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Appendix A MODUSIM
MODU Movement Simulation Program

User Manual

MODUSIM
MODU Movement Simulation Program

A1. Introduction

A1.1 Introduction

MODUSIM is a computer simulation program developed for simulating the MODU's movement in hurricanes. It is based on simplified load, capacity and movement calculation procedures developed for the joint industry - Government sponsored research project called "***Securing Procedures for Mobile Drilling Units in the Gulf of Mexico Subject to Hurricanes***".

This research has been performed at the University of California at Berkeley, Department of Naval Architecture and Offshore Engineering by Research Assistant Jun Ying under supervision of Professor Robert Bea. The theoretical background of MODUSIM is documented in previous chapters of this report.

A1.2 Application Range of MODUSIM

MODUSIM can be applied to typical semi-submersible drilling units with generic geometry's and some special types of Jack-up platforms. The loading and mooring capacity has been calibrated to platforms located in 0 - 300 ft water depth. At this stage, MODUSIM is expected to give some reasonable results. For information on other limitations of the program, please refer to next sections of this appendix.

A1.3 Program Structure

The program is developed using Microsoft Excel Software. The following Excel files are bounded together under the workbook named MODU.xlw:

- Welcom1.xls
- MODUSIM.xlm
- modu.xls
- Stokev.xls
- Dbase.xls
- Coll.xlm
- Result.xls
- Route.xlc
- Histogram.xlc

A1.4 Installation

A1.4.1 Backup Disk

Before any installation begins, it is always a good practice to backup the program diskette in the back of the report. We assume you are already familiar with DOS commands or Windows operation. For example, in DOS you will need the DISKCOPY command to make backup copies of your program disk.

A1.4.2 System Requirements

To run MODUSIM 2.0, you must have a 486 or higher based PC with 8MB RAM at least, MS DOS 5.0, Windows 3.0, EXCEL 4.0 and @RISK 3.0.

A1.4.3 Installation

To install MODUSIM 2.0, first copy all the files in the attached disk to your hard drive under the directory "c:\MODUSIM". Then you can open the file 'MODU.XLW' directly from EXCEL4.0 & @Risk3.0. Or you can specify the program group name, item name, and the path of MODUSIM to windows. Type WIN to execute Windows, select New from File menu in program Manager to add the program group. The following window will appear, select Program Group and then OK.

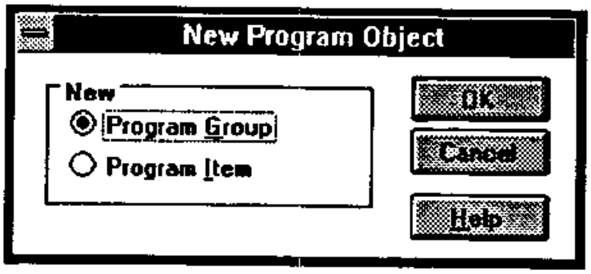


Figure A1.1: Select 'Program Group' for the MODUSIM program.

Next the following window will appear. Fill in the Description and Group File as indicated. Then select OK.

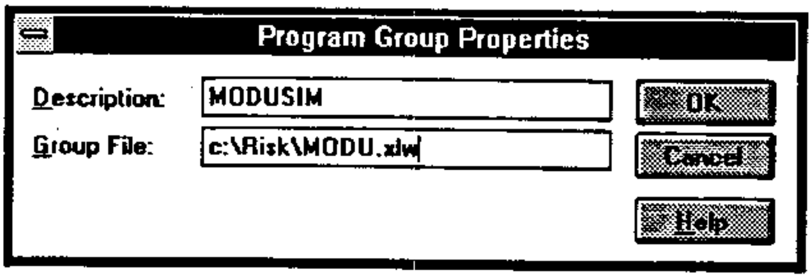


Figure A1.2: Specify the group name and the filename and path.

Notice that a new program group MODUSIM has been created in your Microsoft Windows. Now you can double click the icon to start MODUSIM.

A2. Input Data

A2.1 Introduction

After double clicking the **MODUSIM** icon, the main window will pop up like the following Figure 2.1. The menu bar can be changed to general Excel 4.0 menu bar by "Ctrl+M" and back to MODUSIM by "Ctrl+A". Those users who are not familiar with windows operation are recommended to following the step-by-step directions in this chapter. Here, for example, let's say we have a MODU named "Zane Barnes".

Figure A2.1 MODUSIM is popped up.

There are principally two ways of data input in the program:

a) by stepping through the input menu and defining the necessary parameters or

b) by opening an input file that has been originally created by stepping through the input menu and subsequently saved.

There are three commands under the **File** menu. **Open Input File** command allows to open the saved simulation input and result file. **Save Input As** command allows to save the current simulation setting and simulation result.

SIMULATION RESULT

MODU NAME:		ZANE BARNES			
LOCATION:		MOORING CAPACITY		FAILURE MODE	
X	Y	MEAN	STD.	NOM	NOB
50	28.1	3500	1000	8	6
Probability of collision:			0.0114		
Target 1	Target 2	Target 3	Target 4	Target 5	Mooring
0.0048	0.0006	0.0048	0.0006	0	0.09

Figure A2.2 Saved Simulation Result

Click **Exit** to quit the application.

Warning: All the current simulation setting and results will be lost if you leave the program. Save the simulation setting and results if necessary.

The data that needs to be defined by the user is subdivided into five principle categories:

- General MODU Information
- Mooring System Information
- Simulation Setting Data
- Execute the Program
- General Jackup Information

A2.2 General MODU Information

There are five commands under **Input** Menu to input the required information.

MODUINF command allows to input the MODU's general information. The dialogue box 'MODU INFORMATION' will pop up when **MODUINF** command is selected.

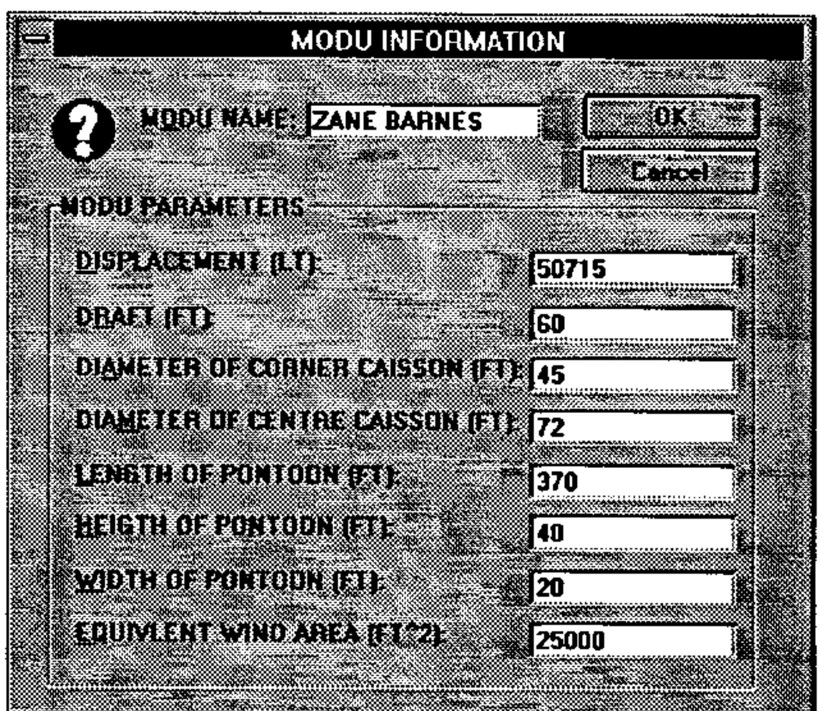


Figure A2.3 Input MODU General Information

To input the information, you can click on the certain box with mouse or type 'ALT' + 'Underline letter'. For example, to input **DISPLACEMENT**, type **ALT+D** When you finished, click **OK**, or you can click **Cancel** to cancel the dialogue.

MODULOC command allows to input coordinates of MODU's initial location. When **MODULOC** command is selected, the dialogue box 'MODU LOCATION' will pop up.

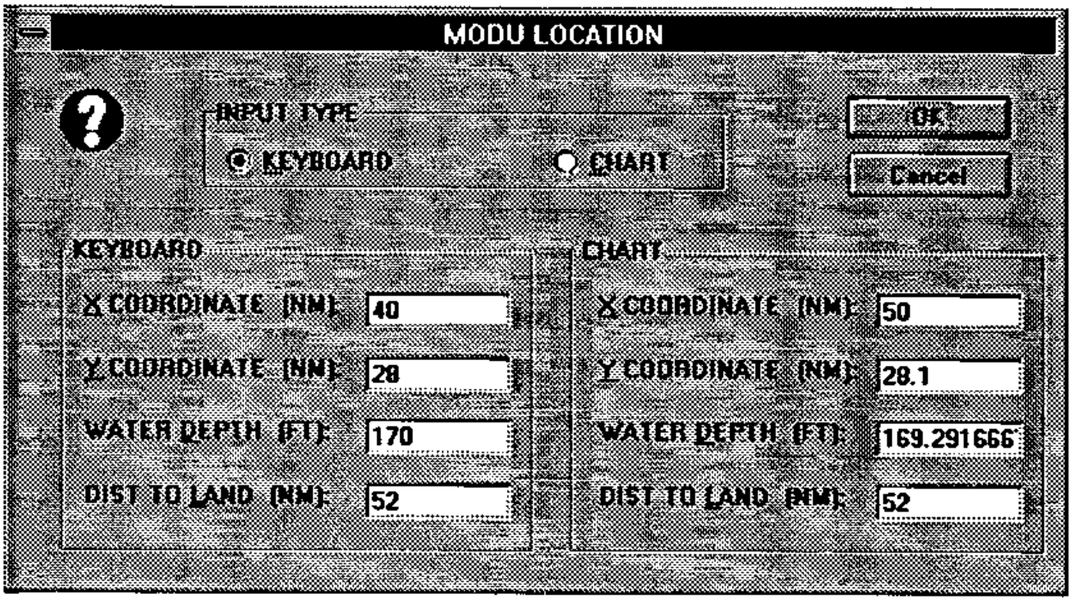


Figure A2.4 Input MODU Initial Location

In the group of **Input Type**, if **Keyboard** is selected, the information will be input from keyboard to the box in the group of **keyboard**. The input information includes X, Y coordinates, water depth of MODU location and the distance from X-axis to coast. If **Chart** is selected, next command **LOCHART** need to be selected to input information from chart. It is recommended that **Keyboard** function is used to input the initial location and **Chart** function is used to change the location of MODU.

If **Chart** was selected in the **MODULOC** command, **LOCHART** command need to be selected, and the chart 'MODU Moving Route' will pop up. To change the location of the MODU, click on the MODU while hold down **CTRL**, then drag MODU to wherever you want it to be sited.

LARGE FACILITY INFO command allows to set up the simulation for probability of collision within target circles. 'LARGE FACILITY INFORMATION' dialogue box will pop up when it is selected.

- **Number of Platforms**: Structure number within the target circle.
- **Radius of Circle**: Radius of target circle
- **Radius of safe Distance**: The safety distance between the MODU and structures.

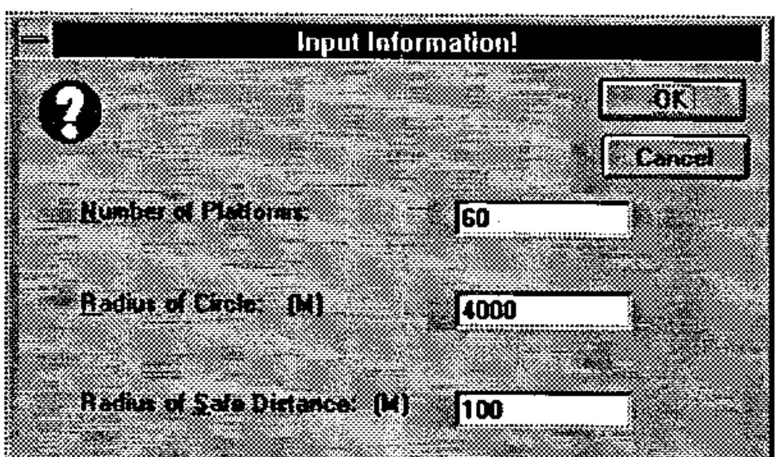


Figure A2.5 Input Target Circle Information

Note here, the location of target circles is determined by the user from file [MODU.xlw]modu.xls. You can choose as many as 5 target circles.

CALCU PROB command allows to begin the simulation of collision within the target circle. When the simulation is completed, a dialogue box will pop up the calculation result. A pre-calculated curve about the probability of collision within the target circle with R=0.6 to 4.8 NM is presented in Figure 4.3. For a target circle with given radius and number of structures, the probability of collision can be found from the curve.

A2.3 Mooring Capacity Information

Mooring Command under **Input** menu allows to input mooring system information. The dialogue box 'Mooring System' will pop up when **Mooring** command is selected.

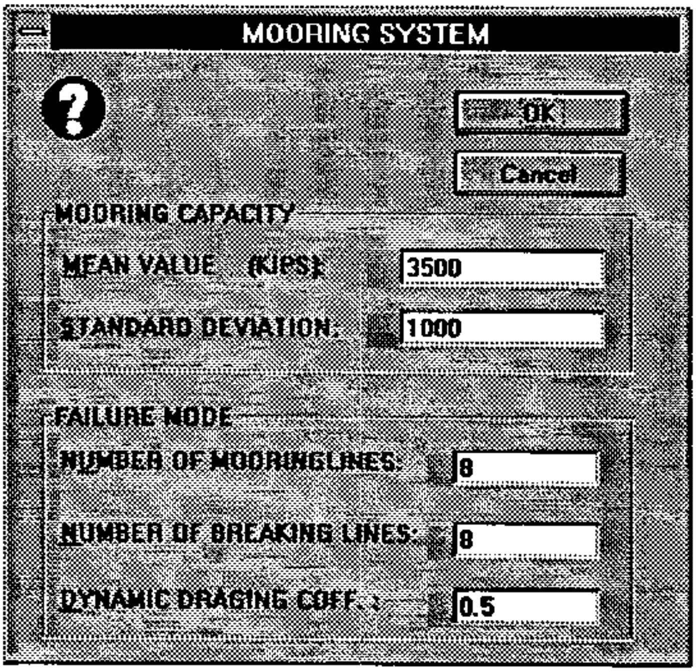


Figure A2.6 Input Mooring System Information

In the group of **MOORING CAPACITY**, input the mean value and standard deviation of mooring strength; in the group of **FAILURE MODE**, input the total number of mooring lines, number of broken lines while failure and the dynamic dragging coefficient of anchor while they are dragging in the bottom of the sea.

A2.3 Simulation Setting Data

There are five commands under the **Simuset** menu to define the required data:

SIMUTYPE command allows to set up the simulation. The dialogue box 'SIMULATION TYPE' will pop up when **SIMUTYPE** is selected.

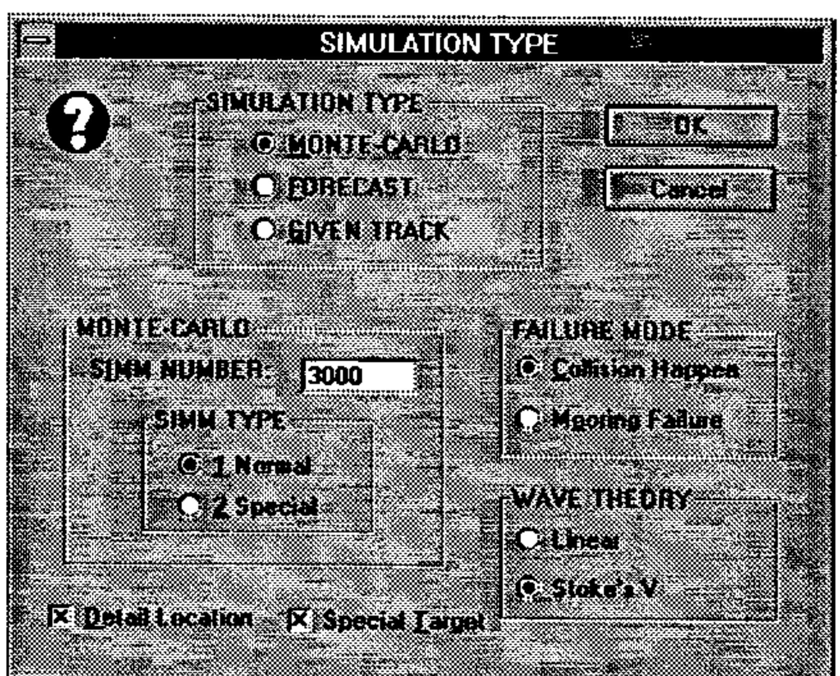


Figure A2.7 Set Up the Simulation

Following are the selected combinations to get the specific MODUSIM functions mentioned in Chapter 4.

Function A:	**Monte-Carlo+Normal;**
Function B:	**Forecast+Normal;**
Function C:	**Given Track;**
Function D:	**Monte-Carlo+Normal.**

Click **Collision Happen** to define failure mode as collision happens. Click **Mooring Failure** to define failure mode as mooring lines break. Select wave theory as **Linear** or **Stoke's** 5th theory. Check **Detail Location** to include the MODU information within target circles. Check **Special Target** to calculate the probability of collision within a given target.

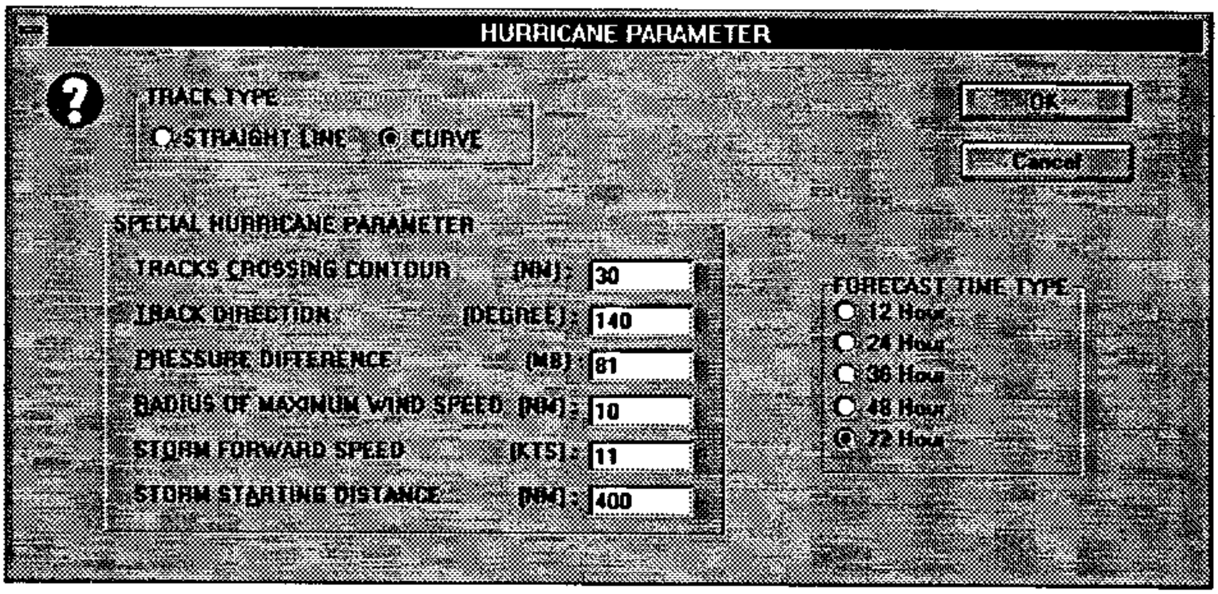


Figure A2.8 Input Hurricane Parameters

If **Forecast** is selected, the given hurricane parameters should be input in the following 'Hurricane Parameter' dialogue box. Check **Straight Line** or **Curve** to determine the type of hurricane tracks in the simulation. Select forecast time type for Function B.

If **Forecast** is selected, the following 'Env. Data Simulation Setting' dialogue box will pop up after the 'Hurricane Parameter' dialogue box. Select **Env.Forecast** to perform environmental condition forecast.

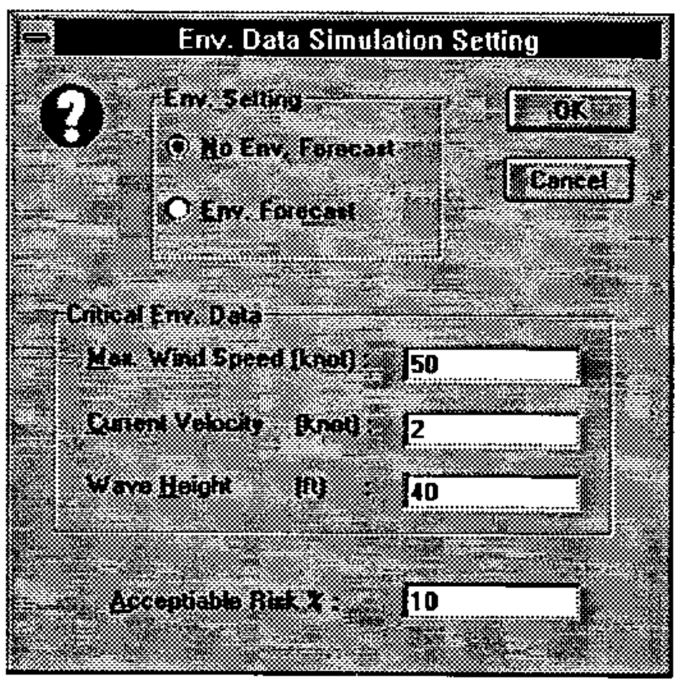


Figure A2.9 Environmental Simulation Settings

If **Given Track** is selected, the 'Given Hurricane Track' dialogue box will pop up after the 'Simulation Type' dialogue box. Input the general hurricane information in the group of **Hurricane Parameter.** There are at most eight points that can be input to describe the hurricane track. **DT** is the time step between the adjacent points.

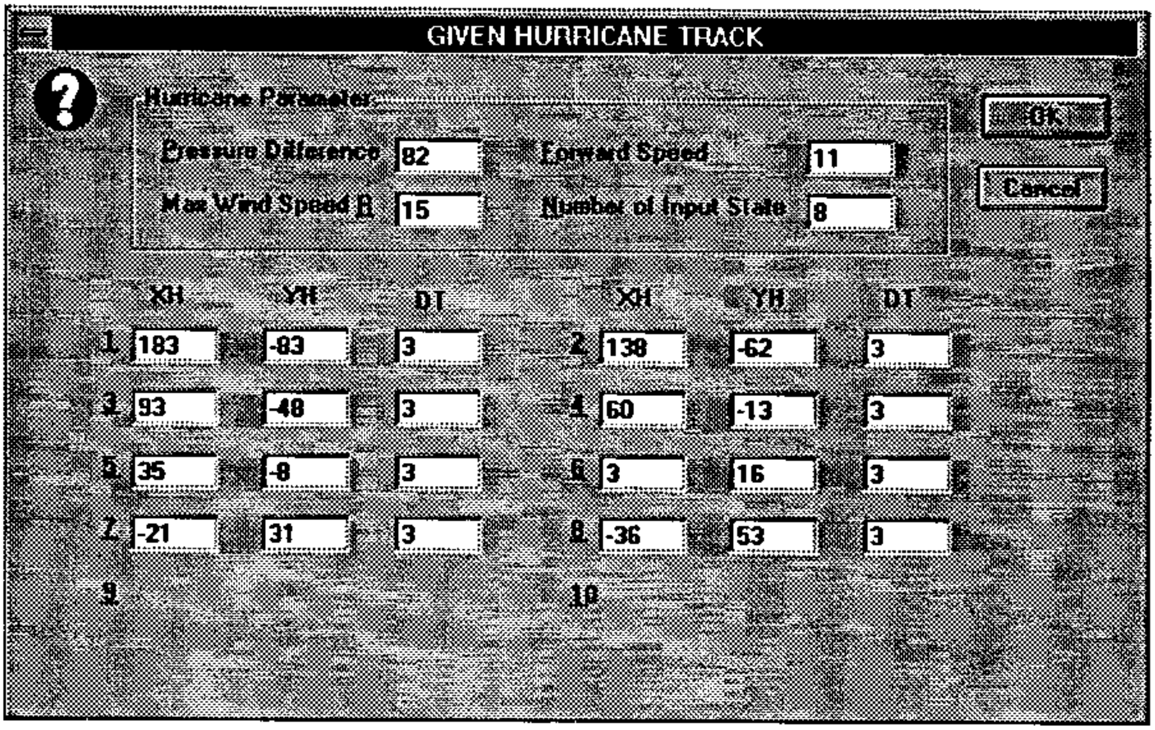


Figure A2.10 Given Hurricane Track Information

SIMUPARA command allows to input calculation coefficients. The dialogue box 'SIMULATION PARAMETERS' will pop up when it is selected. Input the wind, wave and current force coefficients in **FORCE PARAMETERS**, Select the type of current velocity distribution in **CURRENT TYPE,** Select the time step between the re-calculation of environmental forces in **TIME STEP.**

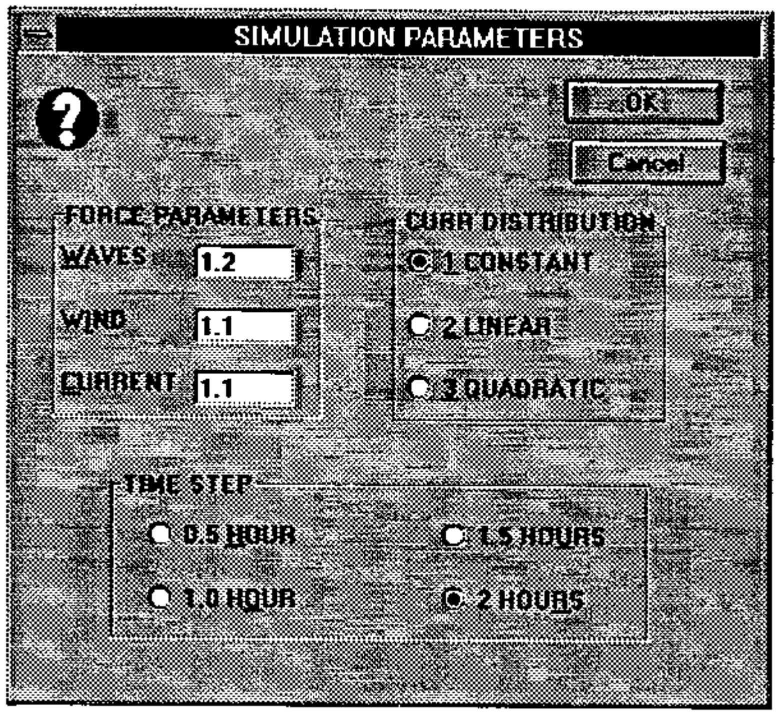


Figure A2.11 Input Calculation Coefficients

RAND PARA command allows to input probability distributions of random parameters. The dialogue box 'RANDOM PARAMETER' will pop up when **RAND PARA** command is selected.

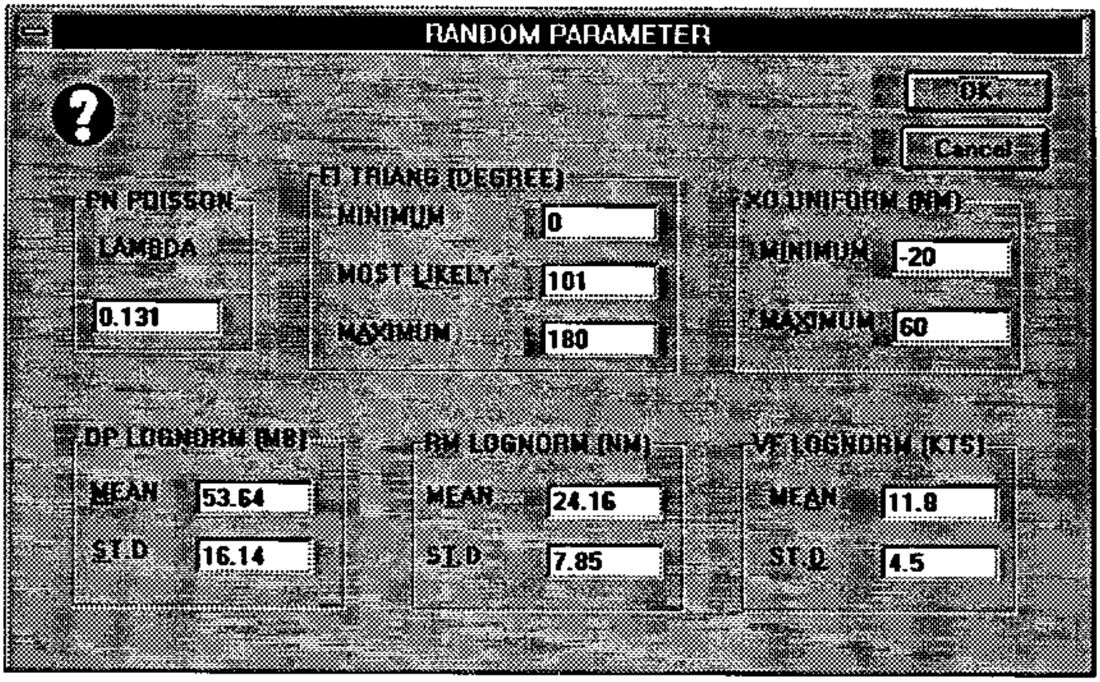


Figure A2.12 Input Random Parameter Information

Note here, Lamta is the hurricane occurrence rate at a point in the selected reference per year per nautical mile.

PARA CORRELATE command allows to input correlation among random parameters. The dialogue box 'PARAMETER CORRELATION' will pop up when it is selected.

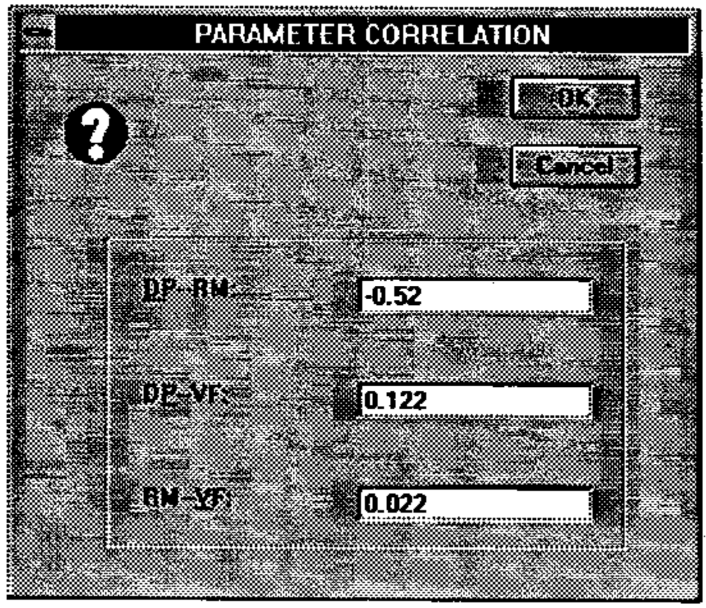


Figure A2.13 Input Correlation Coefficients among Random Parameters

Markov Modeling command allows to input the definition of states in Markov chain model and the transition probability matrix.

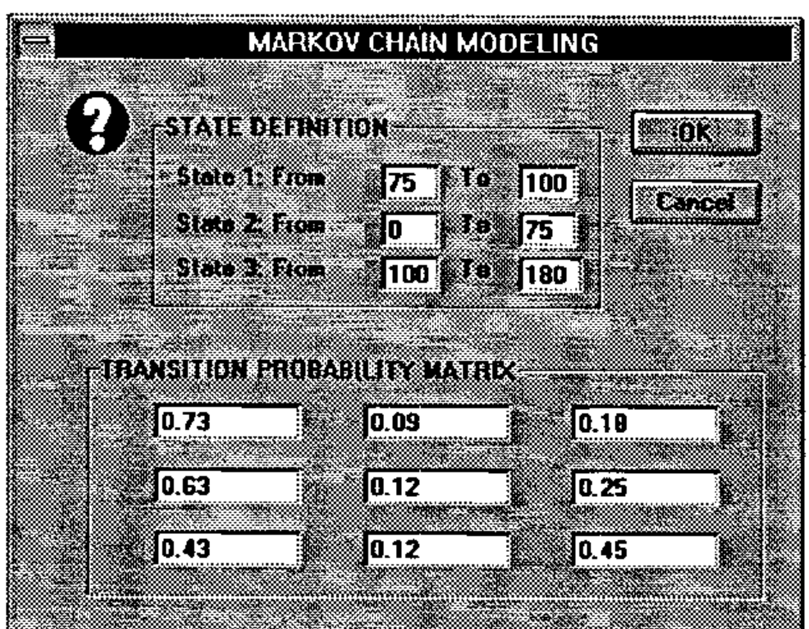


Figure A2.14 Input Markov Model Setting

A2.4 Execute the Program

There three commands under **RUN** menu:

RESET command allows to reset the program before each simulation.

RUN command is clicked to begin the simulation. Before click **RUN**, you should set up @RISK simulation parameters. The recommended @RISK simulation settings is as in Figure 2.12. After the simulation is completed, a dialogue box will pop up.

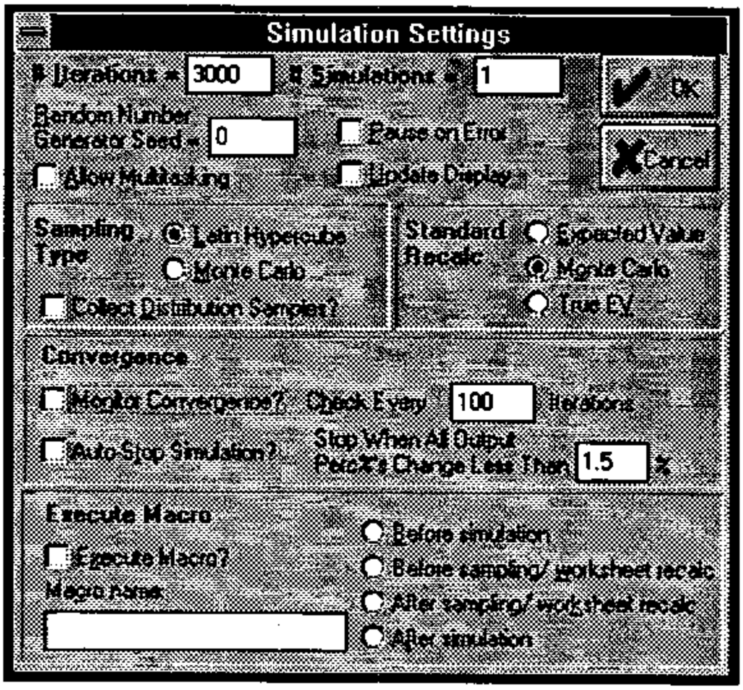


Figure 2.15 @Risk Simulation Setting

Strategy command allows to do strategy simulation to determine the best place to site the MODU within the acceptable area.

A2.5 General Jackup Information

The MODUSIM has been updated to simulate the movement of bottom founded MODUs.

There are three command under the **Jackup** menu.

Jackup Type command allows to determine the MODU type, foundation type and failure mode.

Jackup Info allows to input the general information of the jack-up.

Capacity allows to input the foundation capacity and leg capacity.

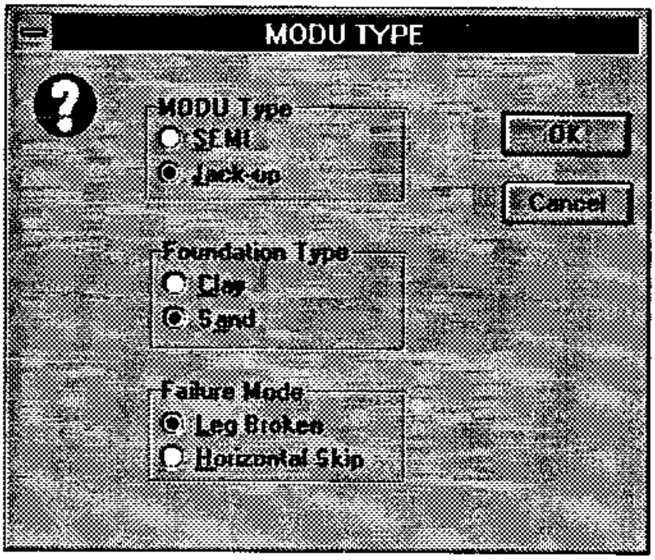


Figure A2.16 Jackup Type Input Information

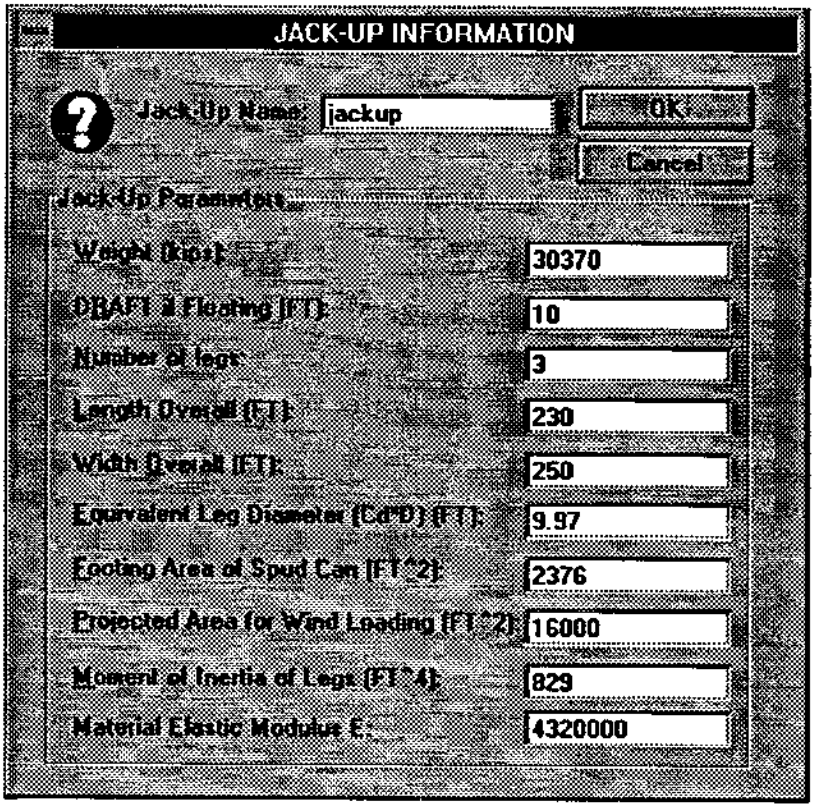


Figure A2.17 General Jackup Input Information

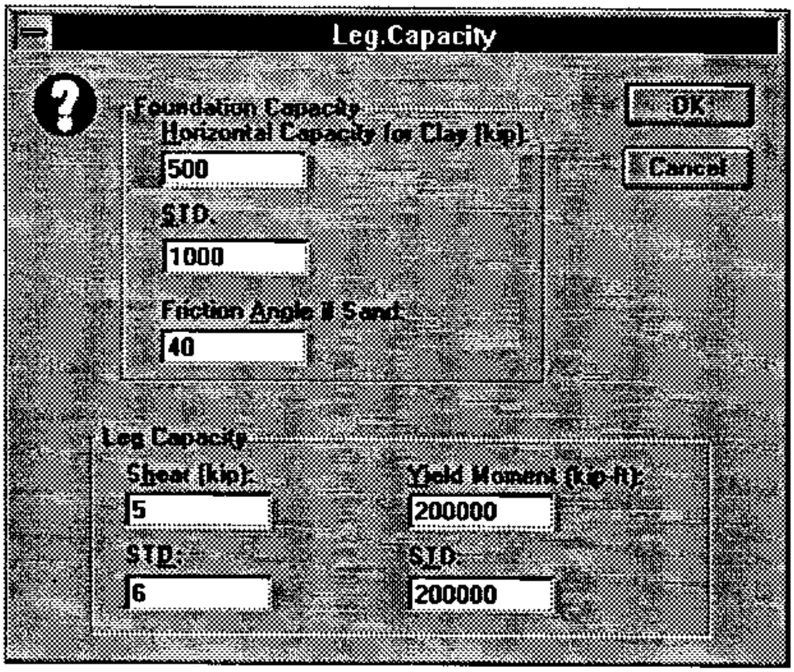


Figure A2.18 Input Jackup Capacity Information

A3. Output

The output of MODUSIM can be in numerical and graphical format.

Click **RESULT** command for simulation result.

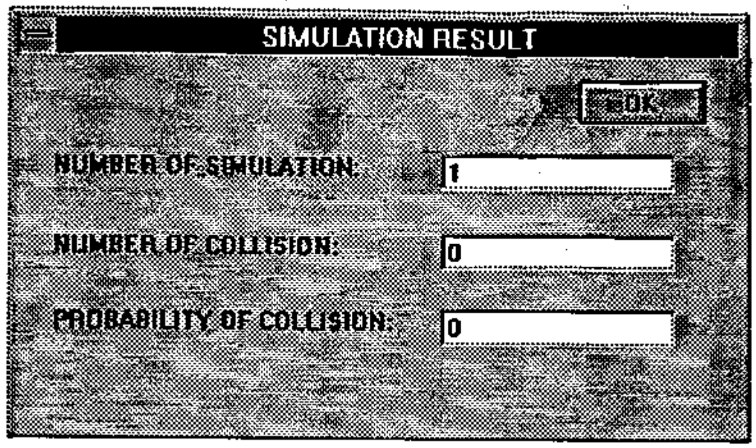


Figure A2.19 Simulation Result

Click **RESUTAR** for output of special target collision probability.

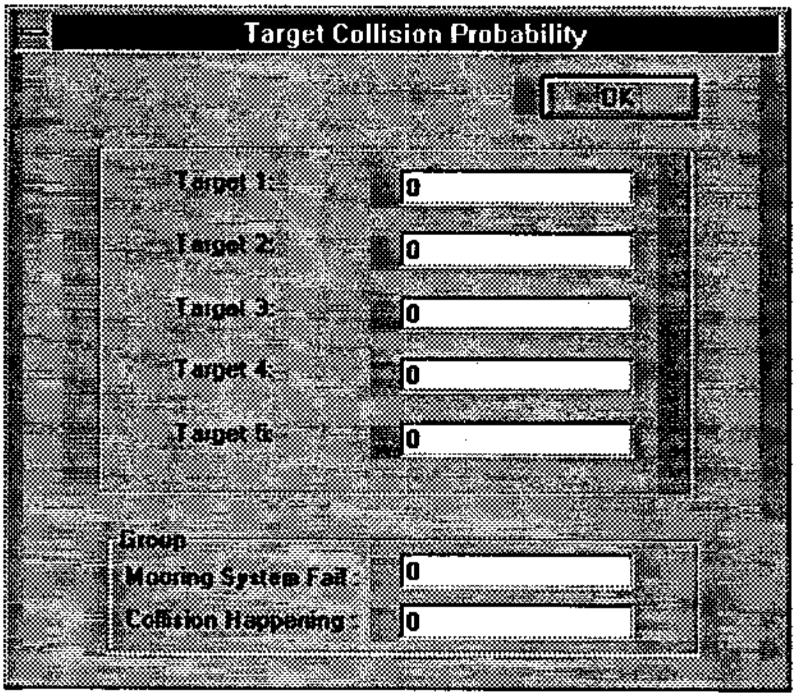


Figure A2.20 Simulation Result for Target Circles

Click **Summary** command for the simulation result from Strategy function.

Click **Env.Result** to get the result from the simulation of the environmental conditions.

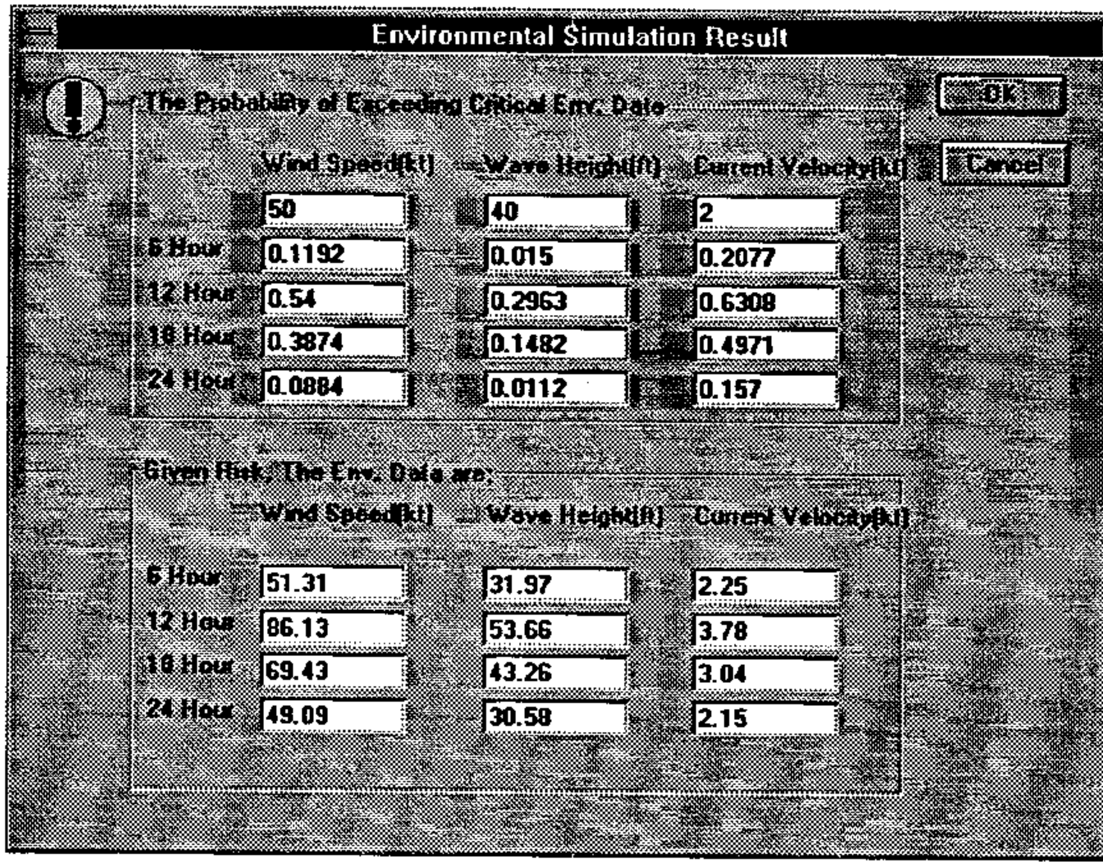


Figure A2.21 Environmental Condition Simulation Result

Click **Histogram** command to get the histograms of environmental condition. The following 'Type of Histogram' dialogue box will pop up. Select different forecast time and different forecast type of hurricanes.

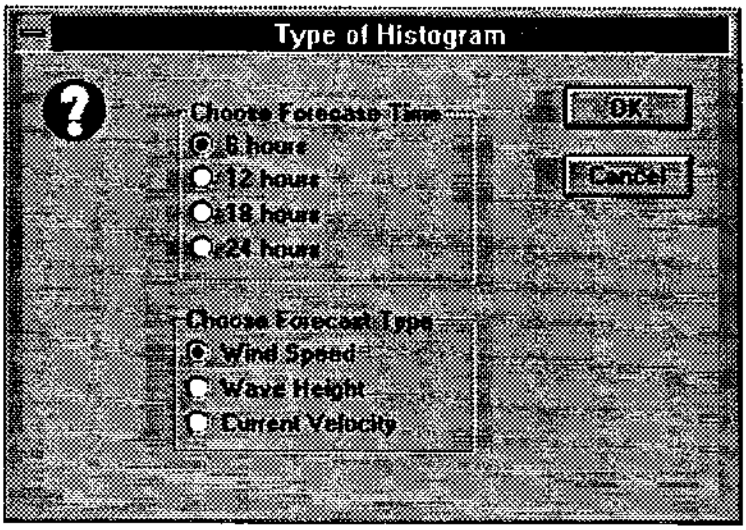


Figure A2.22 Type of Histogram

Click **Return** command to return to the welcome screen.

In case of simulation the MODU's movement during a given hurricane, click **ROUTE** command to get the MODU's moving route during hurricanes.

During the simulation of a given track, a dialogue box 'COLLISION HAPPENING' will pop up whenever a collision happens. Click **STOP HERE** to stop the simulation. Click **NO REPORT** to skip the 'COLLISION HAPPENING!' dialogue box after the following collision. Click **HOLDING** and input **HOLDING TIME** to make the MODU stop at the collision place for a while.

If **Update Screen** is clicked, the MODU route and hurricane track will not be updated each step on the screen. This will make the simulation faster.

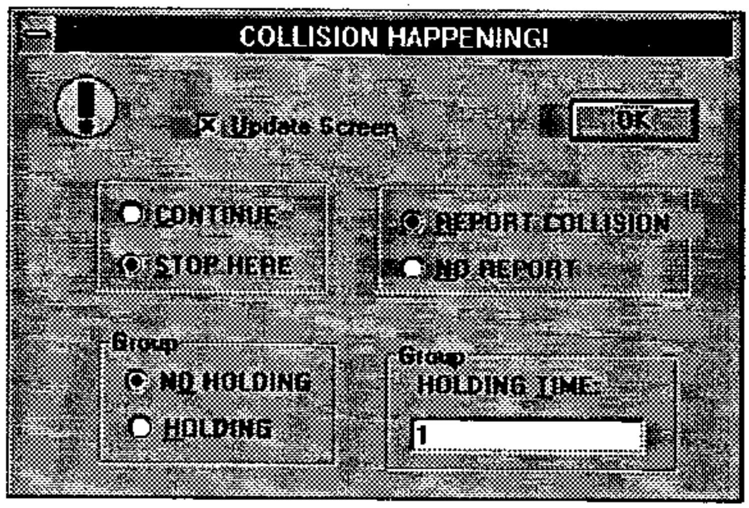


Figure A2.23 Collision Happening Dialogue Box

APPENDIX B
EVACSIM

MODU Evacuation Procedure Simulation Program

User Manual

EVACSIM
MODU Evacuation Procedure Simulation Program

B1. Introduction

B1.1 Introduction

EVACSIM 1.0 is a computer simulation program developed for simulating the MODU's evacuation procedures in hurricanes. It is based on offshore evacuation simulation models and associated weather-related downtime techniques developed for the extension research of joint industry - government sponsored research project titled "*Securing Procedures for Mobile Drilling Units in the Gulf of Mexico Subject to Hurricanes*".

This research has been performed at the University of California at Berkeley, Department of Naval Architecture and Offshore Engineering by Research Assistant Jun Ying under supervision of Professor Robert Bea. The theoretical background of EVACSIM is documented in previous chapters of this report.

B1.2 Application Range of EVACSIM 1.0

EVACSIM 1.0 can be applied to typical offshore platform evacuation procedure simulations with project duration up to 3 days. With upgrade version, it can be used to simulate more complex long-term weather sensitive offshore projects. The upgrade version will be available upon request.

B1.3 Program Structure

The program is developed using Microsoft Project 4.0 and Excel 4.0 Software. The following files are bounded together under the directory EVACSIM:

- evacsim.mpp
- merge.mpx
- prtemp.mpx
- ptemp1.mpx
- temp.xlw
- input.xlw
- sinput.xlw
- sdata.txt
- pdata.txt
- input.txt
- temp.txt

B1.4 Installation

B1.4.1 Backup Disk

Before any installation begins, it is always a good practice to backup the program diskette in the back of the report. We assume you are already familiar with DOS commands or Windows operation. For example, in DOS you will need the DISKCOPY command to make backup copies of your program disk.

B1.4.2 System Requirements

To run EVACSIM 1.0, you must have a 486 or higher based PC with 8MB RAM at least, MS DOS 5.0 or higher, Windows 3.1 or higher, Microsoft Project 4.0, EXCEL 4.0 and @Risk for Excel 3.1.

B1.4.3 Installation

To install EVACSIM 1.0, first copy all the files in the attached disk to your hard drive under the directory "c:\evacsim". Then you can expend the zip file by type: pkunzip evacsim.zip.

B2. Input Data

B2.1 Introduction

To run EVACSIM 1.0, you must start MS Project 4.0 and Excel 4.0 at the same time. The program will transfer data between MS Project and Excel automatically. Then, in MS Project, open the file evacsim.mpp under the directory c:\evacsim.

The evacsim.mpp has a evacuation procedure model which is performed on Zane Barnes. The user may modify the model by adding or dropping some tasks or resources, changing task duration or changing task relationship, etc., or even building another new evacuation procedure model. All this operations may be done through tools in MS Project. Please refer to MS Project user menu for detail operation procedures.

B2.2 Input Hurricane Forecasting Data Information

The hurricane forecast data input file is *pdata.txt*. The example input file is as follows:

Evacuation Simulation Input Card
Forecast Data Begin Time:
11/03/95 00:00 AM
Forecast Data at (16.0,114.5):
6,25,4.0
12,26,4.5
18,28,4.5
24,29,5.0
30,30,5.5
36,30,5.5
42,35,6.0
48,52,8.0
54,62,9.7
60,43,7.1
66,32,5.6
72,28,4.7

The file includes the forecast data beginning time: *11/03/95 00:00 AM*; forecast data point location: *(16.0,114.5)*; and every 6 hour forecast data for wind speed and wave height at forecast location up to 72 hours after the forecast beginning time. The forecast data is formatted as: hours to the forecast beginning time, wind speed and wave height. The units can be chosen by the user, but should the same unit system with that used in the input file, *input.txt*.

B2.3 Input Resource Environmental and Operational Down-Time Criteria

To edit resource environmental and operational down-time criteria, click the command **Edit Resource** under the **Option** Menu. The program will shift to MS Excel 4.0 and open the file *input.txt*. The format of *input.txt* is as follows:

Evacuation Simulation Input Card					
Restricted Resource Number:					
5					
Name	ID	Wind.Spd	Wave.Hi	Duration	All(0)/Half(1)Day
Worker.a	1	100	100	1	0
Worker.b	2	100	100	1	0
Tool.a	3	50	8	4	0
Trans.boat	4	36	6	1	1
Ship	5	70	10	2	0
# of Sim	DT of Sim.				
36	6				
Number of Task to be Check:					
1					
Task ID	Res.ID	Allow.Dur			
13	4	3			

User can edit parameters directly in Excel worksheet. **Restricted Resource Number** is the number of the resources which have environmental or operational restrictions on them. Here, five resources are listed. **ID** is the id which is assigned to each resource in the MS Project. They may be found in project view of resource sheet. Wind speed and wave height are the two environmental criteria used here. The units should be the same as that in *pdata.txt*. **Duration** is the minimum continuous operational duration for each resource. In **All(0)/Half(1) Day** input, 0 means the resource can work day & night and 1 means only day time. **# of Sim** is the latest evacuation start time of simulations in terms of hours from forecast beginning time. And **DT of Sim.** is the interval in hours of different evacuation start time. The last inputs, **Number of Task to Be Checked, Task ID, Res.ID and Allow.Dur,** are the number of un-separatable tasks, task id, associated resources id and the maximum allowable operating duration in hours.

After edit the resource parameters, click **Return to Project** command under the **Project** menu to return to MS Project.

B3. Simulation Procedure

The simulation procedure includes deterministic and probabilistic simulations.

B3.1 Deterministic Simulation

Click command **Run Evac** under the **Option** menu to perform the deterministic simulation at a given evacuation start time. The program will pop a window for input of the start time. The simulation result will give the whole project information, includes duration of whole project and of each task, the critical path of the project, etc..

Click command **Run Detsimu** under the **Option** menu to perform the deterministic simulation with the start time changed from 6 hours after the forecast beginning time to the latest simulation evacuation start time which is inputted by the user, with **DT** hours interval. The program will shift to Excel to present the result. The result will be in chart format as in Figure 5.6 and 5.7. Also, user can click command **Forecast Data** under **Project** Menu to show a chart of forecast data as in Figure 5.5. Click **Return to Project** to back to MS Project.

B3.2 Probabilistic Simulation

To perform simulation in probabilistic region, first step is to generate the random environmental simulation data based on the forecast data. In the @Risk for Excel 4.0, open the file *sinput.xlw*, and follow the instructions to generate the data, then back to project. Click command **Run Probsimu** under **Option** menu to begin the simulation in probabilistic region. The simulation will take almost 30 minutes for a typical 486-66 PC.

The program will present the simulation results in Excel chart format as in Figure 5.8. The chart shows the probabilities of evacuation failure in different evacuation start time vs. evacuation start time. Click command **Forecast Data** to see forecast information and click **Back to Project** to return to MS Project.

APPENDIX C
DISTRIBUTION FITTING AND GOODNESS-OF-FIT TEST

C.1 Estimating

The goal of Distribution Fitting is to find the parameters of the distribution that best fits the input data from a group of parametric distribution families. The distribution families used in this research are: Beta, Exponential, Lognormal, Normal, Rayleigh, Triangular, Uniform and Weibull. These distributions are used because they are popular in engineering applications. The fitting performed in the research finds a distribution from the distribution families that best fits the input data.

Distribution fitting goes through the following steps to find the best fit for the input data:

- For each distribution type, a first guess of parameters is made using **maximum-likelihood estimators**;
- The Chi-square is minimized using the **Levenberg-Marquardt method;**
- The fits of the best-fitting parametric distributions are compared;
- The parameters of the overall best-fitting parametric model are reported as the parameters of the best fit distribution.

In principle, one should adjust the Chi-square using the number of fitted parameters in model selection. That adjustment is not important here because the number of parameters is about the same for all models (2-4), and the number of data is large ($10^2 - 10^3$).

C.2 Maximum Likelihood Estimators

To fit a distribution to the data set, nonlinear iterative procedures such as the Levenberg-Marquardt algorithm need an initial set of parameters. The maximum likelihood estimators are derived for each distribution function. The MLE of a set of parameters are those values that maximize the likelihood function given a set of observation data. For any density function f(x) with a parameter vector α, and a corresponding set of independent observational data X_i, an expression called the likelihood may be defined:

$$L = \prod_{i=1}^{n} f(X_i, \alpha) \tag{C.1}$$

To find the MLE, one maximizes L with respect to α by finding a stationary point

$$\frac{dL}{d\alpha} = 0 \tag{C.2}$$

and solving for α.

C.3 The Levenberg-Marquardt Method

The maximum likelihood estimator need not fit the data best in a Chi-square. The Levenberg-Marquardt Method is a nonlinear least-square solver which we can use to improve the Chi-square fit beyond maximum likelihood, using MLE as an initial guess of the parameters.

The Levenberg-Marquardt method does not find the absolute minimum for chi-square, rather, it finds a local minimal. The performance of this method depends on the initial parameters used. Therefore, a good first guess will produce a good result, while a poor first guess might not provide a useful result.

The following steps outline the Levenberg-Marquardt method:

1. Calculate the "first guess" of all parameters;
2. Find the goodness-of-fit of the input data to the function using these parameters;
3. Vary the parameters by an amount proportional to a factor m;
4. Measure the goodness-of-fit with the modified parameters;
5. If the modified parameters produce a better fit, update the parameters with these values and decrease the value of m by an order of magnitude;
6. If the modified values produce a worse fit, do not update the parameters; increase the value of m by an order of magnitude;
7. Return to step 3.

These steps are repeated until it finds that varying the parameters has little effect on the goodness-of-fit (measured as the percentage change in the chi-square value). This point is a local minimum of the goodness-of-fit statistic, the sum of squared residuals.

C.4 Goodness-of-Fit Test

The process of calculating MLEs and minimizing the sum of squared residuals gives a "best guess" for each distribution. Then we measure whether each fit is probabilistically adequate using goodness-of-fit statistics.

We can characterize the goodness of fit by the probability that the data would be obtained if the fitted model were correct. This probability is called the P-value. If the P-value is small, the data cast doubt on the validity of the model. If the P-value is large, the data are compatible with the model.

There are a lot of goodness-of-fit tests, e.g., chi-square, Kolmogorov-Smirnov and Aderson-Darling. The Chi-Square is the most common.

Chi-Square Test:

The Chi-Square test is the most common goodness-of-fit test. It can be used with any type of data and any type of distribution function. A weakness of the Chi-Square test is that there are no clear guidelines for selecting intervals (number of classes). In some situations, one can reach different conclusions from the same data depending on how the intervals are chosen.

The Chi-Square statistic is defined as:

$$\chi^2 = \sum_{i=1}^{n} \frac{(P_i - p_i)^2}{p_i} \qquad \text{(C.3)}$$

where

P_i = the observed probability of the data in the ith histogram bin

p_i = the theoretical probability that a value will fall with the X range of the ith histogram bin

Kolmogorov-Simirnov Test:

The Kolmogorov-Simirnov Test does not depend on the number of intervals. A weakness of the Kolmogorov-Simirnov Test is that it does not detect tail discrepancies very well.

The Kolmogorov-Smirnov statistic is defined as:

$$D_n = \sup\left[\left|F_n(x) - \hat{F}(x)\right|\right] \tag{C.4}$$

where

n = total number of data points

$\hat{F}(x)$ = the hypothesized distribution

$F_n(x) = \frac{N_x}{n}$

N_x = the number of X_i's less than x.

Anderson Darling Test:

The Anderson Darling Test is very similar to the Kolmogorov-Simirnov Test, but it places more emphasis on tail values. It does not rely on the number of classes.

The Anderson-Darling Statistic is:

$$A_n^2 = n\int_{-\infty}^{+\infty}\left[F_n(x) - \hat{F}(x)\right]^2 \Psi(x)\hat{f}(x)dx \tag{C.5}$$

where

$$\Psi^2 = \frac{1}{\hat{F}(x)[1-\hat{F}(x)]}$$

$\hat{f}(x)$ = the hypothesized density function

$\hat{F}(x)$ = the hypothesized distribution function

$$F_n(x) = \frac{N_x}{n}$$

N_x = the number of X_i's less than x.

C.5 Confidence Levels and Critical Values

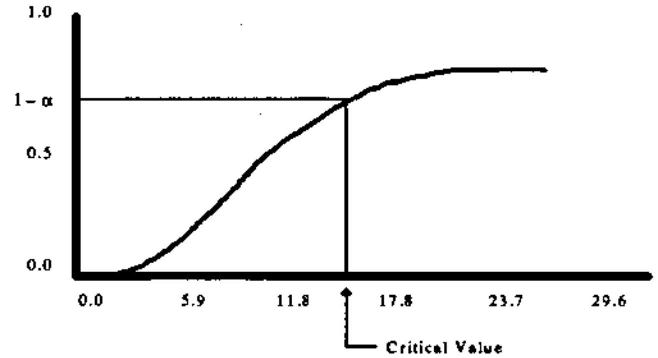
The goodness-of-fit statistic tells how probable it is that a given distribution function produced the data set. But how good is good enough? A critical value is the value in a test that separates the rejection region from the acceptance region. For the goodness of fit tests, this value determines whether or not one should reject a fitted distribution. Statistical hypothesis testing provides a structured analytical method to make a decision regarding fit test results. This method allows one to control or measure the uncertainty involved in the decision.

In the case of research work here, the decision we need to make is whether the input data were generated from the distribution function reported as the estimate. The critical value involved is a goodness-of-fit measurement that is compared to the goodness-of-fit of the best fitting distribution.

The significance level, α, is the probability of rejecting the null hypothesis (in this case, that the estimated distribution is correct) when it is true. In other words, a small value of

α decreases the probability of incorrectly rejecting the null hypothesis that a given set of parameters produce the input data.

For the chi-square test, the critical value is the $1-\alpha$ percentile of a chi-square distribution with N-1 degrees of freedom (N is the number of classes).



A Chi-Square Distribution with 10 degrees of freedom

When the calculated Chi-Square statistic is larger than the critical value, the null hypothesis should be rejected (the distribution is not a good fit). Equivalently, one should reject the null hypothesis when the P-value is less than the significance level.

Critical values for the Anderson-Darling and Kolmogorov-Smirnov goodness-of-fit statistics have been found by Monte-Carlo studies, detail can be found in References.