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PROJECT N°: GRD1-2000-25208-SEAM

ACRONYM: SEAM

TITLE: Assessing concepts, systems and tools for a Safer, Efficient and Environmentally Aware and Friendly Maritime Transport

PROJECT CO-ORDINATOR: METTLE

PARTNERS:

METTLE	France
GRIMALDI	Italy
ISL	Germany
BMT	United Kingdom
MRC	United Kingdom
AMRIE	Belgium
ROTTERDAM	The Netherlands
SWH Bremen	Germany
SAT	Italy
SAL	Sweden
EMIL	Ireland

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DISCLAIMER

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1. OBJECTIVES AND STRATEGIC ASPECTS

1.1. Framework

Unquestionably, all shipping operations exert pressures on the marine environment.

In parallel, legal framework on this issue is rapidly evolving at international, European and local levels, in order to reach a safe and environmentally acceptable maritime transport system.

Three different environmental issues are of particular importance in this context and have been treated in parallel in the SEAM project:

- Ballast water management
- Use of antifouling paints
- Air emissions from ships

The acceptance of the hazards and risks associated with the use of antifouling paints, the discharge of ballast water and emissions from ship exhaust has led to research and development into methods to mitigate these effects.

1.2. Objectives of SEAM

The research project SEAM focuses on formulating safety and environmental measures to mitigate the impact of these three key elements of shipping operations on the marine environment: ballast water management, antifouling paints and air emissions.

The measures proposed in the SEAM project have to meet acceptable risk levels of shipping operations taking into account the views of the main stakeholders (shipowners, ship managers, ports, terminals, regulatory bodies) and have to be assessed regarding their economic viability.

1.3. Methodology and Work undertaken

The research work in SEAM follows the main steps of the Formal Safety Environmental Assessment, as identified in

Figure 1.

The first step of the work was dealing with the activity description, the identification of hazards and the collection of relevant data, for the three issues analysed in the project.

The outputs of this work feed into the second step in which risks have been assessed on two geographical examples (German Bight, Gulf of Naples). A numerical model has been developed, based on scientific methodologies for the evaluation of the environmental risks, and interfaced with a GIS (geographical information system), in order to simulate environmental risk ratios (derived from various exposures), the geographical domain and profiles of contaminant concentration, abundance of species and environmental risk ratios as well as the probability distributions of risk ratios for the impacted area.

A number of mitigation measures has been identified, categorised and analysed for the three SEAM issues, and submitted to a sample of stakeholders, representing scientific and technical experts, ship owners/operators, shore-based operators, environmental experts.

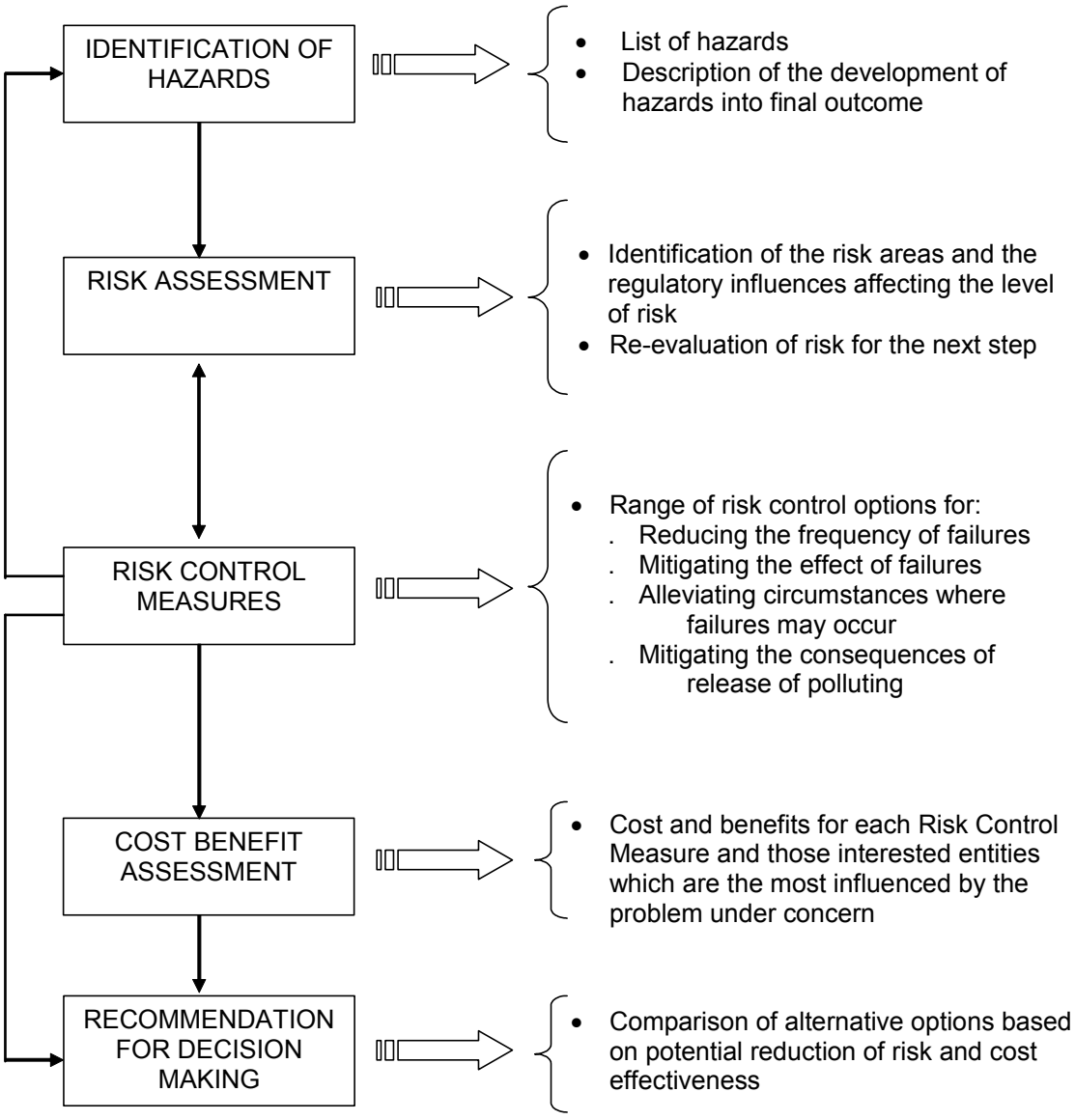

Figure 1 - FSEA methodology

The scope was to reach an agreed level of acceptable risks based on various user requirements and current scientific knowledge regarding the impact of antifouling compounds, the discharge of ballast water and the quality of fuel and ship emissions on the marine environment. The measures of mitigation against the impact of the shipping on the marine environment that were acceptable to all stakeholders have been identified. These measures are not necessarily the most efficient or economic, but represent acceptability. has been identified.

Then, the feasibility of potential mitigation measures have been evaluated in some precise case studies (route Cork-Esjberg, route Salerno-Valencia, port of Rotterdam).

Finally, a cost-benefit analysis has been carried out for selected mitigation measures, based on the collection of individual costs by ship types and the calculation of expected benefits.

To achieve its objectives, SEAM comprises of 7 Work Packages (WP) based on the SEAM-FSEA approach and a horizontal users-group which bring together all stakeholders:

- **WP1: Management**

The main objectives are to provide the project management, to undertake relationships with the European Commission and to represent SEAM project to parties outside the consortium.

- **WP2: Activity description, hazard identification and data collection**

The main objectives of this Work Package are to give a comprehensive view over the three SEAM issues (ballast water management, use of anti-fouling paints and quality of fuel and emissions from ships), to identify hazards and to collect data.

- **WP3: Risk assessment for safety and environmental measures**

The aim of this Work Package is to assess risks incurred by these three issues and their resultant impact on environment.

- **WP4: Environmental risk acceptance level and mitigation measures**

The main objectives of this Work Package are to determine an agreed level of acceptable risk and to propose alternative mitigation measures and procedures that meet acceptable risk levels of shipping operations taking into account the views of the main stakeholders (shipowners, shippers, ports, terminals, regulatory bodies).

- **WP5: Case studies and full scale evaluation**

The main objectives of this Work Package are to study the technical feasibility and the economic parameters of the proposed measures for a selected variety of likely shipping environments: Mediterranean Sea, North Sea and Port.

- **WP6: Cost benefit analysis and economics of operating ships**

The purpose of the cost-effectiveness analysis is to assess the expected outcomes and resource costs of alternative mitigation measures. The other objective of this Work Package is to carry out a financial assessment in order to show the impacts of the measures on the parties involved.

- **WP7: Dissemination and Exploitation**

The aim of this Work Package is to define the dissemination of SEAM project and results, the exploitation plan of SEAM as well as the consortium recommendations and market approach and strategy.

2. PARTNERSHIP

2.1. Introduction

SEAM partnership includes two groups of partners: the safety and environmental engineering and economics providers hereafter named the technical providers and the end-users (the ship-owners, the ship-managers, the ports, the shippers, the terminals).

The technical providers include knowledge and expertise in Safety and Environmental Maritime Engineering and FSEA applications in the maritime industry (METTLE), Economics of Shipping Operations (ISL), Maritime Environmental know-how, in-house expertise and impact (MRC), Research Centre specialised on EIA (Environmental Impact Assessment) (BMT).

While in the end-users side a leading expertise in shipownership, management as well as shipper and terminal operations is provided by GRIMALDI Group, while Port requirements and specifications are present with Europe's leading shipping port, the Port of Rotterdam. Maritime authorities are also represented by the Harbour Master of Bremen (SWH) and maritime interests by the association AMRIE.

2.2. Overview of the Consortium

Participant		**Organisation Name (Abbreviate)**	**Country**	**Business Activity / Main Mission / Area of Activity**	**RTD Role in project**
Activity Code	**Nr**				
IND	1	**METTLE**	F	Engineering, Maritime Safety, Intelligent Transport Systems, Logistics and SDCM	Coordinator and WP5 Leader Safety Engineering and FSEA
IND	2	**GRIMALDI**	I	Shipowner, Short-Sea Shipping Operator	Stakeholder HA and WP2 Leader
REC	3	**ISL**	D	Institute of Economics for Shipping and Logistics Transport economics, telematics, logistics management	WP6 Leader Data Collection; Cost-effectiveness analysis and Economics of Shipping Operations

REC	4	**BMT**	UK	British Maritime Technology Research and Development, Marine Technology	WP3 Leader Risk-assessment and Environmental impact assessment for shipping operations
HES	5	**MRC**	UK	Maritime Research Center, Southampton Institute Higher Education and Research; Maritime Environmental Institute	WP4 Leader and overall scientific responsibility for the ballast water, antifouling paints and fuel
OTH	7	**AMRIE**	B	Maritime Regional Interests in Europe, Ports, Shipowners, Shippers, Terminals, Regions, Cities, Universities, etc	WP7 Dissemination and Awareness Actions
IND	8	**ROTTERDAM**	NL	Rotterdam Municipal Port Management (RMPM)	Participate in HA and WP4 Port related expertise, knowledge and networks within the port industry and (operational) information on port activities)
OTH	9	**SWH**	D	Harbour Master and Port Authority of Bremen	HA and other WPs, representing the International and European Association of Harbour Masters
OTH	10	**EMIL**	IE	Shipping Agency	Participate in HA
OTH	11	**SAL**	SE	Scandinavian Auto Logistics Shipper	Participate in HA
OTH	12	**SAT**	IT	Salerno Auto Terminal Terminal	Participate in HA

2.3. Description of the partner

2.3.1. METTLE, France

Mettle offers important competence in Engineering and RTD for maritime technology, design and re-engineering including Maritime Safety, Information Technologies, Intelligent Transport Systems, shipbuilding and ship design, automatic control, marine environment, safety and risk analyses, together with broad experience of full-scale marine operations. METTLE also designs and develops customised designs and projects, and validation

methodologies often based on know-how and expertise from full-scale experiments and scale experiments and scale model tests, combined with theorical approaches.

Goals

- To rationalise abilities and resources in the corporate maritime, transport and tourism industry fields.
- To aim to assist companies throughout their projects before and after any investment.
- To sustain the innovation process for the maritime industry. The exploitation at full scale and the technology transfer and consultancy of maritime engineering and design to the industry is a key factor of the METTLE corporate policy and strategy.

Main activities:

Industrial activities

- Design of ships, luxury boats, fast crafts, and others.
- Concurrent engineering of shipbuilding activities.
- Prototype of new concepts.

Information Society Technology

- Application of telematics to the Maritime Industry.
- Software Development and Production
- System Integration and Implementation of telecommunication and information technologies to shipbuilding, shipping and transport.
- Intelligent Transport Systems applications

Consultancy

- Project management of large industrial and engineering project.
- Business planning.
- Logistics and Inter-modal Transport

Company Capability

- Extensive knowledge and involvement in Engineering, and RTD activities for the transport, shipbuilding, including marine equipment sector.
- Extensive knowledge and involvement in Project Management and RTD activities for the shipping and shipbuilding sector.
- Extensive knowledge and involvement in RTD activities for the marine resources sector.
- Good understanding, and contacts within the European Commission, government Departments, Research Organisations and the maritime, transport and tourism industries.

2.3.2. Grimaldi Group, Italy

The Grimaldi Group, with over 50 years of experience in the shipping business, is specialised in the operation of roll-on/roll-off vessels and car carriers. It is an established carrier for several major car manufacturers and a dedicated supplier of integral logistic support.

The Grimaldi Group is specialised in the transport of cars, commercial vehicles and other ro/ro cargo, containers and general cargo. It is the largest privately-owned ro/ro ship owning company in the European Union with offices in Italy, the United Kingdom, Belgium, Sweden, West Africa and Brazil.

Its fleet is made of ro/ro multipurpose vessels, pure car carriers, general cargo vessels. The Group is currently in the process of modernising and expanding its fleet.

The Group offers the following ro/ro services:

- Euro-Med Service linking on a weekly basis and at fixed day sailings 17 ports in 13 countries of North Europe and the Mediterranean: Cork, Portbury, Esbjerg, Wallhamn, Antwerp, Southampton, Livorno, Malta, Piraeus, Izmir, Ashdod, Limassol, Alexandria, Palermo, Salerno, Savona, Setubal.
- West-East Med Service linking every 12 days the ports Ashdod, Limassol, Alexandria, Piraeus, Malta, Savona, Fos, Barcelona and Valencia.
- Short Sea Service linking the ports of Livorno, Salerno, Palermo, Valencia and Barcelona.
- Adriatic Service linking weekly the ports of Venice, Trieste, Ravenna, Koper, Izmir, Piraeus, Ashdod, Haifa and Alexandria.

Since May 1999, the Short Sea Service Line, with the Ferry Malta Express, offers a weekly passengers and RoRo service from Salerno to Malta and to Valencia, waking up again the old Company tradition in passengers transport.

Moreover the Grimaldi Group offers a ro/ro and container service linking North Europe with South America and West Africa.

Apart from the maritime services the Group has been rapidly developing car terminals in the Mediterranean Sea. Currently it operates port terminals in Salerno, Palermo, Alexandria and Valencia while it also investing in trucking companies.

The companies which operate under the trade name of The Grimaldi Group are: Grimaldi Compagnia di Navigazione S.p.A., Inarme S.p.A., Atlantica di Navigazione S.p.A.

2.3.3. ISL, Germany

The Institute of Shipping Economics and Logistics (ISL) is an independent, private non-profit foundation that was established in 1954. ISL deals with business management, transport and telematics in logistics and transport systems as well as with technology and prospects for maritime transport systems and acts as information centre for maritime transport and logistics worldwide. ISL with its three research departments "Logistics Systems", "Transport" and "Telematics" has accumulated a wealth of experience that enables it to develop and to guide the realisation of innovative strategy concepts as well as to carry out market analyses in combined land/sea traffic. The harmonisation of logistic and transport operating

sequences is a prerequisite for efficient organisation of the macro logistics and the integrated application of telematics.

The four main fields of work in the "Logistics Systems Department" are strategic corporate concepts, cooperative systems, location, and marketing macro logistics systems. Corporate concepts for global logistics have to be designed to be practice-oriented, upgradable and economically efficient. Logistics systems are cooperative systems as the logistic enterprise is together with its partners a service provider for distributed production and trading processes. The development of logistics locations has also to consider factors like global supply and waste management. The planning of networked macro logistics systems is a main focus of transport policy programs. The "Transport Department" has built wide ranging analytical skills in data analysis and transport modelling for the whole European transport market. Included in the various analytical approaches are modal split assumptions with regard to land and sea transport as well as forecasting of domestic and international goods traffic. Most recent activity is the establishment of European/worldwide combined data bank/modelling system on freight origin/destination matrices including modal split and route choice. The "Telematics Department" focuses on the optimisation of logistics through the interaction with information/communication technology. The possibilities offered by innovative technologies are incorporated into the design of logistics systems.

2.3.4. BMT, United Kingdom

BMT is a privately-owned totally commercial Contract Research Organisation. About half of its turnover comes from commercial Contract Research and Development (CR&D), the rest of the turnover representing consultancy, services, the sale of products or the proceeds of investment.

BMT is a non-profit-distributing organisation. All profits are ploughed back into the Company and fund amongst other things BMT's internal R&D programme. . The impact of this investment in R&D can be gauged by the growth of CR&D turnover. Even against a background of general economic recession BMT's CR&D turnover keeps rising at about 16% a year.

The investment in partly-funded EU research projects can be seen as part of this process. BMT utilises the experience, the generally applicable methods and the software components produced in EU funded projects in its commercial consultancy and in commercial Contract R&D services to industry and government.

The results of SEAM fit within the corporate strategy of BMT that is, as mentioned above, to use the results of internally-funded research to spur the sales of CR&D, consultancy, services and products. Though the development and application of Formal Safety Assessment tools to environmental issues will be invaluable to provide the basis for decision making, for EU policy and the development of legislation. BMT is especially well positioned to undertake the risk management on marine Environmental issues.

2.3.5. MRC, United Kingdom

Southampton Institute is a major UK University Sector College offering high quality education courses of a vocational nature, leading to a range of diplomas, degrees and

postgraduate qualifications. The Institute also carries out research and consultancy work across a wide subject area, including Maritime.

The Institute is located on two sites. The city campus is in the centre of Southampton, whilst the Warsash Campus is located on the River Hamble where it meets Southampton Water. This provides a marine activities base for teaching and research, with a pier, boathouse and laboratories, etc.

Maritime Research Centre

The Maritime Research Centre (MRC) is the research arm of the Maritime Faculty of Southampton Institute.

The MRC was established in 1993 and is based at the City Campus within purpose-designed accommodation. The Maritime Research Centre is responsible for co-ordinating the research activities of the postgraduate research group, and all staff. There are currently two Research Fellows, three Research Assistants, 12 Research Students. The Centre also welcomes visiting researchers. In the past two years we have hosted visitors from China, Egypt, France, Italy, Korea, Russia and Switzerland. Activities span a wide sector of the maritime world, which are housed in four main areas:

- Maritime Leisure Youth and family participation in water sports and leisure management within the maritime area.
- Maritime Environmental Science Research interests in underwater light field, anthropogenic contaminants in coastal waters (including antifouling compounds), coastal processes, coastal management.
- Maritime Operations Navigation systems, VTS, Short Sea Shipping, Maritime Industries Skill needs, Port and shipping safety issues, port and shipping environmental issues (antifouling, ballast water port waste reception).
- Maritime Technology Naval Architecture, Hydrodynamics, decommissioning of offshore structures, materials, control systems.

The MRC is involved with many UK, European and other international research projects.

Facilities in the Maritime Faculty include: Towing Tank, Wind Tunnel, Stability Tanks, CAD Suite/ Design office, Fluids Laboratory, Marine Environmental Science laboratories, including an Ocean Science and Wet Marine Ecology Laboratory and Yacht Technology Laboratory, Chartroom, Navigation Systems Laboratory, Marine Navigation Simulators, and a range of powered and sailing craft.

2.3.6. AMRIE, Belgium

AMRIE was formed in 1993 on the initiative of Members of the European Parliament.

The mission of AMRIE is to give the maritime regional interests in Europe an effective political voice and to contribute to establishing an "integrated maritime strategy". AMRIE is the platform for people involved to express their ideas, protect their interests and develop the prosperity of the European maritime economy at the regional level.

Its 60 members cover all maritime interests (Regional Authorities, cities, ports, research centres, universities, industries, qualification societies, trade unions, etc.) and are located in

all Member States of the EU plus Isles of Man and Malta. This gives AMRIE a wide range of expertise on every maritime issue.

Its main activities are lobbying the European Commission, the European Parliament and all other European Institutions to favour a development of the European Maritime Economy, networking between our members to launch common projects and circulating information.

The main themes of AMRIE policy are employment, environment and excellence, all within the framework of improving competitiveness. The areas covered include:

- Spatial planning and inter-regional cooperation,
- Competitiveness and productivity in maritime transport and maritime industries,
- Development of new information technologies,
- Employment and availability of human resources,
- Education and training throughout a person's career,
- Research and development,
- Safety at sea, shipping quality standards and elimination of substandard ships and operators,
- Protection of the environment,
- Quality of life for citizens.

AMRIE has 5 Specialist Working Groups which meet 3 times per year: "Centres of Excellence", "Shipping Quality", "Regional aspects of Short Sea Shipping", "Ports and Maritime Regional Interests", "Marine Environmental care".

2.3.7. Port of Rotterdam, Netherlands

The Port of Rotterdam area covers 10,000 hectare port and industrial area with an extent of 40 kilometres from the eastern city limits to the North sea. The hinterland of Rotterdam includes the entire Europe and the port is the gateway to a market of 350 million customers.

Rotterdam is the largest port in the world with a throughput of more than 300 million tons of cargo annually, transported to and from Rotterdam by approximately 30.000 seagoing ships. Also some 120.000 inland vessels are calling at Rotterdam every year.

Main port Rotterdam has three functions, being: transport and transhipment, industry and distribution. All these activities are providing (indirect) work for 300.000 people. Rotterdam's contribution to the Gross National Product of the Netherlands is € 23 billion, around 12% of the total GNP.

The Rotterdam Municipal Port Organization is a service provided by the Rotterdam Municipal Council. The Rotterdam Municipal Port Management has 1163 employees within two Directorates:

- The Directorate Infrastructure and commercial affairs, responsible for the design, construction and management of the infrastructure. Attraction of new customers and the issue of new sites to customers is also handled by this directorate.
- The Directorate Shipping, which is responsible for the waterside management and development,

as well as the safe, effective and efficient handling of shipping traffic in the Rijnmond region. Also included here is providing for the needs of waterside infrastructure.

2.3.8. SWH, Harbour Master, Germany

The main works carried out by the Harbour Master of the port of Bremen are:

- Implementation of and ensuring compliance with all national and international laws, rules and regulations
- Safety of the port, its population, the environment and the ease of traffic
- Participation in passing, changing or amending the rules and regulations relating to the port area
- Supervision of the safe handling of cargo in the port incl. labour safety
- Organization, policy matters as well financial, technical and personnel planning
- Coordination with other governmental bodies
- Negotiations and supervision of port tariffs
- Advising the state government on all maritime and port matters
- Representative of the Bremen port authority in local commissions and committees
- Expert representative on behalf of state of Bremen and/or the coastal states in federal commissions and committees in the maritime field, especially in the area of port safety, carriage of dangerous goods and marine and port environmental protection
- Representative of the federal German states in EU – bodies
- Member of the German delegation to international bodies like IMO, EU, etc. as expert on port matters, dangerous goods, and environment protection
  Member or chairman of national or international working groups (UN, OECD, IMO, EU, UNEP, IAPH, IHMA, and PIANC)
- Consultant to the International Maritime Organization (IMO) in port safety, handling of dangerous goods, and environment.

2.3.9. SAT, Italy

The Salerno Auto Terminal (SAT), realised in partnership with other important operators and shipowners, has been inaugurated in May 1996, has a surface of about 60.000 sq.m. and moved 250.000 new cars in 1988. Automar, a joint venture among Grimaldi and some strategic partners, runs a trucking company serving Fiat, Ford, Opel, Peugeot, Renault, Seat, and VW. It also manages its own car terminal with a compound of 185.000 sq.m. at Pontecagnano near Salerno, linked to road and rail and offering its PDI facilities to the main car manufacturers.
It is a company specialised in handling of cars, vans, trailers and brand new trucks in the commercial port of Salerno. For this purpose SAT has a fenced and watched terminal of 70.000 sqm, it can also count on a well skilled and qualified organisation being able to

provide all types of services in order to guarantee the most efficient quality and information management of products that main Italian and Foreign Manufacturers entrust them with.
The port of Salerno is positioned in a favourable logistic position as to the markets of Centre and South Italy and is well linked by regular lines and served with RORO vessels to all destinations.

2.3.10. SAL, Sweden

Scandinavian Auto Logistics AS provides logistical services for the automobile industry via strategically allocated vehicle hubs.

Comprehensive services are offered in partnership by SAL in the delivery of the vehicle from the factory to the dealer through a well integrated chain of supply.

Scandinavian Auto Logistics AS operates both inland and port terminals:

- Directly located at the quayside
- Serving main carrier
- High frequency af calls
- Multi user port
- Secure video-monitored parking areas
- Technical processing
- Survey

Scandinavian Auto Logistics AS offers the automobile industry via Grimaldi Lines direct weekly sailings linking 18 European ports in 14 countries to the Scandinavian ports of Esbjerg in Denmark and Wallhamn in Sweden.

At their own terminal and hub in Esbjerg, SAL offers a complete stevedoring package at an exclusive quayside of 500m, with a draft of 10.3 m.

2.3.11. EMIL, Ireland

The EMIL is a specialised maritime logistic operator for all over Ireland based in Ringaskiddy (Cork). Our issue is the distribution of vehicles and containers in Ireland. Presently we are operating the distribution of Fiat vehicles and soon we will start also with containers. We have a compound of 40.000 sm. and we already ask to the port other 50.000 sm. that in few months will be available. The company owns six car transporters and we foresee to develop soon our fleet. For the beginning of the summer 2000 EMIL will operate also as stevedoring company.

3. SCIENTIFIC AND TECHNICAL ASSESSMENT

3.1. Activity Description, Hazard Identification and Data Collection

A detailed description relating to the three key issues of SEAM (ballast water management, anti-fouling paints and quality of fuel and emissions) has been provided. The main inputs were the SEAM technical visits and workshops, the expertise of each partner, and the data collected on the state of the art (reports, web site reviews, etc.). This description includes both the technical and the operational aspects of the SEAM items, as well as a review of their legal framework. In addition, the main European maritime operational environments have been described. The deliverable D2.1 – *Activity Description* comprises these descriptions as well as the questionnaires used to collect information on rules and procedures.

Priorities among shipping operational procedures were identified as agreed by the stakeholders involved in the SEAM activities. Stakeholders included scientists, port authorities, shipmasters, ship owners and economists. This has been reported in deliverable D2.3 - *Operating Scenario Priorities* as well as the results of the workshop on '*Operational procedures priorities'*.

Afterwards, hazards and accidental events related to the three SEAM issues have been identified. As a hazard is an event with a potential for causing loss or damage to life, property and environment, whether it is on a continuous or accidental basis, both operational and accidental releases have been identified for the three potential pollutants. The hazard and accidental event identification have been reported in deliverable D2.2 – *Catalogue of SEAM Hazards and Accidental Events*.

The assessment with regards to the three issues investigated indicated that the main cause for the release of pollutants was ship operation. The investigation also demonstrated that it is unlikely to establish the exact quantity and impact of ballast water discharge in a particular area. The work therefore concentrated on establishing the quantity of Tri-butyl-tin (TBT), anti-fouling paint, *sulphur dioxide (*SO_2) and *nitrogen oxide* (NO_x) that has been released in a particular area during a given year. This work has been carried out by using the environmental information system MARION. Two areas have been investigated: the German Bight, thanks to data collected with the assistance of the port of Bremerhaven, and the Gulf of Naples.

The results of the MARION calculation in the German Bight and the Gulf of Naples for the years from 1992 to 1999 as well as the description of the MARION system have also been reported in deliverable D2.2 in April 2002.

3.2. Risk Assessment for safety and environmental measures

By modelling the release of TBT, TBT-substitutes, ballast water and the atmospheric emissions caused by ships, the results of the MARION calculation are used to evaluate the pollution risks caused by these pollutants in the two selected areas (German bight and Gulf

of Naples). As the results of the MARION calculation in the Gulf of Naples were late, the work was started for the German Bight.

Generic solutions for the modelling and evaluation of risks have been established, agreed and reported in deliverable D3.2 - *Ship Risk Assessment Model Specification*.

Initial evaluations of different pollutants have been simulated using risk-modelling system. Assessments were then made on the environmental impact and risk for the marine and atmospheric pollutants considered.

A generic method for modelling the dynamics of exposure concentrations of TBT and other anti-foulant within a region of study has been developed. The method takes into account multi-sources of release of pollutants in space and time, the environmental hydrodynamic conditions and the geochemical pathways for chemical transfer dynamics. For the establishment of risk caused by ballast water release, a first order kinetic method has been adopted for the dynamic modelling of the degree of abundance of foreign species, introduced to a new marine environment. The biokinetic modelling approach relies on the availability of species characteristics data. The model for assessing risk from atmospheric emission caused by ships is three dimensional and predicts species (gases) concentration within 30 layers in altitude across the whole regions of studies. A software specification that incorporates these three environmental risk-modelling tools is being developed. The evaluation of the environmental risk is produced in geo-referenced contour plots dynamically in time.

For the German Bight, the case study has been achieved and the results comprise:

- TBT Dispersion in Marine environment
- Conservative vs. non-conservative cases

In the conservative case, there is no TBT degradation but a cumulative process in the water column, while in the non-conservative case, there is a chemical degradation of TBT in the water column.

- NOx and SOx Emission in different configurations of wind and comparisons with the European Air Quality Standards
- Ballast Water Scenario.

For the Gulf of Naples, the modelling work has been achieved.

The environmental risk evaluation from ship traffic activity around European coastal zones has been dynamically modelled with time, since the environmental exposures are predicted in geospatial and temporal terms with the environment. The use of both marine and atmospheric environmental constraints in the models leads to the prediction of the environmental risks within a whole year period and zones which are most of concern. The environmental risks have been computed from the ratio of the Predicted Environmental Concentrations (PEC) in time to that of the so-called No-Effect Concentrations (NEC). The latter is specific to a toxicity threshold above which a targeted marine species of concern is at high risk. Furthermore, the rate of occurrence of the PEC:NEC ratio levels within the region of study has been predicted. As a result, it is possible to identify the affected coastal zones and correlate it with specific marine species of concern in each coastal zone at various time periods of year.

Similar concepts of risk ratio prediction have been applied to the atmospheric case study. The environmental thresholds have been drawn from the European Union Air Quality

Standards (EU_AQS) or indeed the World Health Organisation standards. Atmospheric emission exposures of SOx and NOx are consequently compared in time with the EU_AQS threshold for instance. In the Gulf of Naples for instance, NOx emission exceeds the EU_AQS threshold at around twenty metres above sea surface offshore but remains below the threshold throughout the year at higher altitude.

New modelling benchmarks for risk assessment and impact of contaminants from ship traffic activity vectors around two European coastal zones have been established during the SEAM project. These enabled the generic evaluation of the environmental risks that can be used for the assessment of maritime transport activity around other European coastal waters.

3.3. Environmental Risk Acceptance Level and Mitigation Measures

The models made earlier have been be used to assess environmental impact and risk for alternative safety and environmental measures for marine and atmospheric pollutants under study.

Data on current technical and scientific knowledge regarding the control of fouling, ballast water management and low-sulphur fuel have been collected. Summary tables have been prepared, presenting a description of the mitigation measures available (Operational Mitigation and Technical/ Scientific Mitigation) with their associated advantages / disadvantages.

Table 1 - Available mitigation measures for ballast water management

BW MANAGEMENT: Mitigation measures	Cost	Advantages	Disadvantages
Filtration: separation of solids from fluids by use of a porous medium	Filtration Unit Running costs Disposal (if in deballast)	Disposal in port (if in ballast) Enhances secondary treatment Preventive measure (if in ballast) Low maintenance	Blocking of filters Resize of pumps Space constrains
UV: use of ultraviolet light as a means of sterilising the ballast water	Installation + pipe modifications Lamp (1000 hours) Running costs	Environmentally sound No negative effect in piping	Possible reduction of efficiency: turbidity, lamp intensity, etc. Potential occupational exposure Penetrating capacity limited.
Open Ocean Ballast Water Exchange			
Sequential: empty/refill method requiring pumping out ballast water taken on in ports, estuaries, or territorial waters until the tank is empty, then refilling it with	Low	Low cost	Safety concerns No guaranteed of complete removal of organisms

mid-ocean water			
Flow through: flushing out ballast water by pumping in mid-ocean water at the bottom of the tank and continuously overflowing the tank from the top until sufficient water has been changed to minimise the number of original organisms remaining in the tank	Installation of piping system Time	Low cost	Time consuming No guaranteed of complete removal of organisms
Brazilian Dilution: water enters via a pipe system and is pumped through a ballast pipeline on the weather deck to each tank and is removed from the bottom of tanks via a separate set of pumps	Installation of piping system Time	Low cost	Time consuming No guaranteed of complete removal of organisms
Onshore treatment: pump the ballast to shore for appropriate disposal or treatment with land-based facilities	Time delay Reception facility Management cost Ship modifications (some occasions) Land in port not always available	Treatment standards guaranteed	Some ships may not be able to keep BW in. Possible delays

Table 2 - Available mitigation measures for antifouling paints

ANTIFOULING: mitigation measures	Cost	Advantages	Disadvantages
Toxic paints: use of toxic biocide coating			
Copper: antifouling paints containing copper compounds	Higher than TBT	Reported efficiency up to 5 years (most effective alternative to TBT)	Non-effective against some foulers May require booster Incompatibility with aluminium hulls Leach of toxic compounds
Biocide boosters: antifouling paints containing biocide boosters	High	Effective	Less universally effective-cobiocides High toxicity Not well understood yet
Alternatives to toxic paint systems			

Natural Defence of maritime invertebrates	Very high	Low environmental impact generally	Still under research
Cleaning of ship hull	-	Non-toxic	Possible introduction of alien organisms
Non-stick Foul-release: use of non-stick coatings mainly based upon silicones and fluoropolymers.	Very high (5-10x)	Non-toxic	Poor mechanical properties and difficult to repair if damaged Difficult application Efficacy problem in areas of severe fouling

Table 3 - Available mitigation measures for air emissions

EMISSIONS: Mitigation measures	Cost	Advantages	Disadvantages
Speed Reduction: Reduction of the speed of a vessel resulting in emission reductions from the propulsion engines	Impact on traffic	Simple and well observed. Safety benefits have been pointed out	Problems in area of high traffic Reduction of competitiveness
Reduction of Sulphur in fuels: limitation of the sulphur content of marine fuels used and marketed in the EU	High	Known amounts of sulphur reduced. Easy of control at source of fuel	Supplies Desulphuration process produces green house emissions
Flue scrubbing: Removal of sulphur and particles from the exhaust gas in a scrubber. The exhaust is showered with sea water and passes through two wet filters.	-	-	Large unit Possible pollution Concerns with storage of scrubber unit
Direct Water Injection: injecting water into each combustion chamber	-	Efficient	Its main drawback is the great modifications to the engine due to the need for the additional injection system. Increased fuel consumption

Humid Air Motor (HAM): pre-treatment of the combustion air supplied to the engine. The system uses waste heat from the engine's internal cooling system and; the air humidification causes a higher mass flow, which helps to maintain the engine efficiency. The combustion is smoother and the combustion temperature more uniform, ensuring crucial NOx emission reductions	Low operating costs High first cost	Large volume of the heat exchanger	High efficiency Easy maintenance Decrease engine thermal stress Reduces fule consumption

Focus groups have been used to determine any operational problems associated with the solutions identified above. The four focus groups were:

- scientific and technical groups
- ship operators
- shore-based operators
- environmental groups

Data was collected from the following sources:

1. SEAM Electronic discussion group
2. Other electronic discussion groups e.g. Globallast
3. SEAM stakeholder partners
4. MARTOB stakeholder partners
5. Other stakeholders e.g. NGO's shipping companies
6. Attendance at other stakeholder meetings e.g. BP emissions trading workshop
7. Published literature and web-based information, e.g. Acid Rain Secretariat
8. Published Scientific Literature
9. EC and government sources of information
10. Personal meetings and communications
11. Attendance at other meetings e.g. IMO-MEPC

During pilot research it became apparent that the numerical ranking of mitigation measures by the stakeholders was unhelpful, however for research purposes it was necessary to obtain some indication of preferences. The use of High, medium and low preferences was adopted as the most practical.

Stakeholder dialogue was undertaken through the stakeholder seminars throughout the SEAM project, Naples, December 2001, Sophia Antipolis, March, 2002, Brussels, July 2002,

Bremen, October 2002, and particularly through the workshop held in Brussels in February 2003. Detailed notes and recordings were made as permanent records of the meetings.

The guiding principles for the composition of the groups for discussion were:

- A sufficient diversity of views
- An equitable distribution of views, endeavouring to create symmetry of power
- To include a minimum of at least two representatives of each stakeholder group
- Avoid having individuals who represent the interests of more than one group

Stakeholder dialogue requires a particular understanding of cultural diversity, not simply in the sense of national cultural diversity but also within the context of corporate and industry specific cultural diversity. The stakeholder dialogue process therefore required the development of trust between the participants encouraged by meta-communications at various stages in the process and in the formal procedures of the discussion groups.

The research is being conducted in a rapidly changing legal environment with continuous scientific and technological development. During the period there were many imitative to gain stakeholder opinion and in a relatively closed industry, the number of individuals and organizations involved in these discussions was limited. Be believe this led to inevitable "stakeholder fatigue" and a reluctance to participate directly. Under these circumstances the original methodology was adapted to elicit the information from other primary and secondary sources:

- The arguments of the different stakeholder groups represent their differing interests. These arguments are sometime complex.
- Some of the stakeholder arguments and preferences appear to be in conflict while in other areas there is agreement and in yet other areas there is room for conciliation.
- Operational measures are becoming increasingly important particularly to Ship owners and operators
- It is apparent that there are different needs for new build ships and older ships needing the retrofit of mitigation measures

The work concluded by recommended the following mitigation measures, as most acceptable solutions from the stakeholders' point of view.

The following measures were recommended and met the wider consensus in terms of acceptability:

1. Ballast Water
   - Open sea exchange – Brazilian method
   - Decision Support Systems
   - On board filtration and combination systems (new builds)
2. Air Emissions
   - Low Suphur Fuel (SOx)
   - Regular engine maintenance (NOx existing ships)
   - Selective Catalytic Reduction (NOx new builds)
3. Antifouling

- Fouling release coatings
- Copper compound toxic antifouling

3.4. Case Studies and Full Scale Evaluation

This work has started in September 2002. The goal is to have a full-scale assessment of the proposed WP4 results in 3 selected shipping environments (Mediterranean Sea, North Sea, Ports). Two different aspects have been considered, namely how risks are managed today and how risk levels could be effectively minimised by using the proposed SEAM results / recommendations.

The proposed solutions have be analysed and evaluated from different points of view: operational, scientific and technical, legal and cost-effectiveness. Several types of activities have been studied before and after applying mitigation measures: Vessel Operations and Maintenance, Management of Operations and Maintenance.

The main objective of these case studies is to have a full-scale feedback of the SEAM preliminary engineering results. Each case study contains a safety and environmental assessment of ballast water management, the use of anti-fouling paints and air pollution from ships in a selected variety of likely shipping environments.

The case studies directly receive input from previous studies and results done within the SEAM project, which give a comprehensive overview of existing activity (identifying hazards of accidental events) and their consequences on global safety aspects and environment.

The proposed solutions have been assessed against real-working and operational conditions in three selected shipping environments: Mediterranean Sea, North Sea and port environment. The assessment has been organized on Grimaldi ships on a North route (Cork-Esbjerg) and on a South route (Salerno-Valencia).

A four-step approach has been proposed for carrying out these case studies. The first step consists of a description of the current situation for each SEAM environmental issue (how the SEAM issue is currently considered and who is in charge of what, how risks are managed today in following activities: Vessel operations and maintenance, Management of operations and maintenance, Decommissioning). The second step consists of identifying current hazards and assessing risks, based on the WP2 and WP3 results as well as technical visits. Within the fourth step, the operational and scientific & technical solutions able to solve the SEAM problems are selected. The final step consists on the evaluation from different points of view (operational, scientific / technical, legal, cost-effectiveness).

The case studies have not practically implemented the mitigation measures ranked by WP4 but provide some mapping on the possibility or not to implement the mitigation measures in the analysed cases.

These case studies delivered information in terms of technical feasibility of the proposed SEAM mitigation measures as well as parameters for the cost-benefit assessment.

Technical visits have been undertaken on board the Grimaldi RoRo ferry *"Grande Mediterraneo"* between Salerno and Savona and then between Cork and Esjberg.

Interviews have been carried out with the crew according to the following subdivision:

On board						**On shore**					
Procedures		Legislation		Machine/facilities		Procedures		Legislation		Machine/facilities	
Existing	Used	Existing	Applied	Existing	Human factor	Existing	Used	Existing	Applied	Existing	Human factor
Divided into the three items						Divided into the three items					

These visits allowed to determine:

- Current situation concerning the three SEAM items
- Current knowledge of the legal framework
- Analysis of Procedures and Operations on board
- Analysis of Machinery/Facilities available
- Analysis of the potential implementation of mitigation measures

3.5. Cost Benefit Analysis and Economics of Operating ships

The work consisted of the following tasks:

- Definition of Scenarios
- Identification of Cost Elements and Expected Benefits
- Comparison of Measures by Cost Effectiveness
- Cost-Benefit-Analysis
- Financial Impacts

Selected scenarios:

With respect to ballast water, the central topic of investigation was onboard sterilisation of ballast water using environmentally friendly products, which seem to lead to relatively high effectiveness and efficiency.

Although the harmful effects of TBT release are recognised, an antifouling device was early seam to be necessary for all vessels, to prevent from other harmful environmental effects, such as increased fuel consumption leading to an increase in greenhouse species in sensible areas.

Out of a number of four several solutions only a solution as effective as TBT antifouling would be environmentally beneficial. This could be the use of TBT-free alternatives, like silicon-based paints or others. The latter appear to be as effective as TBT products in preventing fouling on ships' hulls.

The goal was – among others – to carry out an in-detail study and to evaluate their financial and economic efficiency in terms of costs, dry-dock intervals and related benefits. Finally the crucial aspect of air pollution, mainly SO_2 and NO_x has been analysed in depth.

Identification of Cost Elements and Expected Benefits

Next to the definition of scenarios all relevant cost elements for the three SEAM issues and their alternative solutions have been identified, described and quantified in monetary terms as far as possible. The cost items include:

- investment cost
- maintenance cost
- operating cost (frequently also treated as a benefit as reduction of operating cost)
- training, inspection, certification cost etc.

This identification has been done by literature reviews, technical visits, data collection, interviews with stakeholders, and was done in relationship with WP2 and WP5.

Comparison of Cost Effectiveness

The comparison of the alternative solutions for solving the risk scenarios by means of cost effectiveness was a first step towards evaluation. Given the inputs, namely risk scenarios with defined cost and benefits, the ranking of risk control measures was carried out.

The method contains:

- assignment of the defined cost and benefits to the risk control measures;
- quantifications of cost and benefits by qualitative description and physical units;
- transformation of cost into monetary terms and of benefits into physical values, points and/or monetary terms as far as possible;
- calculation of cost-effectiveness ratios by dividing benefits by cost and/or impact cross tabulations.

Cost-Benefit Analysis

The cost benefit analysis has been carried out by developing excel worksheet applications, allowing to compute the individual costs calculations for seven ship types for the selected risk control measures (mitigation measures).

Financial Evaluation

After the completion of cost-benefit analyses the financial impacts of the measures have been discussed.

3.6. Dissemination and Exploitation

In order to disseminate the results of the SEAM project, a web site has been put on line at www.mettle.org/seam/ and is regularly updated. It has been agreed that the public executive summary of each Work Package is put on line.

The brochure to promote the project, initially scheduled in March 2003, was issued in January 2002, as decided during the kick-off meeting. The brochure has been issued in three formats: a full version of 9 pages with pictures, a reduced version of 2 pages, and a 2-column poster.

The SEAM project has been presented in conferences and other events when opportunities arise.

The following dissemination activities can be underlined:

- Dissemination towards end-users during technical visits for case studies
- Presentation of SEAM project to Plan Bleu and ADEME
- Preparation of dissemination paper for ENSUS conference "Measures to minimize environmental impacts from ship"
- Preparation of a paper for IMO MEPC49 on mitigation measure for ballast water
- Article on work of WP3 risk assessment in BMT's Technology review, June 2002
- Presentation of the SEAM paper - Measures to minimize environmental impacts from ship at the at the ENSUS conference in Newcastle, December 2002
- Presentation of the SEAM project Poster at the AMRIE High Level Conference, Lisbon, November 2002
- Presentation on the environmental problems associated with Ballast water to AMRIE Marine Environmental Care specialist Working Group June 2002
- SEAM material is being used for teaching at Southampton Institute, UK - MSc Shipping, Ports and the Environment (ongoing).
- SEAM material used in PhD thesis on Non-toxic antifouling paints submitted April 2003 Ms Francis Fernández
- Book title, concerning Shipping and the Environment approved in principle by Elsevier press
- 11th International Congress on Marine Corrosion and Biofouling, University of San Diego, California, U.S.A, 21-26 July 2002 – Poster display on SEAM project.
- Presentation at ENSUS, International conference on Marine Science and Technology for Environmental Sustainability, 16-17th December 2002, Newcastle.
- Attendance to the MEPC48 and the Intersessional Ballast Water Working Group.
- Seminars at Southampton Institute where SEAM project was presented.
- Attendance at the Environmental Consensus and Conflict Resolution Workshop, Edinburgh, Scotland, 24-26 September 2002.
- Presentation at Lübeck conference (20/06/02) "The Marine Environment - Thermal Waste Treatment and Prevention of Air Pollution from Ships"

- Presentation of SEAM results to the conference EC Taiex Thessaloniki (DG Enlargement – workshop for EC candidate countries)
- Presentation of SEAM results to the conference Marine Environment Lübeck
- Presentation of SEAM results to the Nautical Academy Rotterdam
- Presentation of SEAM results to the KIMO congress IJmuiden
- Presentation of SEAM results to the Medmaravis Conference Porto Torres, Sardinia
- Presentation of SEAM results to the Environment Conference Opatija, Croatia
- Presentation of SEAM results to the Ecoports Conference, Valencia
- Presentation of SEAM results to the conference Marichem Rotterdam
- Presentation of SEAM results to the conference Sibcon Singapore
- Presentation of SEAM results to the conference Dutch Ship Brokers, Rotterdam
- Presentation of SEAM results to the Tanker Operator Conference, London
- Organisation of end-users' workshops in Naples, Bremen, Brussels
- Presentation of SEAM to workshop concerning "air emissions from big ships", GAUSS, Umweltbundesamt, Bremen, Germany.
- Joint technical paper on the technical aspects and results of SEAM prepared by BMT and MRC, for publication by a learned society.

3.7. Horizontal Action – Users Group

The stakeholders group supporting the entire study (Ports, Shipowners, Local Authorities, Shippers, Terminals, Chemical painting Companies, Oil Companies, Ballast water management technology providers) is represented by the Horizontal Action. Before the first Horizontal Action meeting, GRIMALDI prepared some guidelines for Horizontal Action representatives explaining their role in this activity.

Under the Horizontal Action, three technical visits have been carried out (in Rotterdam in September 2001, in Monaco in March 2002 and in Bremen in October 2002) and two workshop (in Naples in December 2001 and in Bremen in October 2002). The objectives of the visits were to get a comprehensive view regarding port operations relating to the three main issues of concern and to identify environmental priorities.

The deliverable DH2.1 "Report on present situation and safety and environmental issues" has been issued in September 2001 and this report has been delivered at the European Commission in January 2002. The deliverable DH2.2 "Report on findings of visits to local end-users and results of the HA work" has been based on the reporting from the visit in Rotterdam. The deliverable DH1.3-1.4 (jointly DH1.3 and DH1.4) presents the point of view of the HA members towards the progress and results achieved in the project.

Partners from the Horizontal Action did their best to get the data for MARION-system for the Port Authority of Salerno and Valencia Port Authorities. The aim was to obtain data about currents, seasonal winds, etc, with, as possible, the high level of details needed. Their support has been also very useful for the technical visits for the case studies in WP5 and the data collection on costs and benefits for WP6.

4. LIST OF DELIVERABLES

Name of deliverable	*Reference*	*Status*
WP1		
Quality Assurance Plan	D1.1	Confidential
Mid-term Report	D1.2	Confidential
Final Management report	D1.3	Confidential
Final technical report	D1.4	Confidential
Final publishable report	D1.5	Public
WP2		
Activity Description	D2.1	Confidential
Catalogue of SEAM Hazards and Accidental Events	D2.2	Confidential
Operating Scenario Priorities	D2.3	Confidential
WP3		
Report of Pollution Risk Evaluation	D3.1	Confidential
Ship Risk Assessment Model Specification	D3.2	Confidential
Prototype of global ship risk assessment model	D3.3	Confidential
Report of risk assessment of the alternative environmental measures	D3.4	Confidential
WP4		
Analytical report of current technical and scientific knowledge regarding the control of fouling, ballast water management and low-sulphur fuel.	D4.1-4.2	Confidential

Reports from the each specific focus groups (maritime safety, environmental, maritime operators & scientists), identifying the user needs and concerns regarding effective solutions. Identification of the most acceptable solutions for minimizing the environmental impact for each user group	D4.3	Confidential
Final report and recommendations describing the findings from the stakeholder consensus meeting and the determination of the most acceptable solutions for minimizing the environmental impact for all stakeholders	D4.4	Public
WP5		
Report on case studies	D5.1	Confidential
Evaluation report	D5.2	Confidential
Assessment workshop organisation	D5.3	Public
WP6		
Report on defined scenarios and identified costs / expected benefits	D6.1	Confidential
Evalution report on the cost benefit assessment	D6.2	Confidential
WP7		
Internet web site	D7.1	Public
CD-ROM	D7.2	Public
Brochure	D7.3	Public
Technological Implementation Plan	D7.4	Confidential
HA		
Report on present situation and safety and environmental values	DH1.1	Confidential
Report on findings of visits to ports and results of workshops	DH1.2	Confidential
Evaluation report on progress and recommendations	DH1.3-1.4	Confidential

5. RESULTS AND CONCLUSIONS

All the partners provided a significant work during this project. On of the most challenging tasks faced by the partners was the collection of data from various sources, in order to carry risk assessment and cost benefit analysis. Despite some difficulties met, the project has well progressed during this 3 years of lifetime and was able to formulate mitigation measures for reducing the impact of ballast water management, antifouling paints and air pollutions from ships on the marine environment.

5.1. Mitigation measures

The SEAM project has followed each step of the Formal Safety and Environmental Assessment in order to formulate measures that mitigate the impact on the marine environment of ballast water management, anti-fouling paints and air emissions from ships.

From the assessment of risks, desk research of the existing measures and the dialogue with relevant stakeholders, the following mitigations have been identified as for most acceptable:

1. Ballast Water
   - Open sea exchange – Brazilian method
   - Decision Support Systems
   - On board filtration and combination systems (new builds)
2. Air Emissions
   - Low Suphur Fuel (SOx)
   - Regular engine maintenance (NOx existing ships)
   - Selective Catalytic Reduction (NOx new builds)
3. Antifouling
   - Fouling release coatings
   - Copper compound toxic antifouling

These results have been further explored in case studies and cost benefit analysis in order to evaluation the economic feasibility.

Ballast water

The efficiency of the individual treatment methods in reducing the survival rates and number of possible invaders is depending on the following factors:

- The type of ships and the individual ballast water management plan
- Space requirements (footprint of treatment set-up)
- Time needed for the treatment

- Risks involved (ship safety, safety of crew during handling as well as environmental risk such as aquatic toxicity in case of the use of chemicals).

It has been concluded that for vessels less than 50,000 dwt and vessels with a small annual number of voyages, ballast water exchange was less economically viable. In general, the internal rate of return will be the best in case of dry bulk vessels. Positive results are achieved by larger quantities of the handled ballast water and the number of trips made per year.

The ballast water treatment options can finally be assigned to three groups:

Short-Term options:

- Mid-ocean ballast exchange

Short-Term alternatives:

- Non-release of ballast
- Additional of biociodal agent
- Oxygen deprivation
- Load pre-treated ballast water

Long-Term alternatives:

- Biocidal tank coatings
- Screens and Filters
- Ultraviolet light
- Ultrasonics
- Heat treatment
- Discharge to shore facilities

For the treatment techniques it may be pointed out that stand-alone treatments are not efficient enough in case of handling large quantities of ballast water for vessels such as tankers, bulk carriers and container vessels. Only mixed treatment options are successful enough to clean up the ballast water from the different species in all kind of operating areas of the vessels within acceptable time frames.

Antifouling paints

The most preferable identified solutions for now are copper based antifouling and silicones.

In general a copper-based system provides a higher economical viability. Only for small fleet segments, such as passenger ships, or for other vessels operating in restricted areas the silicon-based antifouling is an alternative technique with a positive internal rate of return in the case for ships with more than 4,500 m^2 under water hull.

However, in both cases the alternative systems copper and silicone have negative impacts on the environment which have not been fully taken into consideration, because these are not manifested yet, due to the relative recent nature of these antifouling paints. In respects to this, substantial additional research is required.

Air emissions

For all ship types the Selective Catalytic Reduction systems and Direct Water Injection systems used for NOx reduction seem to be very economically viable. But in general it must be pointed out, that such high economical viability is not a direct benefit for the operators of the ship, because they are not the beneficiary. As the vessel operator is not refunded for the benefits he would produce with reducing NOx emissions, he will have no interest in doing so. Only if external benefits could be internalised such high economical viability would become effective. One possibility would be to reduce port dues in order to produce a direct benefit for the vessel operator

5.2. General conclusion

In general it may be pointed out as a result of the analysis and calculation there is still a lack of consistent information on cost and especially benefits of the different techniques for the reduction of environmental impacts caused by international shipping. However, on the other hand it was possible to collect information on several alternative techniques for the substitution of TBT based antifouling paints, for ballast water treatment and for reducing NOx emissions.

Based on this information and the usual methods of economic cost benefit analysis it can be stated that most of the measures are economically viable from the overall perspective including all external benefits. However, as the benefits are external they are not part of the decision process of the vessel operators and hence will not be realised without legal pressure or remuneration.

6. GLOSSARY

IFO	intermediate fuel oil
IMO	International Maritime Organization
MARION	"Environment Related Information and Analytical System for Maritime Transport"
MDO	marine diesel oil
MGO	marine gas oil
NO_X	Nitrogen oxides
Pollutants	Substances harmful to the environment
SO_2	Sulphur dioxide
TBT	Tri-butyl-tin anti-fouling paint
WP	Work Package