

Safety at Speed - S@S
**IMPLEMENTATION OF MODELS FOR
HUMAN FACTOR
DELIVERABLE No. D2.3.1**

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CONTENTS

1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION.....	5
2. INTRODUCTION.....	6
3. MODEL DESCRIPTIONS.....	7
3.1. LONG TERM ANALYSIS OF MSI AND MII MODEL.....	7
3.1.1. General description of the model.....	7
3.1.2. Implementation of the model.....	8
3.1.3. Use of the model.....	9
3.1.4. Results.....	12
3.2. SHORT TERM ANALYSIS OF MSI AND MII MODEL	12
3.2.1. General description of the model.....	12
3.2.2. Implementation of the model.....	14
3.2.3. Use of the model.....	14
3.2.4. Results.....	16
3.3. HULL GIRDER VIBRATION MODEL.....	16
3.3.1. General description of the model.....	16
3.3.2. Implementation of the model.....	17
3.3.3. Use of the model.....	17
3.3.4. Results.....	18
3.4. INDOOR CLIMATE MODEL	19
3.4.1. General description of the model.....	19
3.4.2. Implementation of the model.....	19
3.4.3. Use of the model.....	19
3.4.4. Results.....	21
3.5. NOISE MODEL.....	21
3.5.1. General description of the model.....	21
3.5.2. Implementation of the model.....	23
3.5.3. Use of the model.....	24
3.5.4. Results.....	29
4. CONCLUSIONS.....	29
5. REFERENCES	30

1. EXECUTIVE SUMMARY SUITABLE FOR PUBLICATION

The present report corresponds to deliverable D2.3.1 of Work Package 2 - Ship Motion Hazards of Safety At Speed (S@S). It presents the work carried out in Sub-task 2.3.1 containing the implementation of calculation models for motion sickness (MSI), safety of footing (MII), hull girder vibration, indoor climate and noise.

The principle, input data and use of programs calculating the characteristics associated with all the five above-mentioned models are presented. Each model has been implemented in separate Excel workbook using macros coded with Visual Basic. Models for MSI, MII and hull girder vibration contain also external executable files performing the more tedious calculations.

There are two program versions for the MSI and MII models. The long-term version calculates the values of MSI (Motion Sickness Incidence) and MII (Motion Induced Interruptions in minute) representing the overall comfort characteristics during one year period in the area of operation. These values are compared with the criteria given in deliverable D2.2.1. The short-term version can be used when investigating the effects of changes in environmental and operational conditions on comfort. The ship motion formulae needed in MSI and MII models are obtained from simplified seakeeping calculation method developed in Sub-task 2.2.2 of WP2.

The hull girder vibration model predicts the lower modes of free vibration in vertical or horizontal bending. The obtained values are compared with the frequencies of the major excitation sources aboard the ship or encounter wave frequencies.

The indoor climate model calculates the required power and air flow of the HVAC systems of a ship using the given requirements for the indoor climate and description of the internal spaces of the ship as input.

The noise prediction model determines the acoustic and vibrational characteristics of the noise source, transmission path and receiver spaces. The sound pressure levels in receiver spaces are compared with criteria.

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2. INTRODUCTION

The present report corresponds to deliverable D2.3.1 of Work Package 2 - Ship Motion Hazards of Safety At Speed (S@S). It presents the work carried out in Sub-task 2.3.1 containing the implementation of calculation models for motion sickness (MSI), safety of footing (MII), hull girder vibration, indoor climate and noise.

The following models have been developed within Work Package 2:

- Comfort and workability models, providing criteria for the effect on human of: ship motions (sea sickness, safety of footing), hull girder vibrations, indoor climate and noise. These models are implemented within Sub-task 2.3.1, and are reported in the present document.
- Risk model associated with broaching (large sudden horizontal and vertical acceleration, capsizing). This model is implemented within Sub-task 2.3.3, and is reported in the deliverable D2.3.3.
- Cost model related to ship availability. This model is implemented commonly within Sub-tasks 2.3.2 and 2.3.3 and is reported in the deliverable D2.3.2.
- Basic seakeeping models for the determination of the response amplitude operators (RAOs) of the ship motions, the accelerations and the midship vertical bending moment (VBM). Based on the RAOs, models are made for calculating the short term most probable maximum values, and the long term prediction of VBM. These models are used partially by the above comfort, workability, risk and cost models developed in WP2. The long term VBM prediction model is also used in WP3 for the determination of loading. The basic seakeeping models are implemented commonly within Sub-tasks 2.3.1, 2.3.2 and 2.3.3 and are reported in the deliverable D2.3.2.

The present report does not include the model for costs due to impaired comfort. The reasons for leaving out the cost model have been described in deliverable 2.3.2 as:

"The major impact of ship motions concerns comfort of passengers and crew and workability of crew. Discomfort does not represent a risk for passengers. It may represent an indirect risk for the crew, by inducing fatigue for instance. However such indirect effects are very difficult to model. Discomfort can also have an influence on costs, either by the costs due to small accidents of passengers or crew members on board, or by reducing progressively the number of passengers. Again, these effects are very difficult to model: loss of balance can be estimated, but its effect is unpredictable. Besides, the effect of discomfort on the passenger turnover will also strongly depend on external factors such as the existence of other passenger ships available on the same route, the existence of other means of transportation, the duration of the voyage with other means of transportation compared to the duration with the 'uncomfortable' ship. According to this, it has been decided not to convert comfort and workability in risks and costs, but rather to display these figures together with risks and costs figures."

The costs due to vibrations, bad indoor climate and high noise levels are equally difficult to assess. Therefore no cost models associated with these phenomena have been introduced either. The calculated results of the models are given as additional information for the designer.

3. MODEL DESCRIPTIONS

3.1. Long term analysis of MSI and MII model

3.1.1. General description of the model

Passenger and crew long term comfort levels with regard to motion sickness and safety of footing are determined and compared with criteria. Relevant parameters are MSI (Motion Sickness Incidence = percentage of passengers feeling sick) and MII (Motion Induced Interruptions per minute = loose of balance per minute). They are utilised in calculating an overall comfort level during one year of operation in a given sea area. As a result the ship's comfort levels are rated as High, Medium or Low. In addition a safety level with regard to maximum horizontal acceleration is determined in the same way. This safety level is compared with the guidelines of IMO HSC Code and it gives another indication of the safety of footing onboard the ship.

In the developed models, the operating and sea state conditions that will be encountered by the ship are defined as a probability distribution of the angle of wave incidences with respect to the ship and by a wave scatter diagram (probability distribution of (T_z, H_s) , T_z - zero up-crossing period, H_s - significant wave height). The ship speed is considered constant for all these conditions (ship speed input by operator). The angle of wave incidence and sea state (T_z, H_s) are considered to be independent variables.

Then, for each combination of wave_incidence(i), and wave characteristics $T_z(j)$, $H_s(k)$ conditions, the MSI and MII values are calculated using motion sickness [1], safety of footing [1] and simplified seakeeping models [2,3] also developed in WP2. The most probable maximum horizontal acceleration value a_{hPeak} is derived from the variance σ_{ah}^2 as:

$$a_{hPeak} = \sigma_{ah} \sqrt{2 \ln(N)}$$

where N corresponds to the number of waves encountered and is estimated by Reference_period / T_z for each considered sea state. The reference period is 300 s according to guidelines of IMO HSC Code. The variance of horizontal acceleration σ_{ah}^2 is calculated as the sum of the variances of longitudinal and transverse accelerations.

These calculations are performed separately for passenger and crew area locations. Therefore the user may supply different criteria for passenger and crew areas if necessary but the default values are the same.

For each condition the MSI rating $\Gamma_{MSI}(i,j,k)$ equals 3 if calculated MSI value is less than the upper limit for high comfort level (representing high comfort level), 2 if MSI is between upper limits for high and medium comfort levels (medium comfort level), and equals 1 otherwise (low comfort level). The overall MSI comfort rating is calculated by summing all ratings that have been weighted by the probability of occurrence of each condition. The overall MSI comfort rating $\Gamma_{MSI,Tot}$ is then given by:

$$\Gamma_{MSI,Tot} = \sum_i \sum_j \sum_k P(\text{wave_incidence}(i)) \times P(Tz(j), Hs(k)) \times \Gamma_{MSI}(i, j, k)$$

Identical calculations are performed for each MII rating $\Gamma_{MII}(i,j,k)$ and maximum horizontal acceleration rating $\Gamma_{ah}(i,j,k)$ using the corresponding criteria for passengers and crew. The overall ratings for MII $\Gamma_{MII,Tot}$ and maximum horizontal acceleration $\Gamma_{ah,Tot}$ are then:

$$\Gamma_{MII,Tot} = \sum_i \sum_j \sum_k P(\text{wave_incidence}(i)) \times P(Tz(j), Hs(k)) \times \Gamma_{MII}(i, j, k)$$

$$\Gamma_{ah,Tot} = \sum_i \sum_j \sum_k P(\text{wave_incidence}(i)) \times P(Tz(j), Hs(k)) \times \Gamma_{ah}(i, j, k)$$

MSI and MII comfort ratings and maximum horizontal acceleration safety ratings can be calculated in several user defined locations (defined by their co-ordinates X, Y, Z in meters with respect to the ship aft perpendicular, centreline and baseline), corresponding to passenger and crew locations. Then the maximum values of MSI, MII and maximum horizontal acceleration ratings obtained over all selected locations of passenger (resp. crew) areas are compared to the limit values.

After the overall comfort ratings with respect to motion sickness and safety of footing and safety rating for maximum horizontal accelerations have been calculated the corresponding comfort levels (or safety levels in the case of horizontal acceleration) can be set:

- Overall comfort (safety) rating is higher or equal to 2.5: comfort level is set to "High".
- Overall comfort (safety) rating between 1.5 and 2.5: comfort level is set to "Medium".
- Overall comfort (safety) rating below 1.5: comfort level is set to "Low".

The seakeeping models used are closed form expressions. They have been developed within WP2 for the calculation of heave, pitch, roll, vertical acceleration, longitudinal acceleration, transverse acceleration and vertical bending moment RAOs and variance. Since the calculations of MSI, MII and maximum horizontal acceleration are based on roll motion and acceleration levels, only formulas for predicting the variance of roll motion together with vertical, longitudinal and transverse accelerations are used. These accelerations result from heave, roll and pitch motions and the lever arms between the calculation locations and the ship CG.

Basic assumptions used by the simplified seakeeping model are:

- For the heave and pitch motions the ship is modelled as a rectangular box
- For the roll motion the ship is modelled as two connected rectangular boxes
- All three motions (heave, pitch and roll) are de-coupled
- Heave and pitch motions are 90° out of phase
- The location of the pitch centre corresponds to the ship CG
- The form coefficient δ is fixed to 0.6

3.1.2. Implementation of the model

The long term motion sickness, safety of footing and maximum horizontal acceleration model has been implemented in the Excel file S@S_WP2_MSI&MII_vi.ii(yyymmdd).xls and two dll-files (MSI_MII_Program_vi.ii.dll and Dforrt.dll).

The Excel file consists of five worksheets containing all the user input and output needed in the calculations of MSI, MII and maximum horizontal acceleration. The actual calculation of these models is done in a dll-file compiled with Compaq Visual Fortran programming language. Visual Basic code has been used for reading the input data, passing all the necessary input and output parameters to and from the external dll-subroutine and displaying the output results.

The Excel file contains five worksheets:

- Main: where the design parameters and speed are input by the operator, the MSI, MII and maximum horizontal acceleration calculation is activated and the results displayed.
- Locations: where the co-ordinates of the locations of passenger and crew areas are given. The locations are defined separately for passenger and crew areas.
- Scatter diag.: where the wave scatter diagram is given.
- Incidence distrib.: where the wave incidence distribution with respect to the ship is given.
- MSI&MII criteria: where criteria for MSI and MII comfort levels as well as maximum horizontal acceleration safety levels are given. The criteria for passengers and crew areas can be different though the default values are the same.

The calculation is done in dll-type library routine file MSI_MII_Program_vi_ii.dll. A Fortran run-time file Dforrt.dll contains no calculation code but it is necessarily needed during the execution.

3.1.3. Use of the model

The colour code used is as follows:

- Light green cells: input data - to be entered by operator.
- Yellow cell: result of the model
- Grey cells: intermediate data calculated by the model.
- Green cells: information for guiding the operator.

Some 'input' cells present comments defining their contents and their default values when applicable.

Before launching calculations ('Calculate MSI&MII:' button in main worksheet) data should be input as follows:

- In 'Main' worksheet input the design parameters values and ship speed and select whether active stabilisation is used or not.
- Check/modify the locations for MSI and MII calculations ('Locations' worksheet), wave scatter diagram ('Scatter diagram.' worksheet), wave incidence probability distribution ('Incidence distrib.' worksheet) and criteria ('MSI&MII criteria' worksheet).

Worksheet 'Main'

This worksheet is the main interface with the user. It contains fields corresponding to input parameters, a button 'Calculate MSI&MII :' which starts the calculation and below the button fields presenting the results.

The default values of input parameters have been set to values corresponding to SuperSeaCat 3. These values are indicated in comment cells which are displayed when the mouse pointer is located on the input cells.

If the roll natural period is unknown, set it to zero. The program will then estimate it from the waterline breadth and the transverse metacentric height by the IMO recommended formula:

$$T_N = 2 \times (0.373 + 0.023 \times B / T - 0.043 \times L_{pp} / 100) \times B / (GM_T)^{1/2}.$$

Where L_{pp} is the length between perpendiculars, B is the waterline breadth, T is the draught and GM_T is the transverse metacentric height.

As an intermediate result block coefficient C_B is also displayed in grey cells. It is calculated from the displacement, length between perpendicular, waterline breadth and draft.

Roll and pitch damping coefficients with and without active stabilisation are given in block N16:P17. The values corresponding to current selection of stabilisation option are shown also in grey cells E14 and E15. The default values of roll and pitch damping are:

	Pitch damping	Roll damping
No active stabilisation	0	1
Active stabilisation	0.5	2

These values are based mainly on SuperSeaCat3 sea trial data. The more thorough reasoning behind these values is given in deliverable D2.3.2.

Worksheet 'Locations'

In this worksheet, the operator defines the co-ordinates where the MSI and MII values and the maximum horizontal accelerations have to be calculated. All these three values are calculated in the same points. The locations are normally different for passengers and crew. Also in cases where these locations are for some reason the same, they should be given separately because the criteria for passengers and crew may be different.

Up to 10 locations can be defined for both passenger and crew locations. The co-ordinates have to be input in meters with respect to ship aft perpendicular, centreline and baseline. The reference frame is: X- longitudinal ship axis positive from stern to front, Y - transverse axis, positive from starboard to port, Z - vertical axis, positive up. The lines corresponding to unused locations can be left blank, provided that the used locations are filled starting from the first line of the charts (no blank line between used locations).

Since the number of computations (and so the time) increases with the number of locations, it is recommended to consider mainly the extremities of the considered zones (most fore/back locations and most starboard/port locations). The default values corresponding to SuperSeaCat3 passenger and crew areas are set to:

- For passenger areas three points on the main passenger deck: first point 57 m from AP on port side 8.55 m from centre line (0.5 x Breadth moulded), second point longitudinally at the level of CG on port side 8.55 m from centre line and the third one at AP on port side 3 m from centre line.
- For crew areas two points on bridge: master's seat 1 m from centre line on port side and chief engineers seat 3 m from centre line on starboard side.

Worksheet 'Scatter diag.'

In this worksheet, the operator defines the scatter diagram of the waves that the ship will encounter. The scatter diagram gives the probability of occurrence of each couple T_z - zero up-crossing period, H_s - significant wave height.

The operator should input the T_z (in seconds) and H_s (in meters) values, as well as the corresponding probabilities. The maximum number of H_s and T_z is 15, but it is possible to use fewer values, provided that the probabilities are always filled from the upper left corner of the chart. The sum of probabilities should be equal to 1. The actual sum is displayed in the lower right corner of the diagram. If the sum is different from one, the program will automatically divide all the probability values by the sum. This can also be done by pressing the 'Read diagram' button from the worksheet.

All the waves are assumed to correspond to the same wave spectrum type. The operator can select the gamma parameter of the wave spectrum; 1 corresponds to the Pierson-Moskowitz spectrum and 3.3 corresponds to the Jonswap spectrum.

As default, the Mediterranean wave scatter diagram modified to have more resolution for smaller periods is used.

Worksheet 'Incidence distrib.'

In this worksheet, the operator defines the wave incidences that the ship will encounter. The wave incidences are defined with respect to the ship longitudinal axis and 180° is head sea.

The wave incidences are considered independent from the sea state, that is all combinations of defined wave incidences and (T_z , H_s) will be calculated.

Up to 8 incidences can be used. The operator has to input the wave incidence (in deg.) and the corresponding probability of occurrence. Less than 8 incidences can be used, provided that the chart is filled from the first left column of the chart.

The sum of probabilities should be equal to 1. The actual sum is displayed in the lower right corner of the diagram. If the sum is different from one, the program will automatically divide all the probability values by the sum. This can also be done by pressing the 'Read' button on the worksheet.

Default values are 0.125 for all 8 angles of incidence meaning that all directions are equally probable.

Worksheet 'MSI&MII criteria'

In this worksheet, the operator defines the values of the MSI, MII and maximum horizontal acceleration criteria. The default values of MSI and MII criteria are based on the values presented in [1] and the maximum horizontal acceleration criterion is taken from the guidelines of IMO HSC Code.

Once all input data have been entered and/or checked as described in the previous section, go to the 'Main' worksheet and press 'Calculate MSI&MII :' button.

The duration of calculation, with the default 15x15 scatter diagram with 152 non-zero entries, 8 wave incidences, three locations for passenger and two locations for crew comfort calculation, is less than 10 seconds on a Pentium 4 computer.

3.1.4. Results

Intermediate results are displayed in grey cells:

- Block coefficient C_B . It is calculated from the displacement, length between perpendicular, waterline breadth and draft.
- Roll and pitch damping coefficients. The values of these parameters depend on the selection of stabilisation option.
- Overall comfort ratings of MSI and MII and safety ratings of maximum horizontal accelerations. The values of previous calculations are erased immediately after the button is pressed. The new values appear after the calculation is finished.

Once the calculation is completed, the MSI and MII comfort levels and the horizontal acceleration safety levels are displayed in yellow cells.

For the motion sickness, safety of footing and maximum horizontal acceleration calculations the most sensitive design parameters are the length, displacement and transverse metacentric height (or roll natural period). The results will obviously also depend on the operational parameters (speed, wave scatter diagram, wave incidence distribution), selected locations of passenger and crew areas and the MSI&MII criteria.

The MSI values are calculated using the vertical acceleration given by the simplified seakeeping model which tends to overestimate the vertical acceleration. The calculated MSI values are therefore conservative. Because the sway and yaw motions are not included in the seakeeping model, transverse acceleration depends on roll motion only. Thus the calculated MII values and maximum horizontal accelerations are somewhat underestimated. As the MSI and MII calculation procedures are linear with regard to the ship motions, the inaccuracy of MSI and MII models is directly proportional to that of the seakeeping program results.

3.2. Short term analysis of MSI and MII model

3.2.1. General description of the model

Passenger and crew short term comfort levels with regard to motion sickness and safety of footing are determined and compared with criteria. Relevant parameters MSI (Motion Sickness Incidence = percentage of passengers feeling sick) and MII (Motion Induced Interruptions per minute = loose of balance per minute) are calculated for a short period of time (2 hours) in one sea state and one angle of wave incidence. As a

result the ship's comfort levels are rated as High, Medium or Low. In addition a safety level with regard to maximum horizontal acceleration is determined in the same way.

For the user given combination of ship speed, wave angle of incidence, significant wave height H_s and zero up-crossing period T_z , the MSI and MII values are calculated using motion sickness [1], safety of footing [1] and simplified seakeeping models [2,3] also developed in WP2. The most probable maximum horizontal acceleration value a_{hPeak} is derived from the variance σ_{ah}^2 as:

$$a_{hPeak} = \sigma_{ah} \sqrt{2 \ln(N)}$$

where N corresponds to the number of waves encountered and is estimated by $\text{Reference_period} / T_z$ for considered sea state. The reference period is 300 s according to guidelines of IMO HSC Code. The variance of horizontal acceleration σ_{ah}^2 is calculated as the sum of the variances of longitudinal and transverse accelerations.

MSI and MII values and maximum horizontal acceleration are calculated in one user defined location (defined by its co-ordinates X , Y , Z in meters with respect to the ship aft perpendicular, centreline and baseline), corresponding either to passenger or crew location. The selection between passengers or crew determines the criteria used in assessing the comfort or safety levels. This distinction is needed as the user may give different criteria for passengers and crew though the default values are the same.

After the MSI and MII parameters and maximum horizontal accelerations have been calculated the corresponding comfort levels (or safety levels in the case of horizontal acceleration) can be set:

- MSI or MII parameter below the upper limit for high comfort level: comfort level is set to "High".
- MSI or MII parameter between upper limits for high and medium comfort levels: comfort level is set to "Medium".
- MSI or MII parameter greater than upper limit for medium comfort level: comfort level is set to "Low".

The seakeeping models used are closed form expressions. They have been developed within WP2 for the calculation of heave, pitch, roll, vertical acceleration, longitudinal acceleration, transverse acceleration and vertical bending moment RAOs and variance. Since the calculations of MSI, MII and maximum horizontal acceleration are based on roll motion and acceleration levels, only formulas for predicting the variance of roll motion together with vertical, longitudinal and transverse accelerations are used. These accelerations result from heave, roll and pitch motions and the lever arms between the calculation locations and the ship CG.

Basic assumptions used by the simplified seakeeping model are:

- For the heave and pitch motions the ship is modelled as a rectangular box
- For the roll motion the ship is modelled as two connected rectangular boxes
- All three motions (heave, pitch and roll) are de-coupled
- Heave and pitch motions are 90° out of phase
- The location of the pitch centre corresponds to the ship CG
- The form coefficient δ is fixed to 0.6

3.2.2. Implementation of the model

The motion sickness, safety of footing and maximum horizontal acceleration model has been implemented in the Excel file S@S_WP2_MSI&MII_Short_Term_vi.ii(yyyymmdd).xls and two dll-files (MSI_MII_Program_vi.ii.dll and Dforrt.dll).

The Excel file consists of two worksheets containing all the user input and output needed in the calculations of MSI, MII and maximum horizontal acceleration. The actual calculation of these models is done in a dll-file compiled with Compaq Visual Fortran programming language. Visual Basic code has been used for reading the input data, passing all the necessary input and output parameters to and from the external dll-subroutine and displaying the output results.

The Excel file contains two worksheets:

- Main: where the design parameters, speed, wave parameters, wave angle of incidence and the co-ordinates of the calculation location are input by the operator. Also MSI, MII and maximum horizontal acceleration calculation is activated and the results displayed.
- MSI&MII criteria: where criteria for MSI and MII comfort levels as well as maximum horizontal acceleration safety levels are given. The criteria for passengers and crew areas can be different though the default values are the same.

The calculation is done in dll-type library routine file MSI_MII_Program_vi.ii.dll. A Fortran run-time file Dforrt.dll contains no calculation code but it is necessarily needed during the Fortran code execution.

3.2.3. Use of the model

The colour code used is the same as in long term MSI and MII model:

- Light green cells: input data – to be entered by operator.
- Yellow cell: result of the model
- Grey cells: intermediate data calculated by the model.
- Green cells: information for guiding the operator.

Some 'input' cells present comments defining their contents and their default values when applicable.

Before launching calculations ('Calculate MSI&MII:' button in main worksheet) data should be input as follows:

- In 'Main' worksheet input the design parameter values, ship speed, wave parameters, wave angle of incidence and co-ordinates of the calculation location and select whether active stabilisation is used or not.
- Check/modify the criteria for MSI and MII calculations ('MSI&MII criteria' worksheet).

Worksheet 'Main'

This worksheet is the main interface with the user. It contains fields corresponding to input parameters, a button 'Calculate MSI&MII :' which starts the calculation and fields presenting the results below the button.

The default values of input parameters have been set to those corresponding to SuperSeaCat 3. These values are indicated in comment cells which are displayed when the mouse pointer is located on the input cells.

If the roll natural period is unknown, set it to zero. The program will then estimate it from the waterline breadth and the transverse metacentric height by the IMO recommended formula:

$$T_N = 2 \times (0.373 + 0.023 \times B / T - 0.043 \times L_{pp} / 100) \times B / (GM_T)^{1/2}.$$

Where L_{pp} is the length between perpendiculars, B is the waterline breadth, T is the draught and GM_T is the transverse metacentric height.

As an intermediate result block coefficient C_B is also displayed in grey cells. It is calculated from the displacement, length between perpendicular, waterline breadth and draft.

Roll and pitch damping coefficients with and without active stabilisation are given in block N16:P17. The values corresponding to current selection of stabilisation option are shown also in grey cells E14 and E15. The default values of roll and pitch damping are:

	Pitch damping	Roll damping
No active stabilisation	0	1
Active stabilisation	0.5	2

These values are based mainly on SuperSeaCat3 sea trial data. The more thorough reasoning behind these values is given in deliverable D2.3.2.

Gamma parameter of the wave spectrum can be selected; 1 corresponds to the Pierson-Moskowitz spectrum and 3.3 corresponds to the Jonswap spectrum.

Beta is the wave angle of incidences that the ship will encounter. The wave incidence is defined with respect to the ship longitudinal axis and 180° is head sea.

The selection between Passenger or Crew determines the criteria used in assessing the comfort or safety levels. This selection is needed as the user may give different criteria for passengers and crew though the default values are the same.

The co-ordinates of calculation location have to be input in meters with respect to ship aft perpendicular, centreline and baseline. The reference frame is: X- longitudinal ship axis positive from stern to front, Y - transverse axis, positive from starboard to port, Z - vertical axis, positive up.

Worksheet 'MSI&MII criteria'

In this worksheet, the operator defines the values of the MSI, MII and maximum horizontal acceleration criteria. The default values of MSI and MII criteria are based on the values presented in [1] and the maximum horizontal acceleration criterion is taken from the guidelines of IMO HSC Code.

Once all input data have been entered and/or checked as described in the previous section, go to the 'Main' worksheet and press 'Calculate MSI&MII :' button.

The duration of calculation is less than 1 second on a Pentium 4 computer.

3.2.4. Results

Intermediate results are displayed in grey cells:

- Block coefficient C_B . It is calculated from the displacement, length between perpendicular, waterline breadth and draft.
- Roll and pitch damping coefficients. The values of these parameters depend on the selection of stabilisation option.
- Calculated MSI, MII and maximum horizontal acceleration values. The values of previous calculations are erased immediately after the button is pressed. The new values appear after the calculation is finished.

Once the calculation is completed, the MSI and MII comfort levels and the horizontal acceleration safety levels are displayed in yellow cells.

The effects of the seakeeping model simplifications and sensitivity to parameters were already discussed in Chapter 3.1.4 dealing with the long term analysis. In the short term analysis it is, however, possible to study in more detail the sensitivity of results to changes of individual input parameter. The MSI results seem to be quite sensitive to the changes in wave spectrum type and zero up-crossing period and the use of stabilisation. As an example the following sensitivity study for SuperSeaCat 3 has been made:

In head seas (Jonswap, $H_s = 2$ m, stabilisation active and ship speed 37 kn) the change in zero up-crossing period from 5 to 6 s increases the MSI value (2 h exposure time) from 4.2 to 11.7 % on the main passenger deck at $x = 44$ m from AP (=midship). If the stabilisation is not used, the corresponding increase in MSI is from 5.5 to 15.6 %. If the Pierson-Moskowitz type wave spectrum is used, the increase in MSI is from 8.3 to 16.7 % (stabilisation active) and from 11.2 to 22.3 % (no stabilisation).

3.3. Hull girder vibration model

3.3.1. General description of the model

The model calculates the free hull girder vibrations of the ship, for modes up to 5 (6-noded mode). It can be used for the prediction of the lower modes of free vibration in vertical or horizontal bending. The obtained values are compared against the frequencies of the major excitation sources aboard the ship (like main engine unbalanced forces-moments, propeller excitation, etc) or the encounter wave frequencies. This is the first step in the prediction of the vibration levels at the early design stages of the ship design.

The program assumes that the hull girder vibrates like an one-dimensional beam. This is a common assumption, made when dealing with the lower modes of the hull girder vibration [4, 5]. The corresponding mathematical model takes into account the longitudinal variation of the elastic and dynamic properties of the ship. The analysis starts with the splitting of the hull girder into a sufficient number of beam (line)

elements and the Bernoulli-Euler formulation is followed for the establishment of the elastic and inertial matrices of the system.

The elastic and inertial properties are assumed constant inside each element/hull segment. For each of them the user must provide the values for the total (structural and cargo) mass and the equivalent hydrodynamic mass of the surrounded water. The later can be derived from the output of 2-D hydrodynamic codes, through the application of the well known 'strip theory'. The frequency-independent upper limits of the hydrodynamic added masses in vertical or horizontal directions are to be included in the data.

Based on the above values, the program forms the total mass matrix of the system following a 'consistent mass matrix formulation' approach. During this, two additional corrections are applied on the hydrodynamic added mass. The first one corresponds to a correction of the 2-D added masses for 3-D flow effects, which is mode depended [4]. The second is an application of a local correction, depended on the vicinity of each beam to the hull girder ends [4]. Both correction factors are computed and applied internally by the program.

The values of the sectional 2nd moment of inertia representing the bending stiffness of the beam in vertical or horizontal direction are used for the construction of the stiffness matrix for each beam finite element[7, 8]. The total system stiffness matrix is then composed and the associated eigenvalue problem is solved by the 'subspace iteration' numerical method [6, 9] in order to obtain the natural frequencies. The Sturm sequence check [9] is also applied at each stage of the subspace iterations, to check the results of the computations.

3.3.2. Implementation of the model

The hull girder vibration model has been implemented in the Excel file S@S_WP2_hull_girder_vibration_v1_00.xls and coded in Visual Basic. The file contains two worksheets:

- Main: where the analysis data are input by the user
- Risc_of_resonance: where the results of the calculations are presented.

In addition to the aforementioned excel file, two other executable files are called internally by the program, through the macro 'Calculate_hull_vibrations' each time the button 'Click to update values' in the worksheet 'Risc_of_resonance' is pressed:

- Program predata.exe: This program is called for the preparation of the appropriate ASCII intermediate data file, which stores the
- Program sasvb.exe: this is the main computing module for solving the eigenvalue problem for the frequencies of the hull girder vibrations. The results are stored in an intermediate file in the directory 'C:\sascomf' and are read automatically by the calling macro of the excel workbook.

3.3.3. Use of the model

The excel workbook 'S@S_WP2_hull_girder_vibration_v1_00.xls' can be stored in any folder. However, the other two executables (predata.exe and sasvb.exe) must be stored in a directory named 'C:\sascomf', in order to be found by the calling macro of the workbook.

Based on the variations of the longitudinal distributions of the elastic and inertial properties of the hull girder (and the data available at this preliminary stage of design) the user has to divide the hull girder of the ship into a number of beam elements, which are assumed to have constant properties along their length. After this preparatory work the user enters the data of each beam (hull section) into the table for the hull sections in the worksheet 'Main'. The total weight of each beam segment (tons), the total added mass (mass tons / 1000 kg), the sectional 2nd moment of area in bending (m⁴) and the length of the segment should be given for each beam, starting from the aft-most beam and continuing to the fore end. A maximum of 50 lines are available in this table for input of beam elements. If the user enters less than 25 elements the code splits internally these elements into equal segments, trying to produce a model having as much elements as possible, in order to improve the accuracy.

After the above, the user must fill the table for the main dimensions of the vessel (Length L_{pp} and Breadth in meters) and the Young modulus of the hull material in kPa. The last entries are for the frequencies of the major excitation sources aboard the vessel. Fields to specify the frequencies (revolutions/cycles per minute) for the blade rate (i.e. RPM x no of blades) of the main propulsors, the running speed of the main engine, major harmonics of them and a field to specify the frequency in CPM of other excitation source (e.g. generator sets) are available.

Once all input data have been entered as described in the previous section, go to the 'Risk_of_resonance' worksheet and press the 'Click to update values' button.

3.3.4. Results

Once the calculation is completed, the calculated frequencies of the free hull girder vibrations are presented in 5th line of the worksheet 'Risk_of_resonance', corresponding to the node number of each mode. In the 2nd column of the table the exciting frequencies, already defined in the 'Main' worksheet are repeated. The rest of the table is filled with the computed values for the resonant proximity percentage, defined by :

$$((\text{Frequency of excitation}) - (\text{Frequency of free vibration})) / (\text{Frequency of free vibration}) \times 100$$

If the computed values for the risk of resonance for a specific source are obtained equal to zero this means that the corresponding vibration source was not included in the analysis.

The minimum absolute of these percentages is used to estimate the risk of resonance. If it is lower than 5% the risk is categorized as High; within 5% to 10% is categorized Medium and above 10% is considered as Low.

For avoiding high vibration levels aboard the ship, it is crucial to avoid any resonance conditions of the vibrations of the hull girder. The output of the model can be used as an estimation of this risk. Furthermore, the excitation sources that are running close to the free vibration modes can be identified.

The output may also be indicative of the necessity for more detailed vibration analysis, especially in the case of resonance on the higher vibration modes, which are more sensitive to the changes in the properties of the hull girder.

3.4. Indoor climate model

3.4.1. General description of the model

The model calculates the required power and air flow of the HVAC systems of a ship, given the requirements for the indoor climate and a description of the internal spaces of the ship.

The adopted approach for the calculation of the thermal loads follows the specifications presented in ISO 7547 [10]. The accommodation spaces of the ship are divided into groups, which are served by individual HVAC systems. For each system the user gives the required indoor temperature and humidity for winter and summer conditions, which must be in accordance to the comfort criteria, (see, for example, [13]), the required ventilation, the estimated infiltration and exhaust air flows, as well as the supplied air temperature and air flow.

Given the heat transfer coefficients for each space, the calculation of the thermal loads is then straightforward, following the simplified formulas and psychrometric calculations presented in [11] and [12]. The required power of the units is then computed and compared against the user supplied values.

3.4.2. Implementation of the model

The indoor climate model has been implemented in the Excel file S@S_WP2_indoor_climate_model_v1_00.xls and coded in Visual Basic. The file contains three worksheets:

- System Data: where the analysis parameters and the data for each HVAC system are given
- Room Data: where the specific parameters describing each accommodation space are given by the user
- System Loads: where the capacities of the HVAC systems described in worksheet 'System Data', necessary to serve the spaces described in worksheet 'Room Data' are presented, based on the calculations of the program.

The values in the last worksheet are updated each time the button 'Compute System Loads' is pressed: the appropriate macro is called, which reads the data of the analysis in the first two worksheets and writes the results in the third one.

3.4.3. Use of the model

The excel workbook 'S@S_WP2_indoor_climate_v1_00.xls' can be stored in any folder. No additional programs/ files are required.

The necessary data for the estimation of the required capacity of the HVAC systems of the vessel, following the general approaches described in [10-12], are given in the first two worksheets of the excel workbook:

Worksheet 'System data'

Worksheet 'System Data' contains the general parameters for the design of the air conditioning system and the data of each HVAC unit. The user must specify in the first table the outdoor and indoor conditions (dry bulb temperatures and relative

humidity) for the winter and summer season. Typical values, proposed in [10], are -10 and 35 °C for winter and summer, and 70% summer relative humidity.

The values for the sensible and latent people heat emission should be given next. Typical values are 70 and 50 Watts correspondingly (people in seating condition).

The user must fill then, in the table for the HVAC systems, the values for the indoor temperature and humidity, supplied air temperature, infiltration, ventilation and exhaust air flow. If a large value is specified for the exhaust air flow, the infiltration is internally adjusted by the program during the calculations, in order to balance the difference between ventilation and exhaust air flows.

There is a choice for the user to specify, if winter humidification will take place or not.

After the values of the summer air flows, the user should give the increase in the supplied air temperature due to the duct work.

In the last column of the table the user should specify the available air flow of each HVAC system.

Worksheet 'Room Data'

In this worksheet the user must give the parameters for the description of each individual room / accommodation space of the ship, served by the systems entered in the worksheet 'System Data'.

Each room/space must be described in a separate line. In the 2nd column a name describing the space must be given.

Next to the above, the number indicating the system which serves the space must be entered. This is the number of the system presented in the first column of the worksheet 'System Data'. It is evident that the system number must correspond to a system already described in that worksheet, otherwise the program stops with a message.

The volume of the space (in m³) and the number of persons are given next.

Following to the above, the sensible and the latent gain due to any source inside the room, other than the loads due to the people, (for example due to the lighting apparatuses) must be given in Watts. It should be emphasized that the thermal loads caused by the people heat emission must not be included in the above loads. These are calculated on the basis of the number of the people and the corresponding coefficients given in the worksheet 'System Data'.

After the above, a group of parameters is repeated for the six surfaces of each room, which is considered as a volume with six surfaces. Following the procedure described in ISO 7547 [10], values for the following parameters must be given for each surface, where applicable:

Av is the surface area, in square meters, excluding any side scuttles and rectangular windows.

- K_v is the total heat transfer coefficient (in $W/m^2 \text{ } ^\circ K$) for the surface A_v . Typical values of this parameter and the general procedure for calculation for the case of specific combination of various insulating materials are given in [10].
- A_g is the area of side scuttles and rectangular windows.
- K_g the total heat transfer coefficient for the above area.
- DT_w Winter temperature difference. If the surface considered is exposed to the outdoor air, this is simply the difference between the indoor temperature and the outdoor one. For temperature differences between air conditioned and non air conditioned spaces, see [10].
- DT_s Summer temperature difference (outdoor minus indoor).
- DT_2 is the excess temperature (above the outside temperature) caused by solar radiation on the exposed surfaces. Specific values are presented in [10], depending on the orientation of the surface and its colour.
- G_s is the heat gain per square meter for glass surfaces exposed to solar radiation.

The aforementioned set of parameters must be repeated for each of the surface of the space.

3.4.4. Results

The output of the calculations are presented in worksheet 'System Loads'. For each HVAC system the calculated sensible, latent and total loads are presented. The contribution of each space to the above values are also given, together with the values for infiltration, ventilation and winter humidification.

Based on the above values and the indoor temperatures specified in worksheet 'System Data', the required air flow for each system is presented, calculated as the maximum of winter and summer values. This value is compared against the value for the air flow given in worksheet 'System data' for each HVAC system in the last column of the 'System Loads' worksheet. If the value is lower than unit, the specified capacity of the HVAC system is considered adequate. It is evident that the power of each system must also be compared against the results presented in this worksheet.

The calculation of the adopted air changes per hour for each system are also presented, as a measure of the achieved ventilation of the spaces.

3.5. Noise model

3.5.1. General description of the model

The theoretical approach followed for the prediction of the noise levels aboard the ship has been originally developed by SNAME, as presented in detail in ref. [14]. A simplified version of this approach was developed in NTUA [15], which forms the basis of the noise prediction model developed in the framework of the S@S project.

In general, the noise prediction requires the determination of the acoustic and vibrational characteristics of three elements: the noise source, the transmission path and the receiver.

Figure 3.1 presents the basic steps in the noise prediction procedure. There are two basic interacting paths inherent to the noise transmission aboard the ship: the airborne and the structureborne one. Following the airborne path, noise is transmitted to the receiver via the air and the common boundaries of adjusted spaces. Usually airborne path is a significant factor only within noise source spaces or spaces adjacent to them.

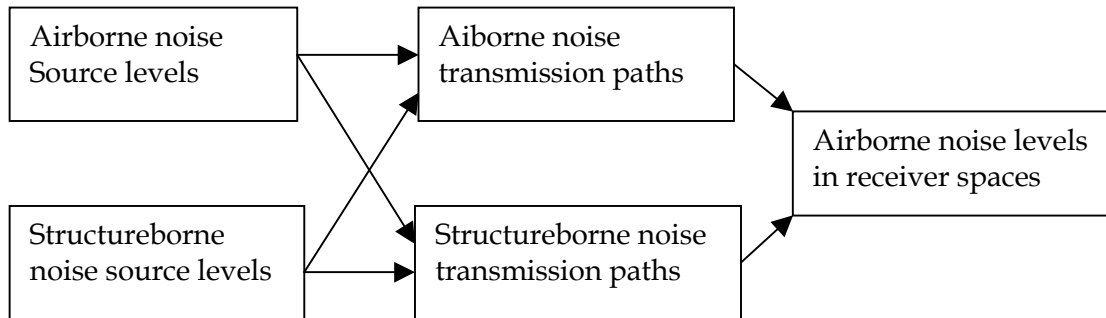


Figure 3.1 : Noise prediction steps [14]

On the other hand, structureborne paths usually carry noise away from the source, as well as to the spaces adjacent to the source areas.

Practical procedures for the control and minimization of the noise levels aboard ships can be found in literature (e.g. [14, 16])

The noise prediction procedure follows the basic path-receiver approach. The basic steps of the procedure are as follows:

- Calculation of the sound power for each noise source and the corresponding source free vibration levels
- Calculation of the airborne and structureborne transmission losses
- Calculation of the sound pressure levels in each receiver space, taking into account the airborne and structureborne transmissions, the contribution of any noise sources inside each space and the acoustic properties of the surfaces.
- Comparisons of the obtained values against the criteria.

The first step in the procedure is the determination of the sound power and free vibration levels for the various shipboard equipment, using an estimating technique based on empirical values. The amount of airborne and structureborne noise that will be transmitted is depended mainly on the acoustic and vibratory power generated by the source. A measure of the acoustic power of the source is given by the sound power level L_w , in decibels, referenced to a power of 10^{-12} Watts. Empirical formulae, presented in [14], for the determination of L_w for each type of the shipboard equipment are used by the model, in order to obtain the sound power level analysed in the standard octave bands.

The structureborne noise source level of each source is measured by the 'free' vibration acceleration level, which is given in dB referenced to 10^{-3} cm/s². After the calculation of the above levels the model computes the acoustic absorption properties of each room, calculate the transmission losses for the airborne and structureborne paths and combine the individual results, as presented in Figure 3.1, in order to obtain the total noise level in the receiver space.

3.5.2. Implementation of the model

The indoor climate model has been implemented in the Excel file S@S_WP2_noise_model_v1_00.xls and coded in Visual Basic. The Excel file contains the VB functions for the implementation of the predictive algorithm and the following eighteen worksheets:

- Room Data : Where the main dimensions of the rooms/spaces of the ship, which enter in the noise prediction analysis, either because they have noise sources or because they are acoustic receiver spaces, are given. The corresponding noise limits are also given here.
- Room Param. : In this worksheet the acoustic parameters for each space are given (i.e. surface noise absorption coefficients and correction factors)
- Noise Sources : where the specific parameters of each noise source are defined.
- Prop. Data : In this worksheet the specific parameters of the propellers relevant to the noise estimation are given.
- Sabine Values : It stores a data base for the sabine absorption coefficients for various materials, commonly used in shipbuilding. The user may alter the values, add elements to the list, based on his experience, or use the values as they are given.
- Source Adjustments : Where a data base for the noise source adjustments of various types of shipboard equipment is given, together with the corresponding values for the acceleration levels and the transmission losses due to the source mounting systems
- Transm. Losses : It is another database storing typical values for the transmission losses of typical panels used in the shipbuilding.
- BHD_TL : The transmission losses in the structural accelerations due to the deck to bulkhead intersections are given.
- Typical Panels : The main dimensions of typical panels of each room/space are given here.
- Room const. : It is an output worksheet. The calculated values for the room acoustic constants of each space are presented.
- Source Levels : The noise and acceleration levels coming from each noise source are given here, as computed by the model.
- Str_borne levels : The computed structureborne acceleration levels for each space are presented here
- Prop. Noise : In this worksheet the noise transmitted from the propeller to each space is given.
- Source Rooms : Where the computed noise levels in the spaces containing noise sources are presented
- Airborne Paths: The user enters here the description for the airborne noise transmission paths.
- Airborne Noise : The calculated values for the airborne noise transmitted to each space are calculated here.
- Str_borne Noise : The noise levels due to the structureborne noise transmitted to each space are calculated in this worksheet.
- Total Levels : The results for the total noise levels at each compartment are given in this worksheet.

3.5.3. Use of the model

The excel workbook 'S@S_WP2_Noise_model_v1_00.xls' is self-contained and can be stored in any folder. No additional programs/ files are required.

The user have to enter the input data of the analysis in worksheets 'Room Data' through 'Typical Panels' and 'Airborne Paths' as described below.

Worksheet 'Room Data'

Input of the main dimensions of each room/space considered in the analysis. The spaces under consideration are these with noise sources, the receiver spaces and the rooms in contact with the noise sources and affecting the noise transmission. The user should enter values in the cyan part of the worksheet. In the first column the name of the compartment should be specified. The main dimensions and the position of the centre of the space are given in the following seven columns. The longitudinal position is measured in meters from the aft perpendicular. The vertical position is measured from the base line, while the transverse position is measured from the centre line. In the next column the deck no for each room, measured from the lower deck should be given. Next to this, there is a column for the input of the sound pressure limits. According to the space considered, these may be obtained from [13], or using the specific tool (noise_criteria.exe) developed in the framework of the S@S project.

There is also a button used to start the execution of model, after the user has completed the input of the remaining parameters, described in the following paragraphs.

In the last column of this worksheet, the A-weighted sound pressure levels (dbA) as calculated by the program are given. The comparison of the predictions against criteria is then easy.

Worksheet 'Room Param.'

In this worksheet the user gives the parameters for the noise adsorption of each surface of the space. As described above, the spaces are considered as hexahedra. The areas of each boundary surface are obtained using the lengths entered in worksheet 'Room Data'. In addition to them, acoustic absorption occurs also in non boundary surfaces inside each room. These surfaces are categorised either as soft or hard [14]. The ratio of each boundary surface (soft or hard) to the total surface of the compartment should be entered in the columns labelled Cfs (for soft) and Cfh (for hard non boundary surfaces).

In the remaining columns the user should give the type of the sabine coefficient of each surface, which should be taken from the worksheet 'Sabine Values'. This is a data base, storing common types of acoustic insulation and the corresponding parameters. The values already entered in this worksheet have been taken from [14]. However, the user can alter them, or add to them new types, according to his experience.

Worksheet 'Noise Sources'

In the 'Noise Sources' worksheet the parameters of the equipment contributing to the noise levels are given.

In the first column the number of the source should be given in ascending order.

The name of each source is entered in the next column.

In the third column the user can select the room containing the source, from those defined in worksheet 'Room Data'.

In the fourth column the user should specify the characteristic group of each noise source: the various types of the equipment aboard the ship are categorised into three main groups. According to each group, the user should give the specific parameters of each noise source, in the columns numbered 1 to 14 in the 'Noise Source Parameters' sub table. The specific inputs, according to the group number are described below:

Group 1- Diesel engines

For diesel engines the input presented in the following Table 3.1 is required.

Table 3.1 : Parameters for noise source Group 1 : Diesel Engines	
Parameter	Description
1	Engine power (HP)
2	Nominal RPM
3	Type of the octave band adjustment appropriate for the engine, taken from the database of worksheet 'Source Adjustments'. Applicable types 1-6
4	Type of the adjustment for the engine unmuffled exhaust noise source level. Worksheet 'Source Adjustments'. Applicable types 7 or 8
5	Type of source adjustment for the diesel engine casing airborne noise. Worksheet 'Source Adjustments'. Applicable types 9 to 14
6	Type of source adjustment for the transmission loss due to air intake pipes. Worksheet 'Source Adjustments'. Applicable types 74 to 94
7	Type of source adjustment for the transmission loss due to the exhaust pipes. Worksheet 'Source Adjustments'. Applicable types 74 to 94
8	Length to diameter ratio for circular air intake pipes or external surface to cross section for rectangular air intake pipes
9	Length to diameter ratio for the exhaust pipes or external surface to cross section for rectangular exhaust pipes
10	Engine weight in lb
11	Max RPM
12	Type of Structureborne noise level adjustment, from Worksheet 'Source Adjustments'. Applicable type 60
13	Type of transfer function for mounting attachment, from Worksheet 'Source Adjustments'. Applicable types 95 to 114
14	Type of transmission loss due to foundation, from Worksheet 'Source Adjustments'. Applicable types 115, 116

Group 2 - Gas Turbines

For Group 2, Gas Turbines the user must give the following parameters shown in Table 3.2.

Table 3.2 : Parameters for noise source Group 2 : Gas Turbines	
Parameter	Description
1	Engine power (HP)
2	Compressor RPM
3	Compressor blade number
4	Type of source adjustment for the transmission loss due to intake pipes. Worksheet 'Source Adjustments'. Applicable types 74 to 94
5	Type of source adjustment for the transmission loss due to the exhaust pipes. Worksheet 'Source Adjustments'. Applicable types 74 to 94
6	Length to diameter ratio for circular air intake pipes or external surface to cross section for rectangular intake pipes
7	Length to diameter ratio for the exhaust pipes or external surface to cross section for rectangular exhaust pipes
8	Type of Structureborne noise level adjustment, from Worksheet 'Source Adjustments'. Applicable types 61 to 63
9	Type of transfer function for mounting attachment, from Worksheet 'Source Adjustments'. Applicable types 95 to 114
10	Type of transmission loss due to foundation, from Worksheet 'Source Adjustments'. Applicable types 115, 116
11	Type of airborne noise source levels for casing, from Worksheet 'Source Adjustments'. Applicable types 25,26,28 and 31
12	Type of airborne noise source levels for intake, from Worksheet 'Source Adjustments'. Applicable types 23 and 29
13	Type of airborne noise source levels for exhaust, from Worksheet 'Source Adjustments'. Applicable types 24,27 and 30

Group 3 - Other equipment

Equipment not belonging to the groups 1 and 2 above, is grouped into the following categories:

Category	Description
1	Gears
2	Generator sets, steam driven
3	Non reciprocating pumps
4	Reciprocating pumps
5	Generators
6	Electric motors
7	Ventilation fans
8	HVAC units
9	Air compressors

For group 3 the following input shown in Table 3.3 should be given by the user.

Table 3.3 : Parameters for noise source Group 3 : Other equipment	
Parameter	Description
1	Category number (1 to 9)
2	Type of airborne noise source levels, from Worksheet 'Source Adjustments'. Applicable types 32 to 59
3	Type of structureborne noise source levels, from Worksheet 'Source Adjustments'. Applicable types 64 to 73
4	Type of transfer function for mounting attachment, from Worksheet 'Source Adjustments'. Applicable types 95 to 114
5	Type of transmission loss due to foundation, from Worksheet 'Source Adjustments'. Applicable types 115, 116
6	Power (HP), applicable for categories 1,3,6,and 9. For other categories put zero.
7	Nominal RPM, applicable for categories 1,3,5,and 6. For other categories put zero.
8	Power in kW, applicable for categories 2 and 5. For other categories put zero.
9	Air flow (CFM), applicable for categories 7 and 8. For other categories put zero.
10	Pump pressure height (psi), applicable for category 4. For other categories put zero.
11	Static pressure of fun unit (inches of water), applicable for category 7. For other categories put zero.

Source dimensions

In column 15 of the 'noise source parameters' sub table the longitudinal position of the centre of the source, measured from Aft perpendicular should be given in meters.

In columns 16 and 17 the length and width of the source are entered. In column 18 the deck number is entered.

Worksheet 'Prop. Data'

If the vessel is equipped with propeller(s), the user should give in worksheet 'Prop. Data' the values for the longitudinal position of the propeller disk, measured in meters from the aft perpendicular, the Lpp length of the vessel, the cruising speed of the vessel in knots, the diameter of the propeller and the cavitation ratio. If the vessel is not equipped with propellers, put zero in the column for diameter.

Worksheet 'Sabine Values'

Worksheet 'Sabine Values' contains predefined values for the sabine absorption coefficients of room surfaces constructed by various materials. The values were obtained from [14]. The user may use these values (in worksheet 'Room parameters') , may alter them, or even add new types according to available data.

Worksheet 'Source Adjustments'

Worksheet 'Source Adjustments' stores predefined values for the noise source levels and source adjustments for various types of the equipment. These values were taken from [14]. They are used in the definition of the source parameters in the worksheet 'Source Param.', as described in worksheet 'Noise sources' previously.

Worksheet 'Transm. Losses'

In this worksheet the typical values for the transmission losses for the airborne noise transmission are presented. The user may use the values as they are, for the definition of the airborne paths in worksheet 'Airborne Paths', or may add new lines in this data base.

Worksheet 'BHD_TL'

The user defines in this worksheet the parameters of the bulkheads and their intersections with the decks, which play significant role in the absorption of the structural vibrations. In the first column the deck number, intersecting the bulkhead is given. In the second column the position of the BHD measured in meters from the AP should be given. In the third column the transmission loss (in dB) of the vibration acceleration level due to the BHD-Deck intersection should be given. This loss depends on the specific dimensions of the intersecting structures. Typical values may be found in [14].

Worksheet 'Typical Panels'

The dimensions of the typical structural panels (length, width and thickness) of the each boundary surface of the rooms should be entered by the user in this worksheet. These values are used for the computation of the noise levels due to the structural vibrations of the boundary surfaces.

Worksheet 'Airborne Paths'

The airborne paths for the transmission of the noise are defined here. The user selects the room in the 'from' column and the room in the 'to' labelled column. Next to them are the columns for the types of the transmission losses (TL) and their increments (DTL) which correspond to the type definition given in the data base of the worksheet 'Transm. Losses'.

After entering the input data, the model program will be executed by clicking on the red button in the worksheet 'Room Data'.

The duration of a calculation is approximately 15 seconds on a Pentium 4 computer.

The program reads the data entered in the aforementioned worksheets, performs the calculations, stores intermediate results in the worksheets presented in the following chapter, computes the A-weighted sound pressure level for each room and writes it in the specific column of the worksheet 'Room Data'.

3.5.4. Results

The main output of the calculations are the sound pressure levels presented in the last column of the worksheet 'Room Data'. These values should be compared against the limiting values, entered by the user in the previous column.

Intermediate results of the calculations are stored in the following worksheets:

- Worksheet 'Room const.': the calculated room acoustic constants for each octave.
- Worksheet 'Source Levels': the computed sound power levels L_w and the structureborne acceleration levels L_a for each source are presented in the tables of this worksheet.
- Worksheet 'Str_borne Levels': The computed values for the structural acceleration L_a levels are given for each room.
- Worksheet 'Prop. Noise': the sound pressure levels due to the ship propeller are given.
- Worksheet 'Source Rooms': the predicted sound pressure levels of the airborne noise for the room with noise sources inside are presented here.
- Worksheet 'Airborne Noise': the sound pressure level due to the airborne transmission are given here.
- Worksheet 'Str_borne Noise': the sound pressure levels due to the structureborne noise are presented for each room.
- Worksheet 'Total Levels': the sound pressure levels due to both the airborne and structureborne noise are given here, for each octave and for each room. The A-weighted levels are also presented.

4. CONCLUSIONS

The present report contains the work carried out in Sub-task 2.3.1. It consists of the implementation of calculation models for motion sickness (MSI), safety of footing (MII), hull girder vibration, indoor climate and noise.

The principle, input data and use of programs calculating the characteristics associated with all the five above-mentioned models are presented. Each model has been implemented in separate Excel workbook using macros coded with Visual Basic. Models for MSI, MII and hull girder vibration contain also external executable files performing the more tedious calculations.

There are two program versions for the MSI and MII models. The long-term version calculates the values of MSI (Motion Sickness Incidence) and MII (Motion Induced Interruptions in minute) representing the overall comfort characteristics during one year period in the area of operation. These values are compared with the criteria given in deliverable D2.2.1. The short-term version can be used when investigating the effects of changes of environmental and operational conditions on comfort. The ship motion formulae needed in MSI and MII models are obtained from simplified seakeeping calculation method developed in Sub-task 2.2.2 of WP2.

The hull girder vibration model predicts the lower modes of free vibration in vertical or horizontal bending. The obtained values are compared with the frequencies of the major excitation sources aboard the ship or encounter wave frequencies.

The indoor climate model calculates the required power and air flow of the HVAC systems of a ship using the given requirements for the indoor climate and description of the internal spaces of the ship as input.

The noise prediction model determines the acoustic and vibrational characteristics of the noise source, transmission path and receiver spaces. The sound pressure levels in receiver spaces are compared with criteria.

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