

Safety at Speed - S@S
**IMPLEMENTATIONS OF MODELS FOR
M&A FAILURES
DELIVERABLE NO. D1.3.2**

Document ID Code: S101.23.03.051.001

Date: 2003-08-22

Contract No. G3RD-CT-2001-00331

CLASSIFICATION AND APPROVAL

Classification: Confidential

DEFINITION

Public after Review:

The document may be freely distributed after successful EC review, given the EC's permission. Publication is governed by the EC Contract and the S@S Consortium Agreement

Confidential for the Duration of the Project:

As for 'Confidential', but only for the duration of the Project. After final Project Approval by the EC, status for reports classified 'Confidential for the Duration of the Project' are automatically down-graded to 'Public'.

Confidential:

The document is for use of the G3RD-CT-2001-00331 Contractors within the S@S Consortium, and shall not be used or disclosed to third parties without the unanimous agreement within the S@S PMC and subsequent EC approval since document classification is part of the EC Contract.

Any executive summary specifically intended for publication may however be made known to the public by the author and/or the Coordinator.

AUTHORS:

Name	Date	Signature
------	------	-----------

<i>Mauro Pedrali</i>	<u>2003-08-22</u>	
----------------------	-------------------	--

<i>Alberto Faravelli</i>	<u>2003-08-22</u>	
--------------------------	-------------------	--

<i>Brice Carnicer</i>	<u>2003-08-22</u>	
-----------------------	-------------------	--

Mario Esposito Lavina

2003-08-22

APPROVAL:

Approved for release by:

Name

Date

Signature

Franco Zuccarelli

2003-08-22

DOCUMENT HISTORY:

Issue:	Date:	Initials:	Revised pages:	Short description of changes: File name:
001a	June 30, 03	MPE/AGF		First draft
001A	July 31, 03	MPE/AGF	All	Including contribution from CETENA and METTLE
001	Aug 22, 03	MPE/AGF	All	Implementing comments from reviewer (SeaContainer)

DISCLAIMER

Use of any knowledge, information or data contained in this document shall be at the user's sole risk. Neither the [S@S](#) Consortium nor any of its members, their officers, employees or agents accept shall be liable or responsible, in negligence or otherwise, for any loss, damage or expense whatever sustained by any person as a result of the use, in any manner or form, of any knowledge, information or data contained in this document, or due to any inaccuracy, omission or error therein contained.

The European Community shall not in any way be liable or responsible for the use of any such knowledge, information or data, or of the consequences thereof.

CONTENTS

1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION.....	7
2. INTRODUCTION.....	8
PART ONE –M&A FAILURES MODEL	9
3. RISK MODEL	10
3.1 BASIC EVENT AND DESIGN PARAMETERS	10
3.2 RESEARCH AND EVALUATION OF MAIN PARAMETERS	11
3.3 APPRAISAL OF CRITICAL COMBINATIONS OF PARAMETERS (RISK MODEL)	11
3.3.1 Parameters Identification and Quantification for Propulsion and Steering Systems	13
3.3.2 Mechanical Failure of the Propulsion System.....	13
3.3.2.1 Parameters Identification	13
3.3.2.2 Quantification	15
3.3.3 Mechanical Failure of the Steering System.....	16
3.3.3.1 Parameters Identification	16
3.3.3.2 Quantification	17
3.3.4 Electric Power System (failure)	18
3.3.5 Navigation Equipment (failure).....	19
3.3.6 Radar (failure).....	20
3.3.7 Communication System (failure).....	21
3.3.7.1 External.....	21
3.3.7.2 Internal.....	22
3.3.8 Flooding in the Engine and Steering Room.....	23
3.3.9 Fire in the Engine Room.....	24
4. COST MODEL.....	26
4.1 EVALUATION OF BUILD COST (C_B)	26
4.1.1 Cost Model for Propulsion System.....	27
4.1.2 Cost Model for Steering System.....	28
4.1.3 Cost Model for Electric Power System.....	29
4.1.4 Cost Model for Navigation Equipment.....	29
4.1.5 Cost Model for Radar System.....	30
4.1.6 Cost Model for Internal Communication System.....	31
4.1.7 Cost Model for External Communication System.....	32
4.1.8 Cost Model for Fire in the Engine Room	34
PART TWO: USER’S GUIDE	36
5. GENERAL VIEW.....	37
6. CONCLUSIONS.....	39
7. REFERENCES	40
8. APPENDICES	41
8.1 APPENDIX 1: BES FOR WP1 HAZARDS	41
8.2 APPENDIX 2: EVALUATION OF MCA WEIGHTS	41

List of Figures

Figure 1 - Overall View of WP1 Hazards Structure	10
Figure 2 - Propulsion System Referential Functional Scheme	14
Figure 3 Steering System Referential Functional Scheme	16
Figure 4 - General Overview of the Process	37
Figure 5 - Expected Expansion of the Ranking of BEs/Parameters Process ('Vision').....	38

List of Tables

Table 1 - Acronyms for the Application of the MCA Method	12
Table 2 - Significant Table Extrapolated from the Risk-Matrix for the Propulsion System	16
Table 3 - Significant Table Extrapolated from the Risk-Matrix for the Steering System.....	18
Table 4 - Risk-Matrix for Electric Power System	19
Table 5 - Risk-Matrix for Navigation Equipment	20
Table 6 - Reference table for Radar System	21
Table 7 - Risk-Matrix for Radar System	21
Table 8 - Risk-Matrix for External Communication System.....	22
Table 9 - Risk-Matrix for Internal Communication System	23
Table 10 - Risk-Matrix for Fire in the Engine Room	25
Table 11 - Cost-Matrix for Propulsion System	28
Table 12 - Cost-Matrix for Steering System	29
Table 13 - Cost-Matrix for Electric Power System	29
Table 14 - Cost-Matrix for Navigation Equipment.....	30
Table 15 - Cost-Matrix for Radar System.....	31
Table 16 - Cost-Matrix for Internal Communication System	32
Table 17 - Cost-Matrix for External Communication System	33
Table 18 - Cost-Matrix for Fire in the Engine Room.....	35
Table 19 - Weights for Propulsion System and Steering Waterjet	42
Table 20: Weights for Navigation Equipment.....	42
Table 21: Weights for the Radar Equipment	42
Table 22: Weights for the Internal Communication Equipment	42
Table 23: Weights for the External Communication Equipment.....	43
Table 24: Weights for Electric Power System	43
Table 25: Weights for Fire in the Engine Room	43

1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION

The work reported in this document constitutes the methodological foundation of a 'design tool' that safety analysts can use in the preliminary design phase of a High Speed Craft for cost effective evaluations of design options that should diminish the probability of occurrence of Collision, Grounding and Striking events.

This document has to be seen in connection with two other reports (i.e., D131 and D133) that, altogether, provide a global approach for comparing costs and risks associated with:

- different Ship Control Centre (SCC) design alternatives for high-speed crafts,
- different design alternatives for the technological systems of high-speed crafts,
- the maneuverability of high speed crafts in restricted waters and those of conventional vessels,

with respect to Collision, Grounding and Striking events. Ultimately, this design tool shows how a small number of design parameters changes can predict build and operational costs.

[S@S](#) is the acronym for Safety at Speed, a project supported by the European Commission under the Growth Programme of the 5TH Framework Programme. The support is given under the scheme of RTD, Contract No. G3RD-CT-2001-00331.

2. INTRODUCTION

The work reported in this document is about the implementation of a risk-cost model, related to Automation and Mechanical Failures, which allows a safety-design analyst to evaluate different technical solutions for tackling collision, grounding and striking events during the preliminary design phase of a HSC. Similarly, two other documents [D131 and D133] will help safety analysts in evaluating the best design options when addressing human and maneuverability errors.

D131, 132 and 133 will jointly provide a common approach for assessing costs and risks related to specific configurations of design parameters that minimize the risk of these events at a convenient cost. This common approach is documented in D134 where an integrated model for controllability is described.

This report is structured in two main parts. While the former provides a description of the results achieved in sub-Task 1.3.2, the latter is more oriented as a user's guide that suggests how to exploit such results.

The first part starts with an overview of the fault trees (FTs) analyses that allowed the identification of those basic events (BEs) leading, for the technical side, to a potential collision, grounding and striking. Secondly, each system involved in a specific BE was analyzed with respect to the characteristics it should have (as required by the IMO HSC Code -- 2000 edition); this allowed to identify the main parameters characterizing that system. Thirdly, these parameters were grouped and put in relationships with the related BE through matrices, expressing how much the different possible combinations of these parameters can affect the occurrence probability of that BE. Finally, similar relationships have been established for design parameters and related cost.

As long as the exploitation of these results is concerned, the second part of this document provides a general overview of the steps that a safety analyst has to follow for acting on the leverages (i.e., design parameters) that can limit the risk of collision, grounding and striking. Because D132 only focuses on a specific problem (i.e., potential automation and mechanical failures leading to these hazards) it has to be integrated with D131 and D133 in order to provide the common approach mentioned before.

PART ONE -M&A FAILURES MODEL

3. RISK MODEL

The foundation of the risk model for tackling collision, grounding and striking hazards is a fault tree analysis that was carried out in Task 1.2 and progressively refined along a number of iterations. The final structure is a combination of semantic networks (i.e., classifications) in its upper part, and Fault Trees (FTs) in its lower part (Figure 1), where the three main hazards Grounding, Collision and Striking are initially categorized according to likely scenarios and then analyzed according to the fault tree logic.

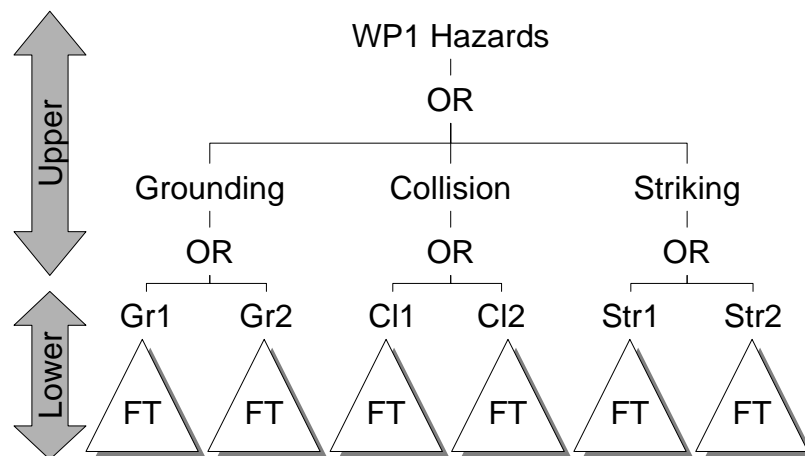


Figure 1 - Overall View of WP1 Hazards Structure.

The upper part of the structure is schematized in the following hierarchical list:

1. Grounding
 - 1.1. Powered grounding
 - 1.2. Drift grounding
2. Collision
 - 2.1. In open sea
 - 2.2. In restricted waters
3. Striking
 - 3.1. With a floating object
 - 3.2. With a fixed object/infrastructure
 - 3.2.1. In open sea
 - 3.2.2. In restricted waters.

The whole structure is reported in D134 whilst the compiled list of Basic Events (Bes) is reported in Appendix 1: BEs for WP1 hazards.

3.1 Basic Event and Design Parameters

As long as Automation and Mechanical failure is concerned, the following BEs were identified:

- Propulsion System (failure);
- Stability System (failure);
- Steering System (failure);
- Electric Power System (failure);
- Navigation Equipment (failure);
- Radar (failure);
- Communication System (failure);
- Flooding (in engine and steering room);
- Fire (in engine room).

3.2 Research and Evaluation of Main Parameters

Because of the vastness of parameters that interact with the systems onboard ships, it was very difficult to establish hierarchies of importance between the aforementioned parameters. Data related to the reliability of the components are difficult to find. Nevertheless, according to a literature review, it turned out that failures related to basic events such as detection equipment, propulsion system, steering system etc., has a percentage of occurrence extremely low. It is clear that a total loss of some systems acting onboard, can not be excluded a priori, but it is practically impossible to provide quantification.

The possibility of failures for technical systems is mainly conditioned by technical but also human factors. It can be generally assumed that human factors affect the mis performance of technical systems through non-observation of procedures (how to use), and incorrect maintenance. Moreover, aspects related to the design phase such as planned numbers of overhaul and number of people dedicated to maintenance can play a critical role in determining the efficiency of a technical systems. From this point of view, the choice of a criterion for the appraisal of parameters that mainly influence the correct functioning of systems can not overlook also the influence of human factors. Beyond this, it seems to be necessary to include in the process of identification and quantification of parameters, aspects regarding emergency situations, which can simply be addressed by considering the REDUNDANCY concept.

As a result of a careful study of documents related to accident occurrence [1] [2], it has been possible to create a first list of parameters that mostly influence the correct functioning of onboard systems.

Starting from this point, it was consequently necessary to find criteria that could be useful in order to establish which, of the aforementioned parameters are the most significant. It has to be clear that we have to localize parameters over which a designer could act at the design phase. Because of that, it is possible to ignore parameters that the designer is not allowed to choose.

By following this criterion, the definitive list of most important parameters has been modified as detailed in the next sub-chapters.

3.3 Appraisal of Critical Combinations of Parameters (Risk Model)

As long as the number of parameters is concerned (necessary when assessing

the functioning of systems), two different solutions have been considered in order to evaluate the correct way of operating of every system:

1. Two parameters with 2 or 3 possible states for each one;
2. Three parameters with 2 or 3 possible states for each one;
3. Four parameters with 2 possible states for each one.

Once the parameters and their possible states were determined, it was then necessary to evaluate which are the most critical combinations. This means to find those that, if used, lead to the biggest probability of having a failure related to the system under study and consequently to an accident.

For doing so, the Multi-Criteria Analysis (MCA) was chosen that allowed us calculating which are the most critical combinations.

By developing the MCA, we obtained results that are easy to fill in a table, in order to assess the influence of every combination. The most critical combinations are those which present the biggest values. Here a brief description of the Multi-Criteria analysis is given.

Ind	Parameter
Pind	Weight to be assigned to an Ind
Indcrit	Value assumed by an Ind
Rifind	Value used to index an Ind
Indcritot	Value related a combination

Table 1 - Acronyms for the Application of the MCA Method

For every Ind, it must be determined the worst value (Rifind). Such value might be either the maximum or the minimum, depending on the characteristics of the specific Ind.

This value will be exploited in order to index the pre-selected parameter so that values are comprised between 0 and 1 and, in particular, those more critical tense to assume 1 as value.

In this way, by using the Pind it is possible to associate a global value (Indcritot) to a combination of parameters.

The value of an Indcritot is calculated as follows:

$$\text{Indcritot} = \sum_{\text{Ind}=1}^{n\text{Ind}} P_{\text{ind}} * f(\text{Indcrit}, \text{Rifind}) .$$

The function $f(\text{Indcrit}, \text{Rifind})$ can assume one of the following forms:

- $f(\text{Indcrit}, \text{Rifind}) = \frac{\text{Indcrit}}{\text{Rifind}}$ for parameters whose critical value is the

- maximum.
- $f(Indcrit, Rifind) = \frac{Rifind}{Indcrit}$ for parameters whose critical value is the minimum.

It is clear that the most critical operation is that of assignment of weights to the parameters. This particular job is entrusted only to the capacity of the expert involved in the calculation.

Finally, it has to be noted that the value of Pind must be chosen between 0 and 1 but the sum of Pind of different parameters is not even to 1.

3.3.1 Parameters Identification and Quantification for Propulsion and Steering Systems

It is necessary to identify the parameters and to proceed into the Appraisal of Critical Combinations of Parameters (Risk Model) using the identified Multi criteria analysis.

With reference to the choice /setting of the parameters and according to the model for the whole WP1, it is necessary to premise that no parameter has been considered if correlated to:

1. man/machine interaction but also organizational and procedural facts , incorrect maintenance/induced failure;
2. quality of the system (performances) such as maneuverability capabilities, stopping abilities, turning capabilities, etc;

This operation of filter has been necessary since these parameters are considered within the human and maneuverability error model (respectively n°1 n°2).

3.3.2 Mechanical Failure of the Propulsion System

3.3.2.1 Parameters Identification

In order to identify those parameters that can lead to a mechanical failure of the propulsion system, and therefore affect its functionality, it is necessary to provide a functional representation of the propulsion system. This representation has to be developed with respect to the knowledge about the system and subsystems in the preliminary design stage. In the preliminary design stage, the designer can identify the major units or sub-systems, the boundary of the system, and the "external" functional connections with the other systems, which encompass fuel supply, fresh water system, electric system, just to mention some ones.

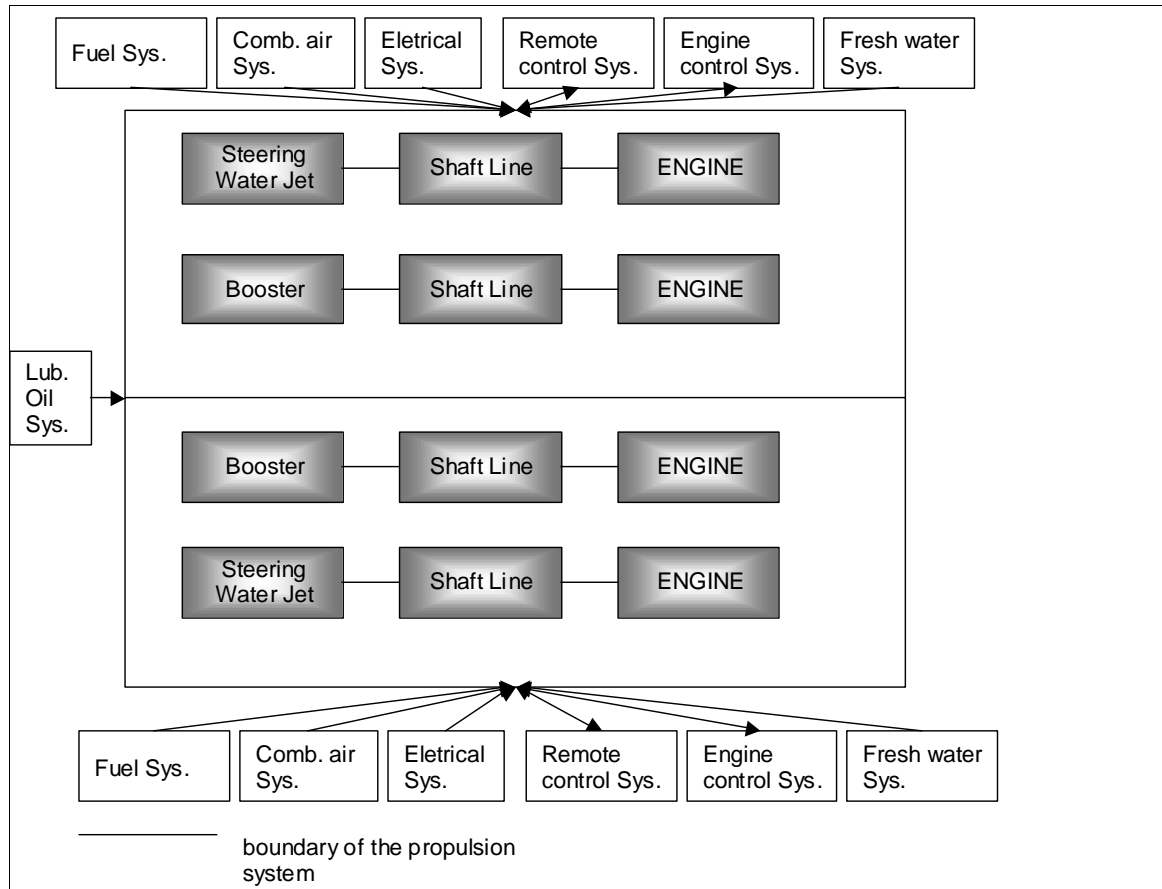


Figure 2 - Propulsion System Referential Functional Scheme

The number of subsystems that affect the correct functioning of the propulsion system is extremely high but according to the development of the whole S@S tool (see the Fault tree conception) all the systems functionally connected to the propulsion system are considered perfectly working. The identification of parameters has to be done with reference to the identified main functional unit of the propulsion system.

Following this procedure, below are listed the final parameters and the technical judgements concerning the choice of these parameters.

The number of main engines has to be considered. In particular, the use of 2 main engines for a water jet is a more reliable configuration (with this assumption it is assumed that all main engine are completely independent each other), and the use of 4 main engine rather than 2 is (obviously) a more reliable configuration (it is assumed that each main engine is designed in order to be able to provide the minimum safety trust function).

Because of the different reliability of the Gas turbine and Diesel Engine, the number of Gas turbine (GT) and of Diesel Engine are taken as main parameters. Hence the final list of parameters is:

- N° of Main Engines;
- N° of Gas Turbines;
- N° of Diesel Engines.

3.3.2.2 Quantification

It is quite difficult to define a range value for the identified parameters. This especially depends on the possibility of having several different configurations, from one ship to another and to the continuous technological development and innovation. However, with reference to a review of the most of the High Speed Craft that are already cruising at sea, a possible range values for the identified parameters are:

$$\begin{aligned}2 &\leq \text{No. of Main Engine (En)} \leq 4 \\0 &\leq \text{No. of Gas Turbine} \leq 2 \\2 &\leq \text{No. Diesel Engine} \leq 4\end{aligned}$$

With reference to the MCA method for the identified parameters it is necessary to assess the weight to assign to the parameters.

With reference to a literature review, it has been identified for each sub-system the value of the Mean Time Between Failure[h]. Due to the bigger “weight” (see Appendix 2 for further details)of the Diesel Engine the weights are:

- $W_{De} = \text{MTBF}_{De} / \text{MTBF}_{De}$
- $W_{TG} = \text{MTBF}_{DE} / \text{MTBF}_{Gt}$

Starting from this basis, it was then possible to calculate the value related to the combinations by using the MCA as explained before. Obviously not very technical configuration obtained in the matrix is feasible, but it is necessary to consider each value for the parameters in order to develop our matrix.

Owing to the real market of marine engine (diesel or gas turbine), it is important to underline that it will not be always possible to have an alternative configuration with the same total output power using, indifferently, diesel or turbine, or two, three or four main engine. This fact is due to the size of the single unit available on the market and to other fundamental factors as the layout, the weight.

Hence, the definition of the possible alternative design configurations, with the same total output power, is definitely left to the designer.

A significant extrapolation from the whole Matrix is showed on the table below:

Parameters	N° of Main Engines					
	2	3	3	4	4	4
	N° of Gas Turbines					
	0	0	1	0	1	2
	N° of Diesel Engines					
	2	3	2	4	3	2
%Deviation	55%	19%	15%	Ref. Value	-13%	-17%

Table 2 – Significant Table Extrapolated from the Risk-Matrix for the Propulsion System

3.3.3 Mechanical Failure of the Steering System

3.3.3.1 Parameters Identification

Following the same procedure and logical paths adopted for the propulsion system, here below the referential functional scheme for the Steering system:

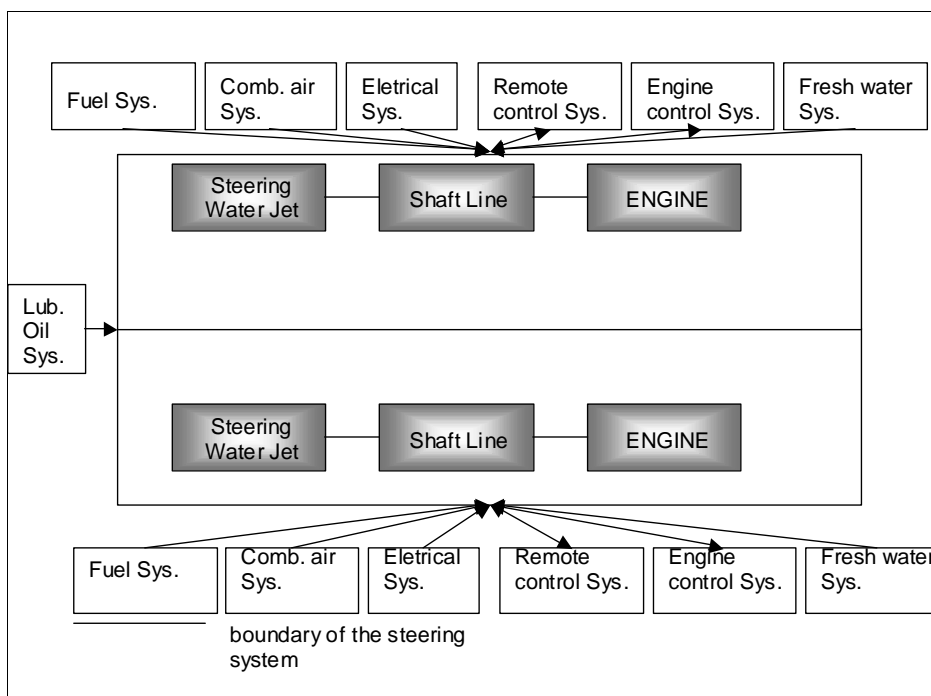


Figure 3 Steering System Referential Functional Scheme

By now, most of the High Speed Craft that are already cruising on the sea make a large use of steering waterjets for steering function. Though it can't be excluded a priori a different configuration. However, in order to have an

effective approach it can be assumed the use of the waterjets if we consider speed > 35 Knots.

The identification of parameters is developed with reference to the identified main functional unit of the steering system and to the possible alternative design parameters in the preliminary design stage.

Hence the final list of parameters is:

- N° of dedicated Engines;
- N° of Steering water jets.

3.3.3.2 Quantification

The most common configuration is a ship equipped by means of 2 at least steering water-jets.

The water jet (booster and/or steering) can be driven by its own engine (the most common configuration) but also with two engines. Alternatively, two waterjets can be fed by one main engine (the most common configuration if the main engine is a gas turbine); the engine can be a diesel engine, a gas turbine or an electric.

It is quite difficult to define a range value for the identified parameters of the steering system.

With reference to an overview of HSC that are already cruising, a possible range values for the identified parameters are:

$2 \leq \text{No. of dedicated Engine (En)} \leq 4$ $2 \leq \text{No. of steering waterjet (SWJn)} \leq 4$

In a similar manner to that used in the paragraph 3.3.1.3, the identified method to assess the weights evaluated the following greatness:

- $W_{Eng} = \text{MTBF}_{Eng} / \text{MTBF}_{Eng}$;
- $W_{SWJ} = \text{MTBF}_{Eng} / \text{MTBF}_{SWJ}$.

Based on this assumption, it was then possible to calculate the value related to the combinations by using the MCA as explained before. Obviously, not every technical configuration obtained in the matrix is feasible, but it is necessary to consider each value for the parameters in order to develop our matrix. Moreover not all future and possible configurations were considered, and the identification of a real possible alternative design configuration is definitely left to the designer.

A significant extrapolation from the whole Matrix is showed in the table below:

Parameters	N° of Steering Waterjet								
	2			3			4		
	N° of Dedicated Engines								
	2	3	4	2	3	4	2	3	4
% Deviation	Ref. Value				-33%	-49%			-50%

Table 3 - Significant Table Extrapolated from the Risk-Matrix for the Steering System

3.3.4 Electric Power System (failure)

The electric plant onboard ships is normally subdivided in Main Electric Power Generation and Emergency Electric Power Generation System. Both systems have configurations quite similar passing from a ship to another one but some differences can be find.

Referring to the reference ship (Super Sea Cat three), the electrical plant is essentially developed as follows:

- **Main Electric Power Generation:**
 - Three Synchronous three-phase Diesel Generators;
 - One main switchboard;
 - Three single-phase transformers.
- **Emergency Electric Power Generation:**
 - One three-phase Synchronous Diesel Generator;
 - One emergency switchboard;
 - Three single-phase transformers.

Other than the above-mentioned main systems, Protection and Distribution systems are present onboard.

Needless to say that a deep analysis of systems, sub-systems and components which are part of the electric plant, is hard to be translated in a risk-matrix as those considered by our methodology. This comes from the countless number of parameters forming the network of the plant such as cables, switches, buttons, relay and so on.

As for the appraisal of the other Basic Events under analysis, it was decided of reducing the overall consideration about the electric plant at the assessment of the macro-parameters that mostly exert influence on the correct functioning of the system.

Overlooking the complete configuration, the sources of electric power onboard ships are usually the Diesel Generators. Inside the Super Sea Cat, the main generation is entrusted to 3 synchronous three-phase Diesel Generators whereas the emergency generation is entrusted to 1 synchronous Diesel Generator. It has been decided to consider these two sources as parameters. Intervals of value for the aforementioned are:

$2 < N^{\circ} \text{ of Diesel Generators} < 3$ $1 < N^{\circ} \text{ of Emergency Diesel Generators} < 2$

As for the other parameters the MCA offered the following results:

Parameters	N° of DE			
	2		3	
	N° of Emergency DE			
	1	2	1	2
%Deviation	2%	-10%	Ref. Value	-30%

Table 4 - Risk-Matrix for Electric Power System

3.3.5 Navigation Equipment (failure)

According to the IMO HSC Code - 2000 edition, the navigation equipment of a ship should be comprised of the following features:

- Compasses;
- Speed and distance measurement;
- Echo-sounding device;
- GPS (Global Positioning System);
- **DGPS (Differential GPS);**
- Rate of turn indicator and rudder angle indicator;
- Search light;
- Night vision equipment;
- Steering arrangement and propulsion indicators;
- Automatic steering aid (autopilot equipment);
- Electric power;
- **Electronic Chart Display and Information System (ECDIS);**
- Automatic Radar Plotting Aid;
- **VTS (Vessel Traffic System).**

VTS, DGPS and ECDIS were considered the most critical ones.

Vessel Traffic Services (VTS) are provided worldwide to improve navigational safety and efficiency, safety of life at sea and protection of the marine environment. In most ports and within territorial seas, participation in VTS is

mandatory under local regulations. Information on available Vessel Traffic Services is given in the Admiralty List of Radio Signals (ALRS). However in other cases the VTS is only based on voluntary decision and on Port and Coast equipment available. The designer will have the choice to include a VTS in order to improve the quality of navigation aid of the vessel.

Parameters	VTS							
	0				1			
	DGPS							
	0		1		0		1	
	ECDIS							
	0	1	0	1	0	1	0	1
%Deviation	50%	26.6%	23.3%	Ref. Value	25%	1.67%	-1.67%	-25%

Table 5 - Risk-Matrix for Navigation Equipment

3.3.6 Radar (failure)

According to the IMO HSC Code – 2000 edition, the Radar equipment of a ship should be comprised of the following features:

- Radar unit - 9GHz;
- **Radar unit - 3Ghz;**
- Electronic Plotting Aid (EPA);
- **Automatic Tracking Aid (ATA);**
- **Automatic Radar Plotting Aid (ARPA).**

3 GHz Radar - to- be fitted as the second radar, which is required on ships of 3000 Gt. and over unless the Administration considers it appropriate to carry a second 9 GHz Radar or to choose a 3GHz radar. The two radar must be functionally independent of each other. In case of Ships less than 3000 gt the designer can have the choice to have additional 3GHz radar.

ATA - To be incorporated in Radar equipment on ships of 500 gt. and over (replacing the requirement for an EPA). On ships of 3000 gt. and over the second radar must also be equipped with an ATA. The two ATAs must be functionally independent of each other.

ARPA - To be incorporated in one radar equipment on ships of 10000 gt. and over. The second unit must incorporate ATA if not ARPA.

GROSS TONNAGE	9GHz RADAR	3GHz RADAR*	EPA	ATA	ARPA
300 – 499	1		1		
500 – 2999	1			1	
3000 – 10000	1	1		2	
10000 +	1	1		1**	1
* Administration may approve a second 9 GHz radar instead ** Or second ARPA					

Table 6 - Reference table for Radar System

The 3Ghz radar, ATA and ARPA were considered the most critical parameters for the correct functioning of the whole radar system.

Parameters	Radar 3GHz							
	0				1			
	ATA							
	0		1		0		1	
	ARPA							
	0	1	0	1	0	1	0	1
%Deviation	51.6%	25.8%	27.4%	1.61%	25.8%	Ref. Value	1.61%	24.9%

Table 7 - Risk-Matrix for Radar System

3.3.7 Communication System (failure)

3.3.7.1 External

According to the IMO HSC Code – 2000 edition, the External Communication System of a ship should be comprised of the following features:

- **VHF Radio;**
- Radar Transponder 9GHz;
- **Safety Information (e.g. INMARSAT, NAVTEX);**
- Satellite;

- Telegraphy;
- **Identification Systems (e.g. AIS).**

The Redundancy of Safety information, the Emergency system for the VHF and the AIS were considered the most critical ones.

Parameters	Redundancy of Safety information											
	1				2				3			
	Emergency system for the VHF											
	0		1		0		1		0		1	
	Identification System											
0	1	0	1	0	1	0	1	0	1	0	1	
%Deviation	100%	68.8%	66%	35%	64%	33%	31%	Ref. Value	52.5%	21.4%	19.2%	11.8%

Table 8 - Risk-Matrix for External Communication System

3.3.7.2 Internal

According to the IMO HSC Code - 2000 edition, the Internal Communication System of a ship should be comprised of the following features:

- **General alarm and PA** (Complete Public Address Systems with integrated General Alarm);
- **Talk back systems** (Talk back system from one up to 30 lines for individual calls or group call as separate system and in combination with the automatic telephone system or integration into the general alarm system);
- Telephone systems;
- **Paging systems** (Wireless paging systems for one-sided paging procedure or on two sides with voice transmission. Initiation of the paging procedure from an operator console or from any other telephone of the connected telephone system. Transmission of a single call, group call or alarm call. Connection with the paging system to the engine control system, fire alarm system ...);
- Fire alarm systems.

The Emergency System for General Alarm and PA, the Talk back System and the Paging System were considered the most critical ones.

Parameters	Emergency System for General Alarm and PA							
	0				1			
	Talk back System							
	0		1		0		1	
	Paging System							
	0	1	0	1	0	1	0	1
%Deviation	100%	68.8%	66.6%	35.5%	64.4%	33.3%	31.1%	Ref. Value

Table 9 - Risk-Matrix for Internal Communication System

3.3.8 Flooding in the Engine and Steering Room

All the basic events related to the occurrence of a flooding are directly related to the corrected functioning of the AUXILIARY SYSTEM. In particular, within the auxiliary system, the parameters that most influence the occurrence of flooding, is the Bilge Pumping and Drainage System.

The technical sub-parameters that needs to take into account when assessing performances of the Bilge Pumping and Drainage System are:

1. Diameter of bilge main;
2. Water's speed through the required bilge pipe;
3. Internal diameter of suction branches.

Diameter of bilge main from IMO HSC Code -- 2000 edition:

In order to calculate the above mentioned diameter the following is used:

$$d=25+1,68*\sqrt{L(B+D)}$$

Where:

- d= internal diameter of the bilge main[mm];
- L is the length of the craft[m]
- B is, for mono hull craft the breadth of the craft[m];
- D is the molded depth of the craft to the datum [m].

Water's speed through the required bilge pipe:

Minimal value of the water's speed, through the bilge pipe, is of 2m/s.

Internal diameter of suction branches:

Minimal value for the internal diameter is 25 mm.

Apart from the diameter of the bilge main, there are other topics that needs to be taken into account when assessing the functioning of the bilge system, in particular:

- N° of redundant pumps(Automatic or managed by humans);
- Subdivision of compartment in order to avoid propagation;
- Unmanned/manned room;
- Monitoring System with respect to the number of related devices(Automatic or by human);
- Arrangements of pipes (N° of compartments served by one pump).

3.3.9 Fire in the Engine Room

The possibility of having fire onboard ships is one of the main hazards that designers, particularly of passenger ships, have been faced with. This naturally comes from the seriousness inherent in the nature of fire which is the most frequent cause of loss of life.

In the case under analysis, we have only considered the possibility of a fire occurrence inside the engine rooms. The reason is a consequence of the structure of the fault tree under analysis, which takes into consideration fire in an engine room as a basic event for the correct functioning of the propulsion system.

Inside the SuperSeacat there two separate engine rooms, fore and aft, which host respectively, the first one the two engines dedicated to steering and the second one the two engines dedicated to propulsion. In fact, in the SuperSeacat vessels all four engines drive waterjets with steering and reversing nozzles.

Referring to the reference ship, components related to detection and fighting of fire inside the engine rooms are followings:

- 11 CO2 fire extinguishers;
- 5 Portable CO2 fire extinguishers;
- 4 smoke detectors;
- 2 heat detectors.

By glancing at the table, it easy to note the absence of sprinklers due to the presence of live electrical parts within the considered room. The minimum number of these systems is fixed by the High Speed Craft Code, which establish that by taking into account the room's type and dimensions, and the type of fire fighting systems. Consequently, it becomes clear that, always following the criterion utilized up to now based on the presence of possible redundancies.

Within the table we have considered as parameters the fixed fire extinguishing systems and the detection systems based on a study of documents and also by following suggestions coming from the WP4 which specifically addressed the problem of fire onboard ships.

The development of calculations as indicated by the MCA offered the outcome listed on the following table.

Parameters	N° of Fire-Fighting Systems (CO2 releaser)											
	9			11			13					
	N° of Heat Detectors											
	2		3		2		3		2		3	
	N° of Smoke Detectors											
	4	6	4	6	4	6	4	6	4	6	4	6
%Deviation	6%	-4%	-4%	14%	Ref Value	11%	11%	22%	-5%	16%	16%	27%

Table 10 - Risk-Matrix for Fire in the Engine Room

4. COST MODEL

The cost model related to basic events has been implemented in order to calculate the change on costs attributable to the change of parameters' characteristics.

According to the cost estimation methodology prepared by WP5, the total cost associated to a parameter can be split in:

- Build Cost (C_b);
- Through Life Costs (C_{tl}).

The total cost (C_T) associated to systems for containment of fire is:

$$C_T = C_b + C_{tl} \quad (1)$$

The cost model will be developed for the parameters affecting the same set of BEs.

- Propulsion system (failure);
- Stability system (failure);
- Electric Power system (failure);
- Navigation equipment (failure);
- Radar (failure);
- Communication system (failure);
- Fire (in engine room).

4.1 Evaluation of Build Cost (C_b)

Build costs (C_b) can be obtained by summing up the following three cost elements:

- Material Cost (C_m);
- Labour Cost (C_l);
- Overhead Cost (C_o).

$$C_b = C_m + C_l + C_o \quad (2)$$

On the assumption that the labor cost (C_l) and the overhead cost (C_o) can be expressed as function of the material cost C_m , the cost model will be implemented starting from the material cost as basis and subsequently calculating the Labor and Overhead costs by using the proportions as detailed within the PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003). [3]

It must be clear that ciphers detailed in the following table are related to the

value of the Build Cost and that Cells filled by blue color are those of reference.

4.1.1 Cost Model for Propulsion System

The cost analysis for the propulsion system started from the configuration of the mono-hull craft Super Sea Cat built by Fincantieri as basis. As already well-know, the Super Sea Cat is equipped by four Diesel Engines, each carrying a power of some 7080 kW (Total Power: 28320 kW). Consequently, the alternative configurations listed within the cost matrix have in common the total power of the propulsion plant.

Besides, in the Super Sea Cat, each of the four Diesel Engines is linked with its independent shaft line. This aspect has represented another milestone while developing the cost matrix related to the propulsion system, as for the risk matrix. Within each one of the matrixes, it has been considered the possibility of using another distribution of the shaft lines, in particular: two, three or four independent shaft lines.

As main parameter, used in order to develop the cost matrix, it has been chosen the type of engines. Nowadays, two main engines exploited within the maritime field are:

- Diesel Engines (DE);
- Gas Turbines (GT).

It is been chosen not to consider the electrical motors, because of their little use within the maritime field of the High Speed Craft.

Figures indicated in the table are for reference, they are not the real prices of engines. The aforementioned engines' costs, are comprehensive of purchase and installation costs, but of maintenance and exercise costs. This reasoning is implicit in the price of each single engine. As a matter of fact, the designer receives from engines' manufacturer data about the reliability and maintainability of a particular motor; consequently the higher the purchase cost is the lower exploitation and maintenance costs are.

Item	Configuration	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		MEuro/Unit		MEuro		
Propulsion System	DE	1.30	4	5.2	1	0
	DE	2.08	2	4.16	0.80	-0.20
	DE	1.30	2	5.6	1.07	0.07
	GT	3	1			
	DE	2.08	3	6.24	1.20	20
	DE	1.30	2	6.4	1.23	0.23
	GT	1.90	2			
	DE	1.30	3	5.8	1.12	0.12
GT	1.90	1				

Table 11 – Cost-Matrix for Propulsion System

4.1.2 Cost Model for Steering System

Likewise the propulsion system, the cost model for the steering system is based on the cost model developed for the whole project, and therefore it is based on the cost matrix.

The cost matrix is built on the “Significant table extrapolated from the Risk-Matrix for the Steering System”, and the identified design parameters that can affect the system failure.

The configuration of the Super Sea Cat is the reference configuration; the different cost matrix values (identified for the whole cost model) have to be calculated with reference to this configuration.

According to the parameters identified in the risk matrix and to the different configurations derived from the risk matrix, in the following cost matrix it has been necessary to make some specific calculation for each configuration. For example, the alternative configuration with 4 steering water jets and 4 dedicated engines it will be more expensive than the reference configuration because of the difference of price between a steering water jet and a booster.

Finally, it has been assumed that the total cost of an engine has a fixed value: the configurations will not differ for the number of engines but for the number of dedicated engines to the steering water jet. The reference configuration consists of 4 Diesel engine whose only two dedicated to the steering water jet.

According to the identified risk matrix and the identified design parameters, it is necessary to know:

- Number of water jet
- Type of each water jet (steering or booster);
- Cost of each water jet.

Due to the order of magnitude of the costs of a single unit, the indicated cost value in the matrix will be comprehensive of purchase and installation and overhead costs. These are definitely basic information well known in a preliminary design stage.

The steering system of mono-hull craft Super Sea Cat built by Fincantieri consists of 2 dedicated engines (arranged one for each engine room) for 2 steering water jets, and 2 dedicated engines for 2 booster. The reference cost indicated in the cost matrix will be the sum of the cost of all water jets; the figures indicated in the matrix can be assumed as a qualitative value and not as an exact value.

Item	Configuration	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		MEuro/Unit		MEuro		
Steering System	SWJ	0.5	2	1.8	1	0
	BOOSTER	0.4	2			
	SWJ	0.5	3	1.9	1.055	0.055
	BOOSTER	0.4	1			
	SWJ	0.5	4	2	1.052	0.052

Table 12 - Cost-Matrix for Steering System

4.1.3 Cost Model for Electric Power System

As detailed within the introduction of the present chapter, the build cost is calculated as follows:

$$C_b = C_m + C_i + C_o$$

From the PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003)[3] the percentages of each single cost voice are:

- 0.025 for C_m
- 0.022 for C_i
- 0.0133 for C_o .

For problems related to the lightness of the table, it will be used the acronym DE in behalf of the entire sentence "Diesel Engine".

Item	Configurations	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		Euro/Unit		Euro		
Electric Power	DE	150000	2	420000	0.6086	-0.3913
	Emergency DE	120000	1			
	DE	150000	2	540000	0.7826	-0.21739
	Emergency DE	120000	2			
	DE	150000	3	570000	0.8260	-0.17391
	Emergency DE	120000	1			
	DE	150000	3	690000	1	0
	Emergency DE	120000	2			

Table 13 - Cost-Matrix for Electric Power System

4.1.4 Cost Model for Navigation Equipment

The navigation equipment has been divided into the compulsory equipment and the equipment that can be chosen by the designer. As a basis the user will understand that it comprises all the standard systems (compulsory) plus the ones mentioned in the table.

As detailed within the introduction of the present chapter, the build cost is

calculated as follows:

$$C_b = C_m + C_i + C_o$$

From the PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003) the percentages of each single cost voice are:

- 0.09 for C_m
- 0.06 for C_i
- 0.0263 for C_o .

Item	Configuration	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		Euro/Unit		Euro		
Navigation Equipment	ECDIS	12000	1	15700	1	0
	VTS	5000	0			
	DGPS	3700	1			
	ECDIS	12000	1	12000	0.76	-0.24
	VTS	5000	0			
	DGPS	3700	0			
	ECDIS	12000	0	3700	0.24	-0.76
	VTS	5000	0			
	DGPS	3700	1			
	ECDIS	12000	0	5000	0.32	-0.68
	VTS	5000	1			
	DGPS	3700	0			
	ECDIS	12000	1	17000	1.08	0.08
	VTS	5000	1			
	DGPS	3700	0			
	ECDIS	12000	0	8700	0.55	-0.45
	VTS	5000	1			
	DGPS	3700	1			
ECDIS	12000	1	20700	1.32	0.32	
VTS	5000	1				
DGPS	3700	1				

Table 14 - Cost-Matrix for Navigation Equipment

4.1.5 Cost Model for Radar System

As detailed within the introduction of the present chapter, the build cost is calculated as follows:

$$C_b = C_m + C_i + C_o$$

From the PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003) the percentages of each single cost voice are:

- 0.09 for C_m
- 0.06 for C_i

- 0.0263 for C_o .

Item	Configuration	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		Euro/Unit		Euro		
Radar System	Radar Unit	6000	1	11000	1	0
	ARPA	5000	1			
	ATA	4000	0			
	Radar Unit	6000	0	5000	0.45	-0.55
	ARPA	5000	1			
	ATA	4000	0			
	Radar Unit	6000	0	4000	0.36	-0.64
	ARPA	5000	0			
	ATA	4000	1			
	Radar Unit	6000	0	9000	0.82	-0.18
	ARPA	5000	1			
	ATA	4000	1			
	Radar Unit	6000	1	6000	0.54	-0.46
	ARPA	5000	0			
	ATA	4000	0			
	Radar Unit	6000	1	10000	0.91	-0.09
	ARPA	5000	0			
	ATA	4000	1			
Radar Unit	6000	1	15000	1.36	0.36	
ARPA	5000	1				
ATA	4000	1				

Table 15 - Cost-Matrix for Radar System

4.1.6 Cost Model for Internal Communication System

As detailed within the introduction of the present chapter, the build cost is calculated as follows:

$$C_b = C_m + C_l + C_o$$

From the PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003) the percentages of each single cost voice are:

- 0.09 for C_m
- 0.06 for C_l
- 0.0263 for C_o .

In the following table, the acronym AI will be used in behalf of the world Alarm.

Item	Configuration	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		Euro/Unit		Euro		
Internal Communication System	Emergency Al.	3000	1	5850	1	0
	Paging Sys.	850	1			
	Talk Back Sys.	2000	1			
	Emergency Al.	3000	0	850	0.15	-0.85
	Paging Sys.	850	1			
	Talk Back Sys.	2000	0			
	Emergency Al.	3000	0	2000	0.34	-0.66
	Paging Sys.	850	0			
	Talk Back Sys.	2000	1			
	Emergency Al.	3000	0	2850	0.49	-0.51
	Paging Sys.	850	1			
	Talk Back Sys.	2000	1			
	Emergency Al.	3000	1	3000	0.51	-0.49
	Paging Sys.	850	0			
	Talk Back Sys.	2000	0			
	Emergency Al.	3000	1	3850	0.66	-0.34
	Paging Sys.	850	1			
	Talk Back Sys.	2000	0			
Emergency Al.	3000	1	5000	0.85	-0.15	
Paging Sys.	850	0				
Talk Back Sys.	2000	1				

Table 16 - Cost-Matrix for Internal Communication System

4.1.7 Cost Model for External Communication System

As detailed within the introduction of the present chapter, the build cost is calculated as follows:

$$C_b = C_m + C_1 + C_o$$

From the PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003) the percentages of each single cost voice are:

- 0.09 for C_m
- 0.06 for C_1
- 0.0263 for C_o .

Item	Configuration	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		Euro/Unit		Euro		
External Communication System	INMARSAT	23850	1	30850	1	0
	Emerg. VHF	750	1			
	AIS	6250	1			
	NAVTEX	1050	0			
	INMARSAT	23850	0	6250	0.20	-0.80
	Emerg. VHF	750	0			
	AIS	6250	1			
	NAVTEX	1050	0			
	INMARSAT	23850	0	750	0.02	-0.98
	Emerg. VHF	750	1			
	AIS	6250	0			
	NAVTEX	1050	0			
	INMARSAT	23850	0	7000	0.23	-0.77
	Emerg. VHF	750	1			
	AIS	6250	1			
	NAVTEX	1050	0			
	INMARSAT	23850	1	23850	0.77	-0.33
	Emerg. VHF	750	0			
	AIS	6250	0			
	NAVTEX	1050	0			
	INMARSAT	23850	1	30100	0.98	-0.02
	Emerg. VHF	750	0			
	AIS	6250	1			
	NAVTEX	1050	0			
	INMARSAT	23850	1	24600	0.80	-0.2
	Emerg. VHF	750	1			
	AIS	6250	0			
	NAVTEX	1050	0			
	INMARSAT	23850	1	24900	0.81	-0.19
	Emerg. VHF	750	0			
	AIS	6250	0			
	NAVTEX	1050	1			
INMARSAT	23850	1	31150	1.1	0.1	
Emerg. VHF	750	0				
AIS	6250	1				
NAVTEX	1050	1				
INMARSAT	23850	1	25650	0.83	-0.17	
Emerg. VHF	750	1				
AIS	6250	0				
NAVTEX	1050	1				
INMARSAT	23850	1	31900	1.3	0.3	
Emerg. VHF	750	1				
AIS	6250	1				
NAVTEX	1050	1				

Table 17 - Cost-Matrix for External Communication System

4.1.8 Cost Model for Fire in the Engine Room

As detailed within the introduction of the present chapter, the build cost is calculated as follows:

$$C_b = C_m + C_1 + C_o$$

From the PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003) the percentages of each single cost voice are:

- 0.09 for C_m
- 0.06 for C_1
- 0.0263 for C_o .

Item	Configurations	Default Cost	N° of Components	Total Cost	1+d (whole)	d
		Euro/Unit		Euro		
Fire in the Engine Room	CO2 Releaser	3000	11	51000	1	0
	Heat Detectors	4000	2			
	Smoke Detectors	2500	4			
	CO2 Releaser	3000	9	43000	0.843137	-0.15686
	Heat Detectors	4000	2			
	Smoke Detectors	2500	4			
	CO2 Releaser	3000	9	50000	0.980392	-0.01961
	Heat Detectors	4000	2			
	Smoke Detectors	2500	6			
	CO2 Releaser	3000	9	49000	0.960784	-0.03922
	Heat Detectors	4000	3			
	Smoke Detectors	2500	4			
	CO2 Releaser	3000	9	54000	1.058824	0.058824
	Heat Detectors	4000	3			
	Smoke Detectors	2500	6			
	CO2 Releaser	3000	11	56000	1.098039	0.098039
	Heat Detectors	4000	2			
	Smoke Detectors	2500	6			
	CO2 Releaser	3000	11	55000	1.078431	0.078431
	Heat Detectors	4000	3			
	Smoke Detectors	2500	4			
	CO2 Releaser	3000	11	60000	1.176471	0.176471
	Heat Detectors	4000	3			
	Smoke Detectors	2500	6			
	CO2 Releaser	3000	13	57000	1.117647	0.117647
	Heat Detectors	4000	2			
	Smoke Detectors	2500	4			
	CO2 Releaser	3000	13	62000	1.215686	0.215686
	Heat Detectors	4000	2			
	Smoke Detectors	2500	6			
CO2 Releaser	3000	13	61000	1.196078	0.196078	
Heat Detectors	4000	3				
Smoke Detectors	2500	4				
CO2 Releaser	3000	13	66000	1.294118	0.294118	
Heat Detectors	4000	3				
Smoke Detectors	2500	6				

Table 18 - Cost-Matrix for Fire in the Engine Room

PART TWO: USER'S GUIDE

5. GENERAL VIEW

This chapter provides a general overview of the steps that a safety analyst has to follow for limiting the risk of collision, grounding and striking by following [S@S](#) approach.

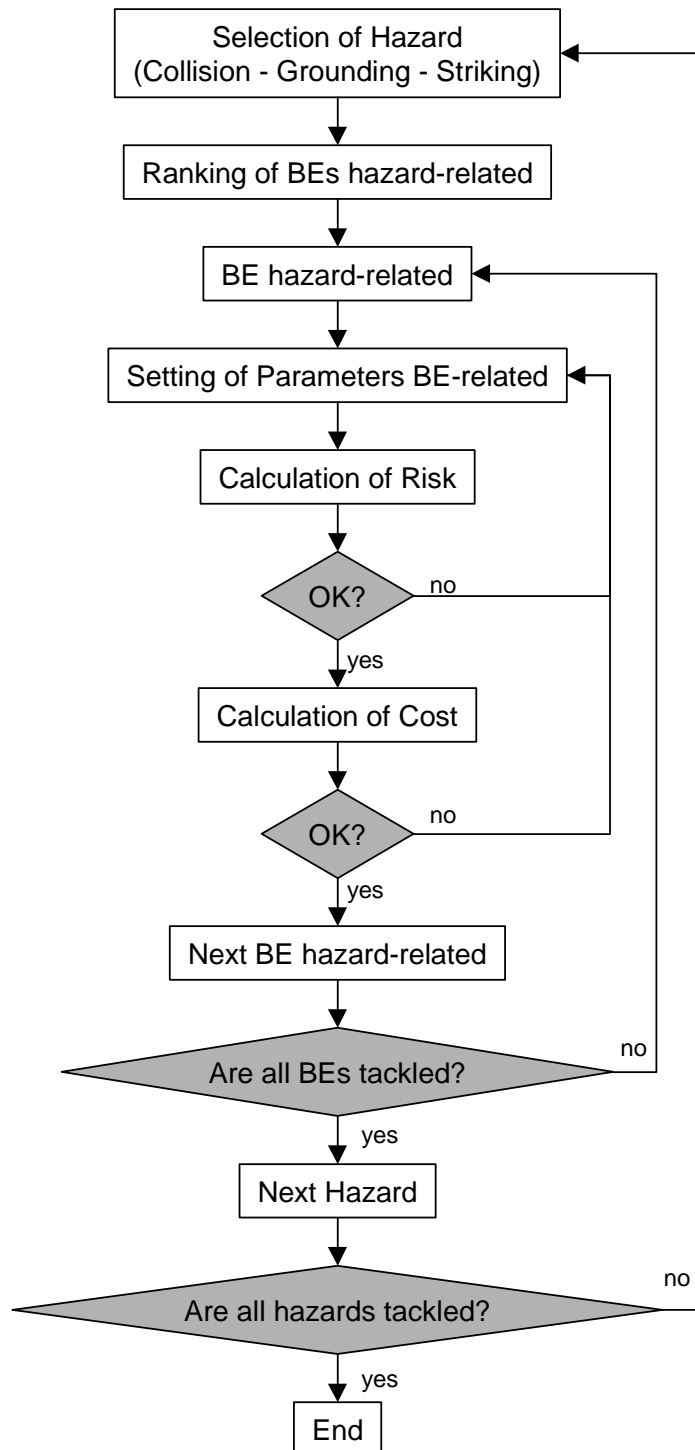


Figure 4 - General Overview of the Process

6. CONCLUSIONS

The work done in Task 1.3.2 and reported in this document still needs refinements in some of its parts, in particular:

- The evaluation of weights used in the MCA approach for design parameters need to be reviewed by safety analysts from the shipyard. At present they are merely the result of a rough estimation, which has no substantial practical foundation.
- Build and operational cost related to the same parameters also need to be reviewed by a shipyard in order to assess whether the percentage variations are reasonable.

Moreover, because of the heterogeneity of the topics covered in WP1 (human errors, mechanical and automation failures, maneuvering errors) and the different methods suggested to tackle them, an merging process is running for the development of the controllability model to be finally incorporated into WP5. This is the main content of D134.

7. REFERENCES

1. Reports from "Transportation Safety Board of Canada (TSB)".
2. Reports from "Transport Accident Investigation Commission (TAIC)".
3. Slide n.5 of PowerPoint presentation prepared by UNEW - Paris meeting, 13-14 March 2003).

8. APPENDICES

8.1 Appendix 1: BEs for WP1 hazards

Referring only to Automation and Mechanical Failures involved in the task T132, the analyzed BEs are the following:

1. Propulsion system (failure);
2. Steering system (failure);
3. Electric Power system (failure);
4. Navigation equipment (failure);
5. Radar (failure);
6. Communication system (failure);
7. Fire (in engine room).

8.2 Appendix 2: Evaluation of MCA weights

The allocation of weights represents the second step of the MCA study, just after the identification of the key parameters. In fact, all the parameters of a category, e.g. navigation equipment, have not the same importance or impact regarding safety. The MCA methodology takes this point into account and includes a number of weights that permit to balance the parameters and their respective level of safety.

The weight is represented by a factor, between 0 to 1, where 0 means “no importance” and 1 “vital”, which will affect the calculations that are the most critical combinations.

The way of allocating these weights is subjective and has to be performed through expert judgements and different solutions have to be tested. Indeed, it is hard to determine precisely if the presence of for example a DGPS (differential global positioning system) is more important regarding safety than the presence of an ECDIS (electronic charts).

The allocation of the weights was usually preceded by interviews with different experts in order to classify by importance the parameters under investigation. Then a ratio has been calculated in order to sort out with an average weight for the parameters. These figures have been finally re-submitted to the expert for the final agreement. The following tables present the repartitions of the weights for all the parameters involved within the task 1.3.4.

Ind	Pind
Diesel Engine	1
Gas Turbine	0,81
Steering Waterjet	0,9

Table 19 - Weights for Propulsion System and Steering Waterjet

Ind	Pind
N° of Vessel Traffic System (VTS)	0,75
N° of DGPS (Differential GPS)	0,8
N° of Electronic Chart Display and Information System (ECDIS)	0,7

Table 20: Weights for Navigation Equipment

Ind	Pind
Presence of a Radar unit - 3Ghz	0,8
Automatic Tracking Aid (ATA)	0,75
Automatic Radar Plotting Aid (ARPA)	0,8

Table 21: Weights for the Radar Equipment

Ind	Pind
Presence of emergency system for General alarm and PA	0,8
Presence of the Talk back systems	0,75
Presence of the Paging systems	0,7

Table 22: Weights for the Internal Communication Equipment

Ind	Pind
Redundancy of Safety Information (e.g. INMARSAT, NAVTEX)	0,8
Presence of emergency system for the VHF Radio	0,75
Presence of Identification Systems (e.g. AIS)	0,7

Table 23: Weights for the External Communication Equipment

Ind	Pind
N° of Diesel Engines	0.6
N° of Emergency Diesel Engines	0.6

Table 24: Weights for Electric Power System

Ind	Pind
N° of Fire Fighting Systems	0.5
N° of Heat Detectors	0.5
N° of Smoke Detectors	0.5

Table 25: Weights for Fire in the Engine Room