffic Centres and of the regular training exercises. During the development of GOFREP information on the operation of similar systems was also studied. As a result of an excellent cooperation with the CNIS, parts of the information and details in the DJP were produced with permission of the MCA UK and are congruent with the CNIS Joint Operating Manual. The objective of making the participation to different SRSs around the world easier for mariners by developing similar maritime systems to different parts of the world was aimed to be fulfilled with this approach.

The work done in the design workshops also gave indications for defining the number and quality of personnel required for ensuring appropriate manning of the Traffic Centres. During Phase 3 it became important to create prerequisites for training and to start training new personnel in good time before the start-up. Also time for recruitment had to be allowed since it is often extensive. The new operators for GOFREP were hired during this phase, six months before the operation started. Design workshops, particularly OE IV, served also training purposes (Sonninen & Nyman, 2005). Thus, in addition to VTS operator training, the operators were able to participate in the system development, trial use of applications and in the planning of their work conditions. In Finland the parallel development of VTS operator training supported this task. The activities primarily focused on the development can also be a part of the initial training of the new organisation. Provision of adequate facilities and resources e.g. in terms of control room and training devices and material are also important. The site acceptance test (SAT) of the new VTS software developed exclusively for GOFREP operation was also conducted during OE IV.

During the time between the third and the fourth Design Workshop five co-operating meetings were arranged for the Finnish and Estonian GOFREP operators. The aim of these meetings was first of all to discuss the content of the Joint Operational Procedures -manual describing the trilaterally agreed procedures of GOFREP. The aim was to ensure that the objectives of operation and the developed procedures would be understood identically in both countries. Another aim was to present the procedures for their assessment since there was still time for modifications. These meetings, as the Design Workshops before were also considered to be very important.

### **6.2.1 Actors involved**

All three levels of the GOFREP development organisation were particularly active during the third phase. The work of the preparatory level can however be seen as the driving force during this phase. The Operational Sub-Committee worked effectively to define the development needs, conducted much of the procedure framework definition and gave tasks to the Expert WG. The Technical Sub-Committee worked hard on the development and implementation of the technical necessities for the operation. It is without a doubt a major challenge to create a common, operative information exchange system for the needs of SRS operation in three countries. All necessary organisations were represented in the Operational and Technical Sub-Committees: the Finnish Maritime Administration, the Estonian Maritime Administration, the Port Authority of Saint Petersburg and Russian Federal State enterprise Rosmorport.

The four Design Workshops produced the necessary information for procedure development. The importance of the expertise and insight of the numerous experts participating in these workshops must be highlighted. This expertise was provided by several organisations: the operators of the Estonian Maritime Administration Coordination Centre, several representatives from the Finnish Maritime Administration and especially from the Gulf of Finland Maritime District Traffic Division and from the Traffic Department, from the management of the Port Authority of Saint Petersburg and their VTS personnel and the Russian Central Marine Research and Design Institute (CNIIMF). During Design Workshops I–III the simulations were assisted by captains and deck officers from the Finnish shipping companies.

When planning and executing the Design Workshops, the contribution of the simulator unit of the Maritime Safety Training Centre (Meriturva) to the realisation of Design Workshops I–III was significant, in addition to the main responsibility of VTT. The success of Design Workshop IV owes a lot to the equipment provider's (Navielektro Ky) willingness to develop their systems beyond the required level and creating the platform for trial use of the procedures by integrating simulation to the real-time traffic picture. Navielektro also played the key role in developing the common XML based GOFREP information exchange standard (Navielektro, 2003).

The Finnish Maritime Administration who commissioned part of the work to VTT led the development and documentation of the joint operational procedures. The Channel Navigation and Information System assisted the development by providing information of their operation and of their documents of the English-French common procedures. Another important organisation that assisted in the development of the DJP was the Gulf of Finland Coast Guard District. The co-operation between the maritime rescue organisation and Helsinki Traffic was defined during the third phase and in addition, the Coast Guard provided their expertise on the radio communications and emergency procedures for the GOFREP procedure.

### **6.3 Supporting activities**

In Finland, the supporting processes of Phase 3 included nationally the *development of training, information sharing between the authorities and planning and building of new premises* according to GOFREP and VTS needs.

The FMA decided that albeit GOFREP is not a VTS, all GOFREP operators shall be qualified VTS operators. The development of VTS training in accordance with the IALA V-103 recommendation was started in 2003. Although the presently accredited V-103 training was not finalised in time before the GOFREP operation started, its development supplemented the development process.

Information sharing between the authorities was enhanced during the whole development process but especially during Phase 3. The cooperation of maritime



authorities has long traditions in Finland and is highly successful. Also in the case of GOFREP development the required national co-operation and information exchange between different authorities was effective. Written procedures were agreed on with the most important partners, such as the Coast Guard and Search and Rescue and the national Coast Radio Station.

The building of state-of-the-art premises was undertaken for two reasons; the quarters of Helsinki VTS had got too small and even more space was needed for the GOFREP workstations. The new premises were simultaneously built to house several VTS-workstations and GOFREP workstations. The building was started in good time from the GOFREP operation point of view since it was finalised a year before the operation started.

## **6.4 Core Task Analysis framework**

The Core Task Analysis (CTA) approach was used as a framework when designing and reflecting the design workshops. As already noted, the concept of a core task means “the shared objectives and the outcome-critical content of work that should be taken into account by the actors in their task performances for maintaining an appropriate interaction with the environment” (Norros, 2004 p. 17). The core task model aims to comprise both the demands that should be met and the realised possibilities for meeting them in order to achieve the aims of safety, productivity and wellbeing in the current societal and economic environment and to create potential for development (Norros, 2004; Norros & Nuutinen, 2002). The result, the core task model, can be either quite general or go into the details depending on the aims of the modelling. The modelling process framed the preparation of the design workshops and their reflection. The modelling of GOFREP was started in this phase and continued up to the last phase, but it was not systematically documented.

### **6.4.1 Modelling of the GOFREP operators’ core task**

The modelling started by defining the general objective of the activity and the object of the system. Next, the characteristics and unique features of the object of the work, vessel traffic in the Gulf of Finland, were analysed. The operation

environment was analysed in a sense of what it could tell about the dynamic, complex and uncertain (DCU; Norros, 2004) nature of the controlled object (e.g. the amount and type of vessel traffic, characteristics of the sea area, dependencies and delays in information exchange) as constraints when aiming for the objective (see also Rasmussen, 1986; Vicente, 1999). The critical functions or “tasks” that should be taken care of in order to reach the objective were outlined based on this. Then the analysis of DCU characteristics and unique features was taken a step further: These were interpreted as constraints and possibilities for taking care of the functions with respect to three interactions:

1. the operator – the object of work interaction: possibilities and constraints of a) knowing the state of the object and b) having an operation control effect on the object
2. the operator – operator interaction: possibilities and constraints of a) co-operating b) communicating
3. the operator – own actions interaction: possibilities and constraints of a) seeing the core task and one’s own contribution to it b) assessing one’s own resources and getting extra resources when needed, and developing one’s own competences and c) reaching a sense of control related to taking care of the core task (Nuutinen, 2005b).

At this stage of the analysis, the investigated work is divided into phases whenever possible to deepen the analysis. In the next step, these can be formulated firstly into core task demands, the general demands to be balanced, and then secondly into working practice demands, in other words, how these constraints and possibilities could be managed by the GOFREP operators. During the modelling process, previous studies on the same or similar domains and domain experts’ conceptions are used to catalyse and complete the analysis and validate the results (about the modelling technique see Nuutinen, 2005b).

#### **6.4.2 Constructing practices: from potential to accepted procedures**

In order to create operational practices and to find out the main obstacles and challenges, we first had to define the potential operational activities and

procedures for them and recognise the resources available or needed for the operators. Then we could progress towards an adequate entity of accepted procedures and realised practices. Also, the main pressures for future changes should be anticipated. In this case, the definition progressed in design workshops guiding them and utilising the material that was produced by simulation exercises and discussions. The adequacy of the set of procedures can be tested by a circular process with the following steps:

1. definition of a potential procedure
2. testing its usability and accuracy in practise/simulation or/and regarding to the core task model
3. evaluating the test results, re-definition and test if needed
4. comparing with forming a set of procedures and other references
5. time for national discussions and reflection, redefinition and test if needed
6. tentative acceptance
7. time for broader discussions and reflection: recognition of potential problems
8. steps 1–6 in the different design workshops
9. commonly agreed acceptance for documented joint procedures.

### **6.4.3 System definition: from vision to operation**

The system formed during this phase. In the design workshops several strategies were used to enhance recognition of the system boundaries, demands for operation and resources and development of practical solutions in terms of procedures and practices. The strategies utilised were:

- Defining the operation in different basic situations with help of the analysis of vessel traffic geographically. For example, entrance to the GOFREP area from different directions, crossing the system boundaries or separation line etc.

- Presenting the recognised (e.g. in the modelling) problem into the common analysis. A way to promote finding solutions was through “what if” scenario building. The same steps used in procedure development served also the system definition. In addition to the core task model the test scheme included consideration of the system from the perspective of the linked services and different vessels.
- Comparisons with similar or near systems. The characteristics of GOFREP could be found by recognising the main differences and similarities. When the similarity was recognised the existing solution could be used as a starting point in the design. For example the procedures and training requirements of VTS were utilised.
- When encountering problems in making decisions or progressing in the definitions the utilised solutions were: going back to the description of the task; going back to the boundaries of the system or going back to the objectives of the system.
- A worst case scenario building.
- Simulations were utilised e.g. in order to: make visible the work load resulting from the different planned task in practice; demonstrate the potential problems of operation and test the planned solutions, procedures and support the emergence of daily practices.

## **6.5 Design workshops**

The general aim of the design workshops was to define the system operation. The more concrete aim was to create procedures for both the GOFREP operators’ primary and secondary tasks to the extent required for harmonisation of operation between GOFREP Traffic Centres and vessel traffic as well as operation between the Traffic Centres themselves. In VTS operation these are the so-called external procedures (IALA, 2004). The internal procedures, e.g. co-operation with national VTS (Vessel Traffic Service) Centres and other relevant stakeholders, such as the sea rescue organisation etc., were not a part of the procedure development scope. The harmonisation of internal procedures was heavily dependent on each of the countries’ national organisations and culture. Thus, it was decided that each of the nationally responsible authorities would

develop the necessary internal procedures along with the development of the external procedures and along the agreed aims of the operation. The IALA guidance for VTS operating procedures (IALA, 2000b; 2004) was utilised in the procedure development.

The division of the GOFREP operators' work to primary and secondary tasks is not unambiguous since the main task of the system varies to some extent between winter and summertime operation. In general, the primary tasks include reception and distribution of the relevant information to and from vessel traffic and monitoring the vessel traffic to observe dangerous vessel encounters and contraventions on regulations (IMO, 1989; 2000; 2002b). The secondary tasks may include activities such as reporting of contraventions to the authorities or providing information to organisations that are not a part of the system i.e. fairway maintenance, shipping agents, port operators, etc.

A part of the system development was the understanding and implementation of the international requirements and guidance to the procedures. Some of the procedures were developed to a large extent on the basis of existing systems and guidance (HELCOM, 2004; IALA, 2000a; IMO, 1989; 1994; 2001; 2002b). Some of the procedure development issues had fairly few alternatives and an effective procedure could easily be found, but the procedures also included issues to which an ideal solution could not be found. In these cases the reason for having to adopt the best available procedure was a technical limitation, the operators' legal liability or the differences of operational culture in the cooperating countries.

Creation of a common goal and genuine cooperation between the participating countries was considered essential for the success of the user-centred GOFREP development. The development required commitment and agreement of all the shoreline countries and it was essential that all levels of the development organisation were committed. One of the aims of the design workshops was to create a sense of common effort and commitment among the participating operators. In addition to this the creation of a forum for the operators to learn to know one another personally was seen to provide for the future operation of the system. It was believed that the effectiveness of GOFREP operation is enhanced if a sense of a shared system with three traffic centres could be created.

### **6.5.1 The use of simulations in the workshops**

The aims of the four workshops varied according to the development stage and the variation was most notable in the simulations. Also the level of simulation varied. The first simulations were simple pen and paper simulations and the last ones were carried out with two full scale VTS simulators with three full scale bridge simulators connected to those, and in the last workshop, in the actual working environment. The lower level simulation provided basic information about the different stakeholders' roles in the operation of GOFREP, whereas the higher level simulations helped for example to envisage the future task load of the GOFREP operators. The lower level simulation focused on the operators' basic procedures for primary tasks such as receiving and storing the information from vessel reports, definitions of geographical limits of the system and management of vessel traffic in a specific monitoring area or monitoring responsibility hand-over situations. No critical or emergency situations were included in the first stage development.

During the second and the third workshop, the level of simulation was increased (FMA, 2004a; 2004b; Sonninen et al., 2004a; 2004b). In these workshops simulation was still used for the same purposes as in the first simulations, but the development of more complex and safety-critical procedures required higher fidelity. During the second workshop a full mission VTS simulator was introduced, but the simulations did not cover all of the vast GOFREP monitoring area, nor were any winter time or emergency situation operations included in the simulations. The third workshop simulations included the geographical area in whole and the amount of simulated vessel traffic in the monitoring area was increased to equal almost the number of congested traffic in the Gulf of Finland. Some critical situations were also added to the simulations. The fourth simulation was an operational trial but also an operator training session (FMA, 2004c; Sonninen, 2004). The aim of the trial was to demonstrate the feasibility of the software developed for the GOFREP operators' work and find possible defects in it as recommended by IALA (IALA, 2002). The software was finalised according to the observations. The simulations in the operational trial were based on real, on-line traffic image of the Gulf but the situations needed for procedure validation were created by adding dummy-targets (virtual ships) to the traffic image visualised in the monitoring screens.

As mentioned earlier, the workshops also served as a training session for the participants. The workshops and the simulation exercises used for procedure testing were cumulative; the following workshop used the results of the previous workshop as the basis of development and the simulations during a workshop included the procedures developed both in the previous workshops and previous simulations during the same workshop. While testing new procedures the participants gained more confidence in using the previously defined procedures. As a result the operators noticed details in the previously defined procedures that needed to be changed and thus the development of the procedures was continuous throughout the process.

### **6.5.2 Reasons for utilising simulations in the design**

Simulation was used as a human-centred design (HCD; ISO, 1999) method for the procedure development. The aim of HCD is to produce a system that supports human users in their tasks, and allows them to carry out their work with effectiveness, efficiency and satisfaction. Simulation is a HCD method that can be used for requirements gathering, requirements validation, and also system validation especially in safety critical environments (Savioja, 2003). In the development of GOFREP, the simulations provided a medium to acquire experience of the intended procedures in different kinds of operating situations (Sonninen & Savioja, 2005). Also, the simulations enabled the participants to make comparisons and judgement between two or more prospective alternatives. The comparison could be made on the basis of effectiveness, feasibility and quality.

The simulation method was decided to be used in the GOFREP procedure development for many reasons. The basic documentation on GOFREP operation described the goals and aims of the system but gave very little guidance as to the working methods. Simulation enabled the participation of subject matter experts (VTS operators and managers) from Estonia, Finland and Russia in the procedure development and their expertise on vessel traffic services could be utilised in the work (Figure 11). Another benefit of simulation was the possibility to measure to a limited extent the future workload of GOFREP operators and to use this information for defining the needs for recruiting new personnel. The workshops were attended by operators from the GOFREP countries. These operators could all participate in the simulations, create a

common understanding of the operation, and express their national view on the procedures. Consequently, the agreements made in the debriefing and summing up session could then be presented as trilateral procedure proposals for the preparatory level.



*Figure 11. GOFREP operators at the third workshop simulation (picture: Timo Raunio).*

There were five different tasks for which simulation was used: definition of the system functions, procedure development, validation of operation, workload assessment, and operator training. All of the arranged workshops included features of these five tasks but the emphasis was placed differently during the process. The importance of defining the system's functions was greater in the first workshops but decreased and played a minor role in the fourth workshop, whereas the importance of validation of the operation was less important in the early stages of process and increased gradually being with training the most significant aspect during the fourth workshop. The importance of procedure development and workload assessment had equal significance throughout the process.



## 6.6 Results and documentation

This phase resulted in the operational GOFREP system: after the actions of Phase 3 the system was operationally and technically ready for trial use. Many details were still to be finished and the information exchange system was not fully operative. The trial use of the overall system was conducted during the next phase.

In the first part of this phase, the Tripartite WG accepted a resolution based on the memorandum of OE I in 2002 listing the primary actions that were required to be completed to ensure that the development of the GOFREP would be finalised successfully and on time. The actions identified in OE I were related to the most significant development challenges of operational and technical matters e.g. development of the common database and information exchange system, development of the DJP, division of the GOFREP area to monitoring responsibility areas, etc. The trilateral acceptance of this resolution and the initiating of the actions required in it truly and finally set in full motion the development of operational procedures, technical tools and the action of the development organisation.

The common operational procedure development resulted in the *trilaterally joint procedures* (DJP) providing guidance to the daily work of the GOFREP operators. Together with the developed simulation exercises they provided the core of the operator training. The same material and simulations could later be used in the operators' training. The development of the needed expertise was already in good progress for those who participated in the design workshops. Definition of the operators' task resulted also in the understanding of the needed competence level. Definition of the GOFREP operators' minimum competence level and what training should be provided was made to the official documentation and national views on the realisation could be created. Adequate human resources were ensured by personnel recruitment.

As a result of this phase the common information exchange and database system for the national Traffic Centres for storing, managing and exchanging the information on vessels transiting the Gulf was specified and realised. In addition to the information exchange system, other relevant systems such as PortNet were utilised as information sources for GOFREP. One of these is the result of Helsinki Commission (Helcom) cooperation, the Helcom AIS system, a

technical system for mutual exchange and deliveries of AIS information which became fully operational in 2005 in all the Baltic Sea countries.

Most of the development of the national tools for GOFREP operation, the software and the user-interface took also place during this phase. It was obvious that the GOFREP operation could not be conducted with the existing technical tools of the VTS system: it lacked the means for entering GOFREP reports from vessel traffic and there was no user-interface for the information exchange system. For this, an additional application module was developed to the existing VTS system by the same equipment provider that has built almost all of the Finnish VTS infrastructure. The application was developed in close cooperation with the Finnish Maritime Administration, the system manufacturer and VTT, and was finalised during the third and fourth phase according to the GOFREP personnel's requests for modifications.

## **6.7 Discussion**

This phase was the most congested with many different tasks of design to finish. A major challenge is how the interrelations between different design tasks can be managed. The process needs a central actor for maintaining "situation awareness" of the different development actions and for ensuring that useless or overlapping work is kept to a minimum. A recognised challenge, although a justified choice, was the separation of the development of technical and operational issues into two different Sub-Committees. However, active interaction between these two committees and the Expert WG guaranteed that gaps could not develop. The organisation ensured that the key persons by position were involved in the development but it could not ensure that these key persons would stay the same during the three years of procedure development. This was however, understandable since the organisation consisted of approximately 35 persons participating in the supporting processes.

The Tripartite WG accepted a resolution listing the necessary actions for GOFREP development on issues identified by the Expert WG in OE I. These actions identified in OE I can now retrospectively be evaluated to be among the most significant actions of the whole development process. This demonstrated indisputably the need for interaction of the bottom-up construction (participation

of the different experts and their efforts to create a common understanding of the system) and top-down standardisation through the development process (1.3).

Simulated situations, i.e. scenarios created for the procedure testing are composed of foreseeable occurrences. Although many problems that have been previously overlooked can be observed in a simulated chain of events, the simulation method does not provide a comprehensive aid for definition of procedures for such situations that are not anticipated. This problem was partly solved by using Core Task Modelling for support. However, the potential of the modelling method could not be used fully in the hectic development. In addition, application of the CTA approach to the design of a new system is still under development. The strengths of the approach are currently more in recognising challenges of the existing system.

The high fidelity full-scale simulators are undoubtedly an effective medium for teaching, but their multifunctional configuration can also have disadvantages. The variety of equipment provided in a full-scale simulator also provides an endless source of distraction to the participant. The use of a part-task simulator is in these cases justifiable, since it provides the trainee all the necessary tools but no extra challenge for his vigilance, thus allowing him to concentrate on the developed procedure. Due to their complexity, full-scale simulators also have technical failures rather often interfering with the testing process. If two optional procedures are being tested in two separate simulation sessions and during one of the sessions the simulator suffers a technical fault, the comparability of these two tests is impaired since the effect of the fault on the participants' decision-making is difficult to estimate. In addition, even high fidelity simulators are somewhat unrealistic from the operation point of view because the operators are well aware that "this is just a simulation". This is the reason why the level of workload or work related stress, for example, is very difficult to measure with a simulation.

The fact that an experienced operator may even unconsciously react to simulation training as it were a video game can, however, to some extent be provided for. With great concern placed on the fidelity of the simulators when simulating VTS or SRS operations the assisting participants' fidelity aspects need also to be considered. Communication is a key element in systems such as GOFREP, and thus a very important part of the simulations. To allow the

participants to take actively part in the simulations or to observe those, additional personnel was hired to produce the radio traffic from the vessel traffic created for the simulations. In the design workshops, communication from the simulated vessel traffic was created by ship officers from the Finnish merchant fleet or by VTS operators. This assisted the formation of a more realistic atmosphere for the simulation. Even though the simulations follow manuscripts including the desired events for the procedure development, the participants can adapt to the development of situations and thus the persons acting as vessel traffic need to be able to react realistically to the changing situations. To some extent the competent persons as “radio voices” can minimise the effect of technical failures by e.g. creating situations that force the operators’ attention to other issues or make the technical failure seem to be an intended part of the simulation.

One of the main challenges as well as advantages of this phase was the differentiation of GOFREP from VTS. The comparisons between these two “sister systems” promoted the development in many senses. However, the fact that the design was mainly based on the knowledge of VTS-related experts occasionally led the development into a path that approached VTS.

Creating of specifications for technical systems largely rely on the defined operational needs and expectations for these systems. The GOFREP document of joint procedures (DJP) is a manual offering the operators guidance on required actions in the various situations that might arise. However, it does not provide a sufficient base for the technical development. It can be concluded that the system operation e.g. actions taken by the operators and the information exchanged in the system should be modelled so that the created model would benefit the development of technical systems. Further, the more detailed core task model of the operator work in the realised system can be highly useful. These are future tasks for the development of GOFREP.

## 7. Phase 4: Validation and implementation

Main activities of Phase 4 are presented in Figure 12 below.

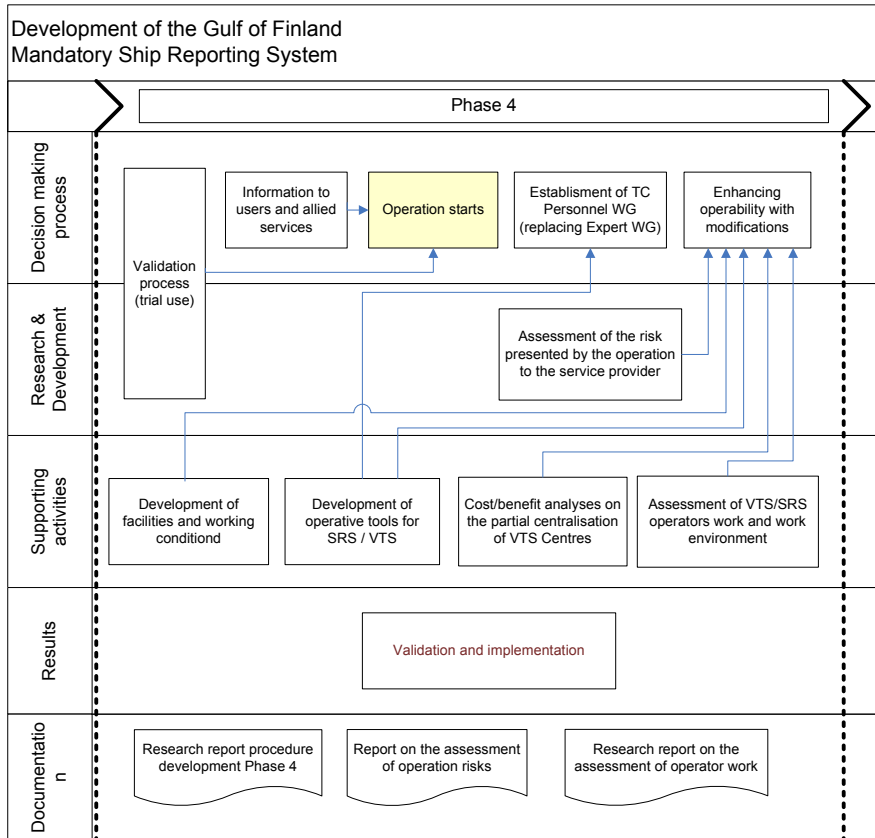


Figure 12. Main activities of Phase 4.

### 7.1 Objectives

The aim of Phase 4 was to ensure that all the conditions required for the operation of the system are finalised in time and that adequate resources are available for the operation. The general objectives of the system were:

- validating the functionality of the procedures and technical facilities as an operational entity
- system start-up
- identification of the risk that the system presents to the national organisation
- amending the operational GOFREP organisation
- checking system operability
- creation of conditions for further development by analysing the present organisation, working practices, organisational culture and conceptions
- informing the system users.

## **7.2 Main activities in decision making and R&D processes**

OE IV was a turnover point between Phases 3 and 4 by changing the development work from designing a new system to the validation and implementation of an existing system. The content of OE IV included already some testing and validation of the Finnish national system but it was more a design workshop aiming to tune the GOFREP software and user-interface. In Phase 4 the testing was first executed for the national systems and as they were evaluated to meet the required quality, the testing of trilateral operations was started.

The validation work was realised through on-site testing of information exchange between the Traffic Centres in Helsinki, Tallinn and St. Petersburg. Though St. Petersburg Traffic was not fully operational at the time of the testing and start-up, it participated in the *validation process* to the extent possible. From the system operability point of view it was regrettable that one link in the trilateral operation net was absent. However, this did not hamper the GOFREP operation significantly since the role of St. Petersburg is to provide information on the vessel traffic navigating in Russian territorial sea to the common information exchange system. Only Helsinki and Tallinn Traffic monitor the vessel traffic in the GOFREP area. The information unavailable from St. Petersburg could be obtained by other means.

The planning of how the *information* on the operation and the requirements of the system is distributed *to the users and allied services* was started in good time before the operation started. The compiling of commonly agreed documents for publication proved, however, to be somewhat more time-consuming than could be anticipated. The creation of a notice to mariners of the whole trilateral system is a challenge, at least if the system definition is as complex as in the case of GOFREP. The Finnish national information documents were easier to write and were published earlier than the international publications.

When the testing was completed, the preparations for the moment when the *operation would start* were trilaterally agreed. The greatest effort was placed on the technical preparedness and the availability of technical experts in situ if any problems should occur. Fortunately the operation started very fluently and the moment when the first report was received minutes after the operation commenced at 06.00 UTC on July 1st, 2004, shall certainly be long remembered by the developers of the system.

When the operation was started, the development organisation needed to reshape to an operational organisation. This did not mean that the development ended, on the contrary a system such as GOFREP is under pressure for continuous development and change. The reshaping included abolishing the development organs that had fulfilled their task and replacing them with organs responsible for operative matters. The Expert WG was abolished and a *Traffic Centre Personnel WG* was established. The development organisation changed very little when turning into an operational organisation.

GOFREP was implemented to reduce the risks induced by increasing vessel traffic. However, the operation also imposes risks for the organisation responsible for the system operation. To engage the identification of these risks and to develop sufficient risk control measures an *assessment of the risk presented by the operation to the service provider* (7.4) was conducted. The assessment was completed eight months after the operation had started and the measures based on the results were undertaken immediately.

Special attention was paid to the quality of operation during the first months of operation for two reasons. Firstly, a system either gains or loses its reliability in the eyes of the users very quickly. If the observed flaws in the operation are not

corrected promptly, the time for obtaining back the trust of the users is prolonged. Secondly, if the operative personnel have time to adjust to ineffective or otherwise unwanted procedures, rectification of these is difficult and takes extra effort, e.g. additional training. Most of the needs for changes in the original operational definition were identified by the GOFREP operators and the *operability was enhanced with modifications* accordingly.

### **7.3 Supporting activities**

New premises for the VTS and GOFREP centres were planned and built during Phase 3. Even though the premises for VTS were finished already in summer 2003 the *development of facilities and working conditions* for GOFREP continued until the operation was started in 2004.

Due to operational needs and new technologies introduced to vessels and VTSs, the FMA develops continuously the tools for VTS and GOFREP operation. This development includes both tools for the operators as well as for data management and utilisation, information exchange and automation of these. Due to the similarity of VTS and GOFREP work the benefits of this development are accumulated.

The creation of conditions for further development by analysing the present organisation, working practices, organisational culture and conceptions is a significant but often forgotten task that should be engaged shortly after the system start-up. These issues were analysed in an *assessment of VTS/SRS operators' work and work environment (7.5)* during the first year of GOFREP operation. The primary aim of the study was to clarify the developmental state of the vessel traffic services at different VTS centres and the main obstacles for adopting and training common working practices. However, the study also created knowledge of the development challenges applicable to the GOFREP development.

The evolving of Finnish VTSs from the mid-1990s to the present day has been strongly based on the work done in the FMA Maritime districts. The districts have been operationally rather independent from central administration and thus the progression of VTSs has varied as has the resulting operation. During the last



years the development in the FMA has led to the idea of moving all VTS-related activities to one department. The need to assess the cost of the present way of operation was part of this development. Originally there were six VTS centres in Finland covering the whole coastline and the inland waterways. To assess the economical impact of *partial centralisation of VTS centres a cost-benefit analysis* was made. In addition to the evaluation of the effects to VTS operation costs the analysis included evaluation of the impact of centralisation to the VTS work. Many of the problems recognised in the Assessment of the VTS/SRS operators' work and work environment -study were results from the deficiency of resources related to the small size of the VTS centres. In addition to the VTS work the results of the analyses could also be utilised for the GOFREP work.

#### **7.4 Assessment of the risks of system operation to the service provider**

Assessment of the risks to the service provider, i.e. the Finnish Maritime Administration, that are caused by the GOFREP operation was conducted during this phase. The aim of the work was to identify the most significant and most probable risks, to assess the adequacy of the existing risk control measures, to define the required risk control options related to the selected key risks and to define the necessary actions for improving the management of GOFREP-related risks to an acceptable level (FMA, 2005). The identified risks were categorised in five risk classes:

1. operational environment
2. cooperation
3. processes and procedures
4. information management and systems
5. others.

The risks were identified by interviewing representatives of the relevant organisations. The identified risks were compiled and prioritised by their significance and probability during an expert meeting. As a result, key risks and the organisations/persons responsible for developing the required risk control measures were identified. It was concluded that the present main risks were related to the prevailing development state of the GOFREP system at the time of

the risk assessment. This study was carried out when the operation was still undergoing development in many sectors: internal procedures, training, systematisation of operations, standardisation, etc. One identified major development need was the cooperation between national authorities and in particular, the cooperating procedures, operational authorisation and responsibilities. Based on the identified risks and the identified “owners” of these risks, the Finnish Maritime Administration started the work for developing appropriate risk control measures.

## **7.5 Assessment of VTS/SRS operators’ work and work environment study**

### **7.5.1 Background and aims**

The study aimed at supporting the development activities at VTS and GOFREP centres. The practical need was to harmonise practices at different VTS centres and to develop accredited VTS and GOFREP training in order to offer better service for the vessels. The part of the study presented here focused on clarifying the developmental state of the vessel traffic services at different VTS centres and the main obstacles for adopting and training common working practices. Since GOFREP operates in the same centre with Helsinki VTS the GOFREP-operators also participated in the study. The study was funded by the Ministry of Finance, FMA and VTT. (Nuutinen et al., 2005a; 2005b; Nuutinen, 2006.)

### **7.5.2 Methods and data**

The data of the study was collected at a kick-off workshop and by visiting every VTS centre. The workshop aimed at modelling the VTS core task on a general level and there were participants from every VTS centre and local office (the maritime district traffic division managers and the centre supervisors), as well as three persons from the VTS authority of the Maritime Administration. The VTS centre data consisted of interviews (two operators per centre), videoed contextual inquiries concerning the operators’ tools and actions, videoed observations in a change of shift situation and recordings of five general

presentation lectures of all but one centre, given usually by the shift or centre supervisor. Available related documents were used in all studies.

The quantitative data concerning e.g. the operative areas was organised by simple operations (percentages, time variations etc.) in order to allow comparisons between the centres. The qualitative data was analysed following the steps of the Contextual Assessment of Working Practices (CAWP) method based on the CTA framework (for details, see Nuutinen, 2005b). CAWP is aimed to support the development of work by defining the core task demands, describing the current working practices, comparing the demands and the practices, bringing out the strengths and weaknesses of the current practices, interpreting their reasons and concluding the development challenges on an adequate level for the purposes of the case (Figure 13).

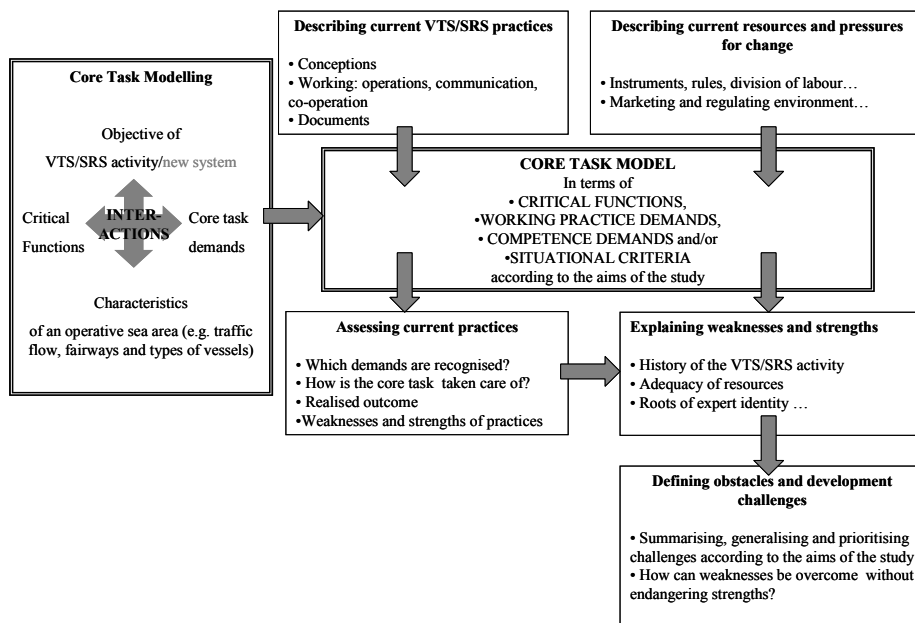


Figure 13. Phases of the Contextual Assessment of Working Practice method (modified from Nuutinen, 2005b; see also Nuutinen et al., in press).

### **7.5.3 Findings from the GOFREP point of view**

Most of the findings are very VTS specific, but the significant development challenges recognised are also strongly related to GOFREP. The findings are shortly presented in Section 8.3 describing a concluding study. There were some general findings that are relevant also from the point of future GOFREP development. The development and maintenance and efficient use of common practises requires continuous effort. According to the findings of VTS the conceptions of the core task of the VTS operations differed from centre to centre to such an extent that even the functions taken care of were different (see also Nuutinen, 2005b). This means that the sources of work motivation and operator identity were different among the VTS operators. In practice, these differences in the foundations of the work have led to a centre-specific VTS practice.

It is very important that the common development could take into account local and national aspects. The VTS centres have been established one by one and responsibility for the development of the VTS activity has been on the local administration offices. This has resulted in quite independent development processes, which has created well-tailored services for the local needs and special circumstances, but not enough uniformity from the point of view of the vessels. One of the positive sides of a locally coordinated development process has also been the possibility to take into account the operators' point of views when deciding e.g. the working hours and shift arrangements contributing to work satisfaction.

However, there is a danger that daily operations obscure the core task, particularly if the task is characterised with workload valleys and peaks and there is no commonly agreed method to manage these. In VTS the unsolved problem of the workload variability and the difficulties in noticing the impact of one's work (e.g. when monitoring traffic) partly explained the vagueness of the boundaries of the service. The operators had filled the quiet moments by taking on extra responsibilities. Although this definitely had contributed to their work satisfaction (which was quite high), it confused the core task and prioritisation of the tasks during a high workload. The task of the VTS operators as well as GOFREP operators should form a meaningful entity – in every kind of situation and also in the future.

Since VTS has already been operative for several years, it offers a possibility to learn from its history and the way it has been developed. The same kind of pressures for change and restricting constraints found in the current VTS activity and VTS history could have an impact on the future of GOFREP.

## **7.6 Results and documentation**

The necessary tests were carried out successfully before the operation started. Some deficiencies that were observed could be corrected before start-up whereas others could not and operational procedures had to be developed to compensate for these deficiencies. In practice, the inoperability of one of the Traffic Centres, St. Petersburg Traffic, meant a lack of vessel reports from vessels departing from the Russian ports. This lack of information connection was one of the deficiencies that were operationally compensated by adding one more information request to the vessels.

Ensuring the development of the object “normative constraints” of the aimed system (see Section 1.3.2), i.e. related rules & regulations, laws, recommendations, etc. is a development task that continues throughout the entire process. In the fourth phase the normative constraints should already be comprehensive except for the documentation produced to inform the users.

The necessary conditions for system start-up could in general be achieved. The timetables for testing of multilateral operations turned out to be problematic when several players in three countries were involved. The tests succeeded but in conclusion it may be stated that in all aspects of multilateral development, a full commitment to the realisation of previously agreed timetables is of utmost importance.

The reshaping of the development organisation was realised immediately after start-up. The organisation formed to a development organisation of an operational system. The only bigger alteration in the organisation was that the operational level, the Expert WG was replaced with a Traffic Centre Personnel WG. The participants of this new WG are mainly GOFREP operators from all the cooperating countries and their task is to analyse their work practises and common procedures and make proposals for improvements to the Operational

Sub-Committee, and if technical matters are in question, to the Technical Sub-Committee. This structure aims at a method of continuous development described in Chapter 7.

## **7.7 Discussion**

As already noted, the testing of trilateral operations was started after the national systems were evaluated to meet the required quality. The testing dates of the trilateral connections were generally agreed already months earlier but the matching of timetables of several authorities and three system manufacturers was not always successful.

As highlighted several times, GOFREP is a trilateral effort and thus the operative organisation becomes unavoidably rather heavy. Matters are in the first stage decided on national forums and then brought to the multilateral forum. The process of getting matters agreed on is long but efficient if the organisation is as objective-oriented and cooperative as the GOFREP organisation. This is why the development organisation changed very little when turning into the operational organisation. There were two reasons that enabled the fluent change of the organisation: firstly this change and the need for it had already been identified and agreed in the Operational Sub-Committee two years before the start-up. Secondly, the change was in fact great since also the need to rapidly correct flaws in the operation immediately after start-up was also agreed beforehand. It is, however, foreseen that the organisation may undergo larger modifications, e.g. less meetings for some organs and more responsibility for the development to the personnel after the first years of operation.

The VTS study showed that there have already been many changes during the history of the VTS and official definitions and visions of the particular activity and the actual content of the work and practices fulfilling it can differ quite remarkably. Then, also the knowledge of the competence and the needed resources could be insufficient. This is, of course, not a good basis for development actions and requires careful consideration also in the future GOFREP. It also supports the idea that the development actions should be based on a periodically conducted careful analysis of the current state of the activity.

## 8. Phase 5: Establishment of continuous development

Main activities of Phase 5 are presented in Figure 14 below.

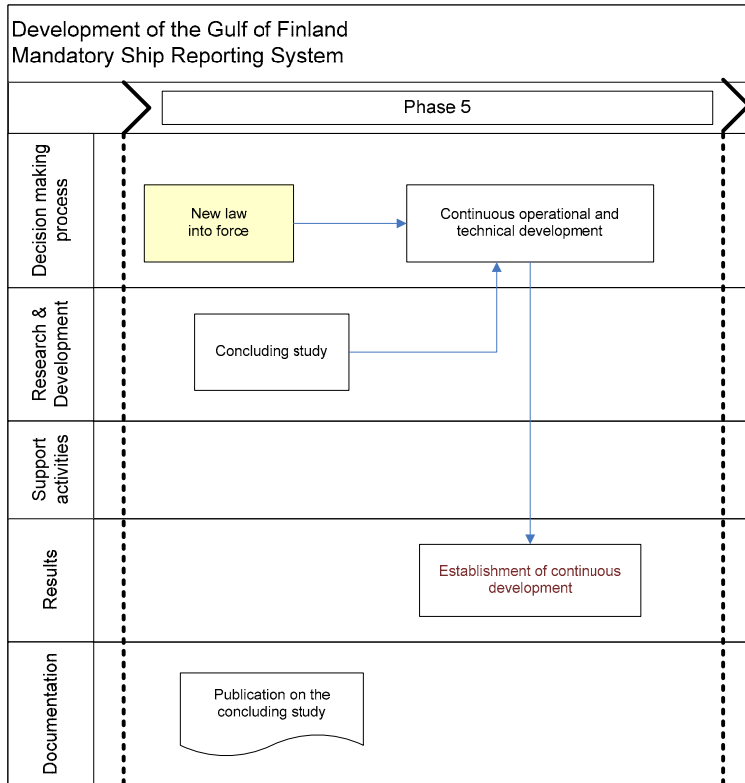


Figure 14. Main activities of Phase 5.

### 8.1 Objectives

This phase is the ongoing phase at the time of the writing of this publication. Even after the system has successfully started up and the recognised needs for modifications are all implemented there are task to do. The aim of this last phase is to ensure that the system remains at its high quality and aimed effectiveness in reducing risks for accidents *when* the operational environment changes and the

daily practices transform. The general nature of GOFREP was defined as a self-reflecting, continuously developing system requiring particular means to come true. The general objectives of this phase are:

- defining and applying a strategy of continuous development
- ensuring continuous development by
  - applying the used design method for continuous development of the existing system
  - identifying methods for supporting daily observations of the need for changes
  - establishing a virtual development organisation.

## **8.2 An interactive strategy**

As already noted the role of standardisation (e.g. in terms of procedures) as the main or even only guiding practical development strategy of a complex socio-technical system in safety-critical domains is quite strong although the strategy is challenged by the demand of adaptation in the human performance in order to reach safety and efficiency of the whole system (Dekker, 2003; Gauthereau, 2003; Hollnagel, 2002; Norros & Nuutinen, 2002). The operators should carefully take into account the present situation and the practices and skills should follow the changing demands of the core task when the surrounding environment is changing. Even the procedures can be kept at the level and form that allow their application in most situations, otherwise they become obsolete when the environment changes. Furthermore, when the procedures are considered as the main way to ensure safety and in practice the ways to do things vary, the problem seems to be that there is a gap between the procedures and the practice, and this gap should be managed. However, the workers actively try to make sense of their activity and what is good practice. They also create goals and adapt artefacts beyond the task descriptions and official definitions of the goals, often to increase the feeling of efficiency and work satisfaction. As McCarthy et al. (2004) have pointed out, people may prefer ways of performing their work that emerge from a sense of fairness, consistency, community or duty. This is a source of commitment, effort and information that can intentionally be



utilised in the remaining necessary development, but this requires a particular development strategy.

The principle of the realised development work is also suggested for the strategy of continuous development. It is the interaction of the bottom-up construction and top-down standardisation processes (see Chapters 5, 6 and 7 and Nuutinen et al., in press). The bottom-up construction is the daily modification of the system (e.g. interpretation of the procedures in different situations, innovative use of resources), understanding of and responding to the demands emerging from the environment produced by the key persons of GOFREP and the authorities. The top-down standardisation includes activities and decisions that restrict, define and enable the development. This can be done by ensuring that the socially constructed conceptions and practices remain in the boundaries of the system and are documented and accredited when justified and by ensuring that the technical development keeps up with the other development. Moreover, the development process was directed by the visions. Together with a reflection of the success of the development and the efficiency of the operating system, this creates another dimension for the suggested development strategy.

## **8.3 The concluding study**

### **8.3.1 Background**

The aim of the concluding study was to analyse the results of the four studies (conducted 2002–2005) focusing on different aspects of VTS and GOFREP in Finland and to contribute to their development. The four studies were: Study 1: Development of VTS/SRS operators' work and work environment (Nuutinen et al., 2005a; 2005b; Nuutinen, 2005b; 2006); Study 2: Cost-benefit study of the centralisation of VTS services (operative analysis) (Nuutinen et al., 2005c); Study 3: Development of operational procedures for the Gulf of Finland Ship Reporting System (FMA, 2004a; 2004b; 2004c; Sonninen, 2002; 2004; Sonninen et al., 2004a; 2004b); Study 4: Customer satisfaction survey. The concluding study raises the question of how to guide the development of a complex socio-technical system (Vicente, 1999) that is emerging (Nuutinen et al., in press). We analysed the current state and the history of the service in Finland in four studies and identified several development needs.

Ergonomic studies are challenging both in the practical and methodical sense. The rapid changes in the work, the ways in which it is organised, the business environment, and especially the rapid introduction of new technology are recognised as challenging for the approaches and methods used in ergonomics. Since the changes continue throughout the life cycle of the system, e.g. the cost effectiveness of ergonomic development is a matter of concern. It is not enough that ergonomic issues are taken into account in the designing phase but they should be addressed in all changes of the system.

### **8.3.2 Framework**

VTS and GOFREP were approached within the CTA framework as a complex Socio-technical system, bound by constraints and enabled by possibilities (Vicente, 1999) of the current and historical constituents of the activity system (Engenström, 1999, Figure 15). We use three integrating concepts of the CTA framework in analysing the interactions within the VTS activity: Core task (Section 1.2.4), working practices and expert identity. The term working practices means a person's or a group's learned way of coping with the different demands of the core task by operating and conceptualising the object of work, cooperating with others and constructing expert identity (Nuutinen, 2005a). This means the ways the VTS operators do their daily work e.g. by monitoring traffic with radar-based surveillance systems and communicating with vessels with VHF, and how they understand their duties and the purpose of their work. Expert identity is defined to consist of three interrelated components: meaningfulness – the sense of the importance of a person's own work; professional self confidence – feeling of possessing experience, the skills and knowledge needed for the work and having the available resources by which the responsibility could be assumed; and a sense of control – the situational emotions awakened by reaching one's goal with the actions (performing by him/herself, others, or automation) (Norros & Nuutinen, 2002; Nuutinen, 2003; 2005a; 2006).

The research questions in this concluding study were: 1) What is the state of the VTS activity in terms of the service outcome, the operators' working practices, the conceptions of the core task and the sources of expert identity? 2) What are the explanations for that state in terms of the current state of the constituents and

the history of the VTS activity? 3) What are the main challenges of the activity?  
 4) What are the first development steps in order to answer the challenges?

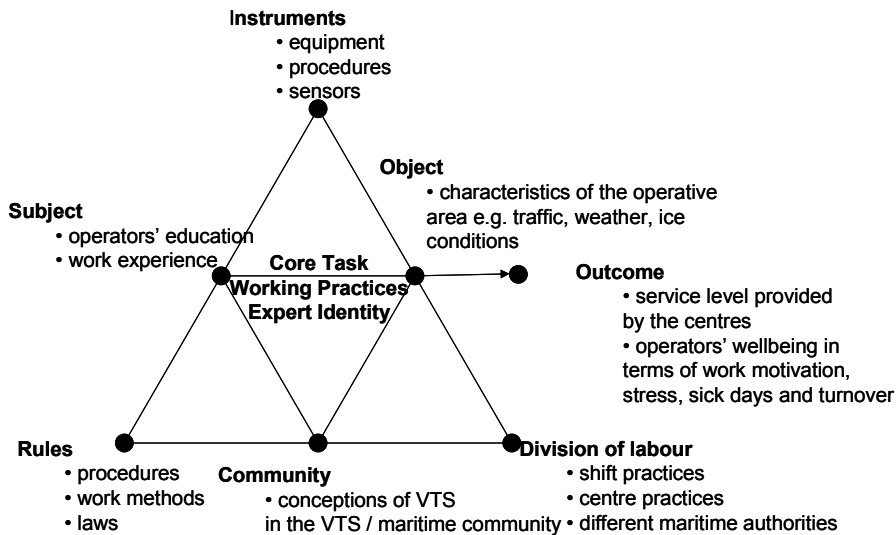


Figure 15. The model of an activity system (modified from Engeström, 1999) and the objects of the analysis. (See also Nuutinen et al., in press.)

### 8.3.3 Data and methods

This study is based on rich material collected in the four complementary studies which all have their own particular practical aims expressed in the name of the studies. The data included interviews, videoed observations and workshops, vessel and weather statistics, digital maps of fairways, different kinds of documents, expert assessment sessions and videoed simulation exercises. The quantitative data was organised by simple operations (percentages, time variations etc. The qualitative data was analysed following the steps of the Contextual Assessment of Working Practices method (see in details Nuutinen, 2005b). The same raw data was used in different phases of the analysis but the point of view to the data and further methods to analyse it changed according to the purpose of the phase and the nature of the data (e.g. qualitative or quantitative).

Altogether, the data of the different studies was analysed according to the research questions. First, the VTS actors' conceptions of the core task of VTS, adopted working practices, sources of operator identities and the produced outcome were identified and compared between persons and the centres. Guided by the activity system model (Figure 15) we then explored explanations for the state by searching for dependencies between the constituents and the historical roots of the current system. Next, we analysed the data in order to recognise pressures for change originating from the maritime community and society. The previous results were then studied from the point of view of potential for development. The borders of the activity system (from one VTS/SRS centre to the maritime authority activity) and the following definitions of the other constituents and the focused time period (past, present, future) were changed according to the aims of the analysis. The previous analysis was concluded in the main challenges of the VTS activity and the steps for the development based on reflection of the past, the present and a possible future of the system.

### **8.3.4 Findings**

The results showed that there are differences between the outcome, practices and conceptions of the core task and the sources of expert identity in the VTS centres, which can be explained by the current state of the constituents and the locally coordinated development history of the activity system.

There were several pressures for change evident in the data. There were indicators that at least a part of the maritime industry is ready to give or even expect a bigger role for the VTS and SRS in promoting maritime safety and efficiency. In addition, the technology (AIS, and VTS systems) is gradually becoming mature enough to allow the new role. Furthermore, there are ongoing changes in society, for example: a rising concern about pollution induced by shipping and transport of dangerous goods, an increasing cost efficiency demand for all authorities, increase in the amount of vessel traffic, introduction of new vessel types, reflagging, and establishing state-owned enterprises from the former units of the FMA.

The development potential of the activity system is limited by several issues. The current conceptions of VTS and SRS and their aim within the maritime

actors differed considerably. Both under- and overservice are problems. The customers do not “learn” what to expect and what is expected from them. This problem was recognised also by the VTS actors themselves. The other side of the recognised high job satisfaction is that giving up the present and committing oneself to the new, shared content of work might be difficult. There were also expressions of experienced inequality between the centres in respect to the possibilities to influence the development of the whole system. In addition, there are major differences between the centres in their resources for development: the number of personnel in the small centres restricts the possibilities for development efforts, e.g. conducting and participating in training, maintaining the equipment etc.

The discrepancy between the available role, the service defined, and the actual service and the differences in the development potential were recognised as the main challenges of the VTS/SRS activity. When trying to conclude the results to the development steps, we realised that there is an essential task still to do: to define what activities are included in good VTS/SRS operation, now and in the future.

We divided the development steps into acute and future-oriented steps. The acute steps were:

1. Defining what is good VTS/SRS service on a concrete level: What is the core task, what is not included; how can the operators know that they have done good work?
2. Defining how this good service can be produced in the different operative areas: Defining the content of work and common practices at the VTS centres.
3. Development of common competences and supporting the construction of operator identity based on the defined core task.
4. Managing the workload changes: e.g. prioritising work tasks, defining practices for dividing work (based on the defined threshold of workload) and creating organisational resources for division and integration of work by e.g. centralisation of small centres
5. Tuning the tools for the defined core task demands.
6. Defining the development strategy for the system.

The development steps oriented to the future are:

7. Defining the potential new role of the VTS/SRS, or a possible new system based on that activity, answering to the societal changes. The suggested new system was based on the integration of the operative activities of the authorities contributing to maritime safety and security, e.g. coast guard and the customs and excise authority. The role of the new system was defined more as a command, control and communicating system. It could manage relevant information from different sources and maintain emergency management readiness (Sonminen et al., 2005).
8. Taking advantage of the new possibilities of the technical tools for taking care of the new objective.
9. Establishing a virtual development organisation i.e. definition of objectives, tools and practices by which the operators and the centre manager can maintain continuous development.

Qualitatively different development phases characterised either by a top-down standardisation or bottom-up construction process were recognised. A combination of these processes was suggested for the future development strategy of VTS and GOFREP. This could allow both continuous development within VTS and recognition of the need for a new system. A promising way to achieve continuous development is to create reflective practices. They can be supported e.g. with annual simulator exercises aimed at procedure development (for development workshops, see next section).

We conclude that solving the current problems and promoting the development of the complex system call for a dynamic, open vision of the target future of the system, in which the pressures from the social, political, and technological environment are taken into account. The results of ergonomic studies can help in self-reflecting, envisaging and developing supportive methods for the system but the persons within the system create the will to develop and find their way towards the development horizon.

## **8.4 Development workshops**

The method used for the design can also be utilised for continuous development of the existing system. As already described in Phase 4, during the GOFREP system development four expert design workshops were arranged by the FMA and VTT. In these workshops subject matter experts from the GOFREP countries created a common understanding of the operation and agreed on the proposals for trilateral procedures. These proposals were then forwarded to the next levels of decision-making for implementation. This bottom-up procedure was deemed highly successful. In addition to the contribution to the development, the workshops also strengthened the commitment of the experts to the development work and served as a training session for the participants. This method of procedure was seen as a necessity also after the system was in service. Thus, it was continued in a slightly altered format where the operators of the system from all three countries convene to system operation evaluation meetings at least twice a year. In these Traffic Centre Personnel WGs the operators discuss and plan new procedures and amend the existing ones when required. In the future simulation shall be also utilised in cases where different methods of operation are wanted to undergo testing for the managing of an identified problematic case. This concept ensures continuous development of the procedures and supports continuous reflection of the practices and recognition of changes in the core task during the daily work.

## **8.5 Methods and organisation of development in daily work**

The development workshops alone, however, do not ensure that development continues. One challenge is to develop methods and practical means for recognising, analysing and saving the problems observed in daily practice so that they can be considered in the workshops and the needed modifications for the system definition, operational procedures and e.g. technical resources may be executed. An excellent example of this is the observed need to amend one of the TSSs in the GOFREP area. Shortly after the system start-up it became obvious to the operators that the location of a TSS unduly impedes the possibilities for manoeuvring of the HSCs navigating in the area. The amendment was made as soon as possible. However, even though this forum for development has been

implemented, it still seeks an effective way of operation. The information flow from the traffic centres to the workshops may not be as comprehensive as it should be. One of the reasons behind this is that the GOFREP operators concentrate on their core task, operating a ship reporting system, which is, of course, exactly what they should be doing. However, this daily work and the operators' experience of the ability of their resources and procedures to support it is the most valuable source of information for the development. Also the transformation takes place there. If the operators are not brought into a common forum, the high quality and congruent service objective is in danger. Thus, the development should be an inseparable part of the daily work with the help of methods that e.g. allow easy collection of material for the workshops.

The latest change of responsibilities in the operational organisation is the aim to enforce the official role of the operators in the organisation by giving them more responsibility on the organisation and managing of the Traffic Centre Personnel WGs (development workshops). Continuous development could be enhanced further by establishing a *virtual development organisation*. By virtual we mean that the members of this organisation are the members of the operation organisation, but they have a mandate, responsibility and also free resources to promote and do development work. The virtual development organisation could also ensure the implementation of the development achievements to the daily work, i.e. the changes to procedures etc. agreed in the workshops.

## **8.6 Results and documentation**

The result of this phase is a development strategy and implementation of that strategy including establishment of a development organisation. This phase should also result in methods and means for reflecting the efficiency of the system, recognising the present challenges and finding solutions for them, but also methods for anticipating the future change and envisaging the aimed future. This requires e.g. measurements for evaluating system effectiveness and success of the development actions and documentation of the history of changes, particularly the changes in the procedures.



## 8.7 Discussion

Continuous development necessitates the interaction between the two processes continuing throughout the life-cycle of the system. We recognised two important premises. Firstly, there should be a continuous development process going on within the system to ensure that the internal operation itself is in order. This also requires retrospective analysis of the operation, i.e. are the set demands and objectives fulfilled with the prevailing operation. Secondly, the self-reflecting evaluation and harmonisation process creates abilities to recognise if a need for a new system complementing the existing ones arises. Designing a new system or changing the existing one drastically can become topical when e.g. the recognised need requires activity that exceeds the authority defined in the international agreements for that kind of a system. When the need for an extreme change in the operation has been identified, it also benefits the actual development of the new system (in terms of experience gained with operation of the existing system) – and also the old system. We also created the hypothesis that the chain of systems could create dynamics that benefit both systems. Although the workers of VTS and GOFREP were the same, working in the system with a new name, in a slightly different place and with a slightly different focus of the work, with others appointed to the new job but still in contact with the workers in “the mother system”, they could perhaps give up some old practices and find ways to construct their new operator identities more easily. Furthermore, the separation process “forces” the old system to identify itself more clearly. In addition, the old system can gain benefits from the development work done around the new system e.g. in terms of finding new methods for development.

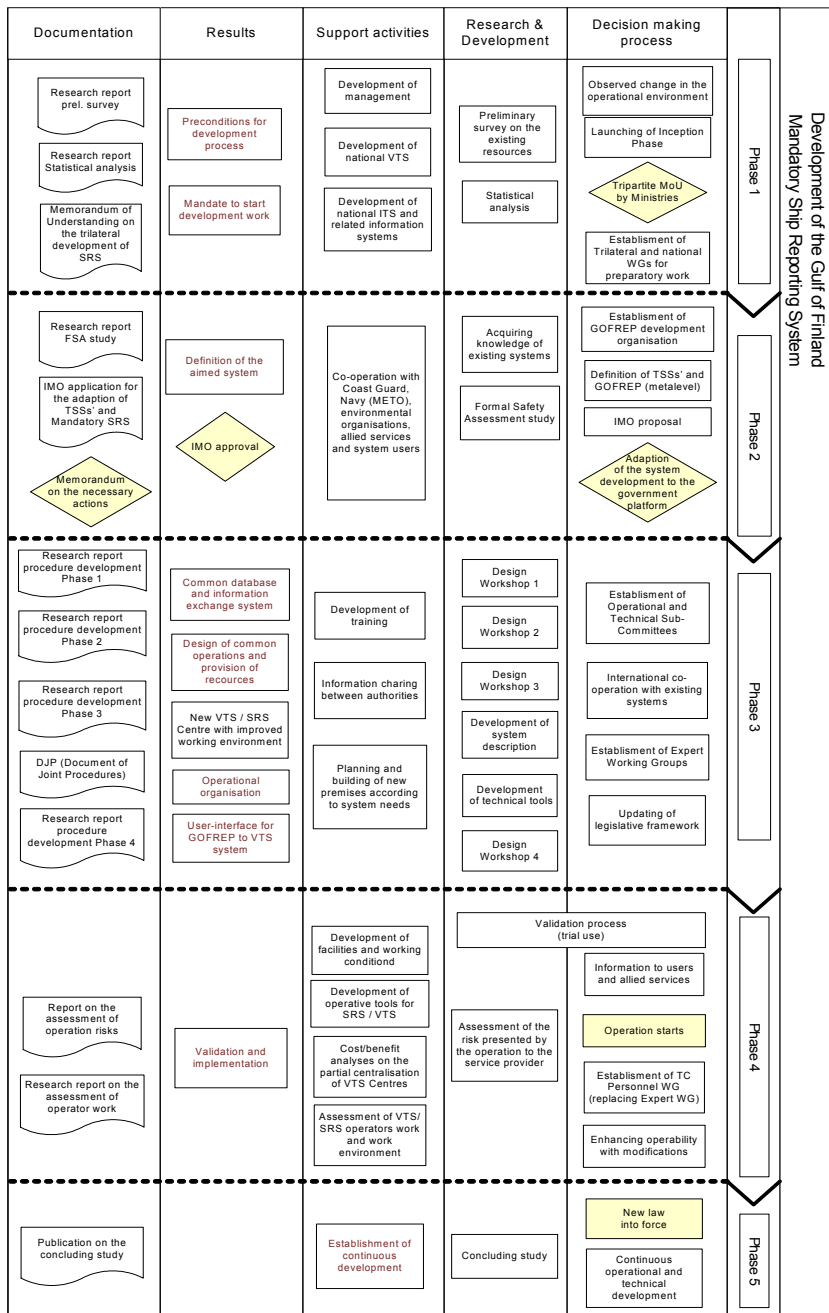
An important aspect of continuous development of the system is that it can be both quantitative and qualitative. Quantitative means that changes are e.g. a result of new skills being gradually added to those that were already there before (“more of the same”). Qualitative refers to the development where the changes are a result of acquiring a new set of skills, “different”. This can be e.g. a result of integrating different systems.

## **9. Discussion and conclusions**

### **9.1 Summary**

The main aim of this publication was to document the development process of the Gulf of Finland Mandatory Ship Reporting System in such a manner that it can be utilised and further developed by others in the construction of a multilateral maritime traffic monitoring and information system. Moreover, the description of the GOFREP development history aimed to reflect it in order to guide the further development of the system.

In this publication the course of actual GOFREP development was abstracted into five phases. Figure 16 summarises the main activities and results of each phase. The focus of the previous chapters was on the development of the operation, whereas the other objects of the development (the resources and normative constraints) got less attention. Particularly, the technical development was described rather superficially.



Development of the Gulf of Finland Mandatory Ship Reporting System

Figure 16. The GOFREP development process.

The process included a variety of activities and methods deemed necessary for successful development. The methods used in the research done during the development of the GOFREP system were:

- Feasibility study (The development of the Vessel Traffic Service and Information System for the Gulf of Finland)
- Statistical Analysis (Statistical Analyses of the Baltic Maritime Traffic)
- Formal Safety Assessment, FSA (The implementation of the VT MIS system for the Gulf of Finland: a Formal Safety Assessment study)
- General risk analysis methods
- User Centred Design (UCD) -methods, in particular the Core Task Analysis (CTA) and Contextual Analysis of Working Practises (CAWP)
- Simulation methods (requirement gathering and validation , System Validation and UCD)
- Use of expert judgement.

These created also an important base for the practical methods used during the development. These practical methods included e.g.:

- design workshops
- different working groups: Traffic centre personnel WG, Expert WG, National WGs etc.

## **9.2 The realised system**

The ambitious objectives for the new system were: the risk of accidents should be reduced; the service provided to vessels should be identical independent of who provides it and the service should be high quality from the first day that the system operates. According to the vessel traffic and maritime accident statistics the relative number, i.e. annual number of accidents out of the annual number of port calls, has clearly decreased from the introducing of VTS and has continued to decline with the implementation of GOFREP. Even without referring to any

particular studies on the effectiveness of GOFREP, the system can be said to have achieved its objectives. GOFREP offers a good model also for new systems.

The importance of establishing continuous development processes into the new system became evident during the development. The transformation of design workshops into development workshops of the operating system was an important innovation which was not obvious from the start but was recognised at such an early state that their potential could be utilised. However, it turned out that this alone is not enough but there is a need for practical methods and means to support the workshops. These methods should allow the inclusion of development practises into the daily operative work. In addition, a strong virtual development organisation is needed.

### **9.3 Development process and method used**

The ambitious objectives required both efficient utilisation of the existing resources and recognition of the main challenges to be considered in the operational development of the new system from the very beginning of the development. The three countries shared the idea of creating a novel system, but no one could imagine the exact operational realisation of the new system. The development history and the nature of the nearest known existing systems, the national VTSSs, created a point of departure in terms of the facilities and conceptions of the aimed activity. Several other factors affected the possibilities and constraints for the development. These were, for example, many EU-projects and the changing international definitions of different information and monitoring systems, the restrictions related to the fact that the new system operates on an international water area and the different EU statuses of the countries, to mention just a few.

The ambitious objectives also directed the focus of the development efforts into the human part of the system: on operations, operational procedures, training and common agreements on the nature of the system. The development of operations was mainly conducted by the intertwined design processes of the definition of the system and its realisation in operations, that is, in the operational procedures. Creating the operational procedures for a new system is always challenging, but because of the recognised challenges common investment of time and energy

into the development was considered necessary. Most of the operation design was made during the preparations for the design workshops and in the actual workshops i.e. Operational Exercises. Continuous work for preparing meetings and workshops for different levels of the development organisation, compiling the required information and preparing documents was maintained throughout the development process. The same kind of method is recommended also for future design tasks.

The way of describing the development as a process (instead of e.g. a project) was a conscious choice which also reaches the actual course of the development. Although the division of the development into phases was somewhat artificial, it was also reasonable since there are tasks that should be finished before going on to the next task. There is always an input from the previous phase(s) to the following ones. Documenting and revision of these inputs is important for maintaining of the common agreement and for the efficiency of the development work. We also claim that there will be new phases of development throughout the life-cycle of the system. There were points when it was necessary to go back and change earlier decisions or descriptions of the system. This is unavoidable, since the understanding about the system to be increases and also the requirements for the system change when the operational environment changes during the design. These points are critical and require careful consideration in order to maintain the commitment of the participants to the design (or to the continuous development).

The simulators provided a necessary environment for the representatives of the three countries in order to discuss, develop, test and, make decisions accepted by all, based on the agreement reached during these three steps. It is the writers' belief that the same results could not have been gained in the same timetable if the representatives had tried to accomplish the provision of common procedures only by sitting at meetings and by discussion. When the design is to some extent based on knowledge of existing similar systems that are operated slightly differently in different cultures, it is not a question of who is right but a question of utilising the knowledge of the different cultures and based on those, trying to build as good a system as possible.

Simulation is an excellent tool as a motor of design, but has flaws that need to be perceived. Although simulation generates new ideas and helps the participants to

anticipate unforeseen problems, it does not ascertain that the unexpected situations have been comprehensively covered. One should also bear in mind that however seriously the participants take simulations and however reliably the technology is working, they shall still be only simulations, not the real world and the test use in a real world would certainly raise new problems requiring immediate consideration.

The development progressed through an articulation of the bottom-up construction and top-down standardisation (see e.g. Nuutinen et al., in press). By bottom-up construction we mean the development achieved by the participation of different experts and their efforts to create a common understanding of the system to be. Top-down standardisation includes activities and decisions that restrict, define and enable the development by ensuring that the socially constructed conceptions and agreements gained within the people participating in the development become documented and accredited. The importance of the visions of the new system and the reflections of the gained efficiency were recognised. The development strategy for the existing system can thus have two dimensions: vertical (the bottom-up construction and top-down standardisation) and horizontal (past – future).

FSA and Human-centred design methods may cover the whole of the required development process. It might seem to be ideal to integrate the humans into a computational model. However, with methods particularly developed to analysing the human part of the system, the quality of the results could be clearly better and more applicable for different purposes than including them with a reasonable cost in the computational models. Matters that can be assessed in a formal way, should be dealt accordingly, but matters related to human conduct should be evaluated with qualitative methods particularly developed for the purpose.

## **9.4 Conclusions**

This publication described and reflected the development process of the Mandatory Ship Reporting System in the Gulf of Finland. The development of the GOFREP system is a good example of a time-pressured complex design task that has remarkable constraints (international, cross-cultural, historical development, regulations, technological maturity etc.). The six guiding

principles of the development and the practical methods used are suggested also for other design of maritime systems. This publication clearly indicates the need of comprehensive expert influence and commitment in the process of evolving a traffic management system. The process also highlighted the utmost importance of implementing research as an essential part of developing safety-critical systems.

The development process is described here as a continuum, but it was constructed during the progress. We believe that in many perspectives the development process benefited from this self-steering. Although the development process was beyond dispute a trilateral success story, much of the development task could have been realised differently. If we had had the knowledge on the abstracted development process that we now have, the process would have undoubtedly been more effective and more comprehensive. We did not fully succeed in abstracting the process, but we hope, however, that this publication will serve as a good platform for future developers meeting the same challenges. At least we hope that they can learn from our mistakes and improve the process.



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Title <b>Development Process of the Gulf of Finland Mandatory Ship Reporting System Reflections on the Methods</b>			
Abstract The main aim of this publication was to document the development process of the IMO-adopted mandatory ship reporting system in the Gulf of Finland (GOFREP) in such a manner that it can be utilised and further developed by others in the construction of a multilateral maritime traffic monitoring and information system. Furthermore, the description of the GOFREP development history aimed to reflect the system in order to guide its further development.  The GOFREP system was jointly developed by Finland, Estonia and Russia and has been operative since July 2004. In this publication the events of the actual GOFREP development are abstracted into five phases. The main objectives of the phases and the main results of each phase are summarised and discussed. The applied methods are also briefly described and the supporting studies reported.  The focus of the publication is on the development of the operation, whereas the other objects of the development get less attention. Particularly, the technical development is described rather superficially.			
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The authors of this publication present expertise that is required among others in the development of such a complex socio-technical system as the ship reporting system is. Sanna Sonninen is a research scientist at VTT with a background as a navigating officer and a VTS operator. She has participated in all GOFREP and VTS related research projects at VTT since 2001 and has been the project manager in many of them e.g. the four GOFREP operational development projects. Maaria Nuutinen is a doctor of psychology and a research team manager at VTT. She is an expert on human-technology interaction, organisational research and development particularly on safety critical domains. Tony Rosqvist is a doctor in applied mathematics and a senior research scientist at VTT. He has conducted several Formal Safety Assessment studies.

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