CAPRA

Probabilistic Risk Assessment Platform

User Manual

Software

FUNVUL-Components V1.0.0

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Contents

Chapter 1

Introduction

1.1. Problem description

The CAPRA Probabilistic Risk Assessment Platform allows to conduct risk assessment against several natural hazards. The vulnerability module requires the definition of vulnerability functions as defined in the CAPRA platform. The vulnerability functions shall be defined for the different assets records in the exposure DB. Those functions allow to quantify the physical and human damage loss in terms of mean damage ratio, MDR that can suffer an asset for a specific hazard scenario.

The vulnerability function represents the expected and variance of the MDR for a given hazard intensity parameter value. Figure 1 shows and example of a vulnerability functions. There are several methodologies to obtain vulnerability functions. The methodologies are based on expert judgment, analytical models and past events. The Probabilistic seismic vulnerability assessment of buildings in terms of economic losses is used in the FUNVUL Components software to define new vulnerability functions.

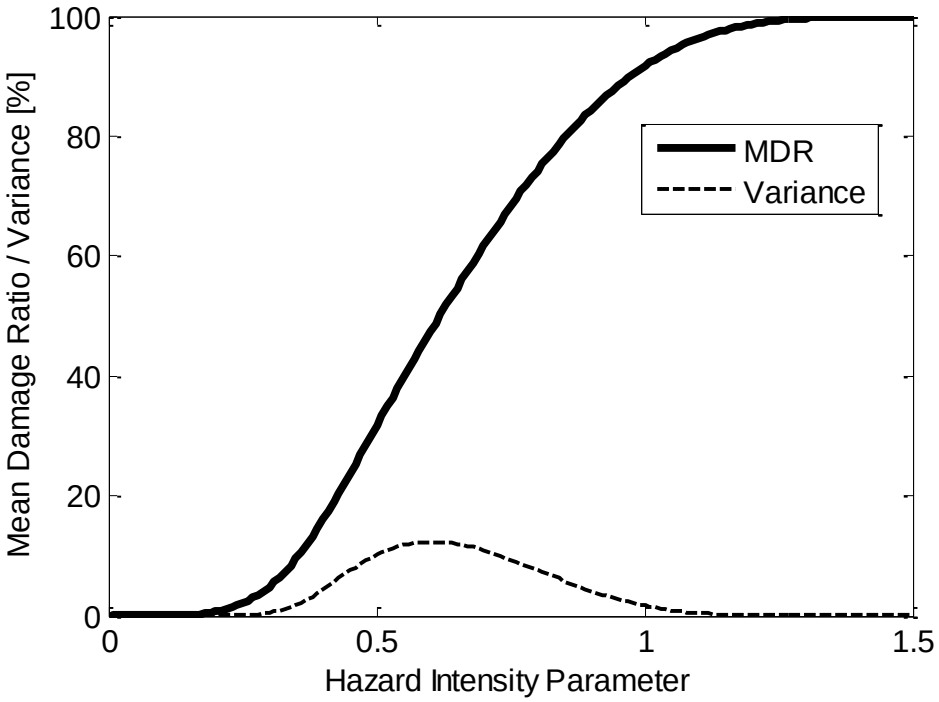


Figure 1 Example vulnerability function

1.2. Theoretical framework

This software uses the methodology proposed by (Yamin et al. 2017). For additional information refers to (Yamin et al. 2017).

The following figure includes the methodological approach used in this software.

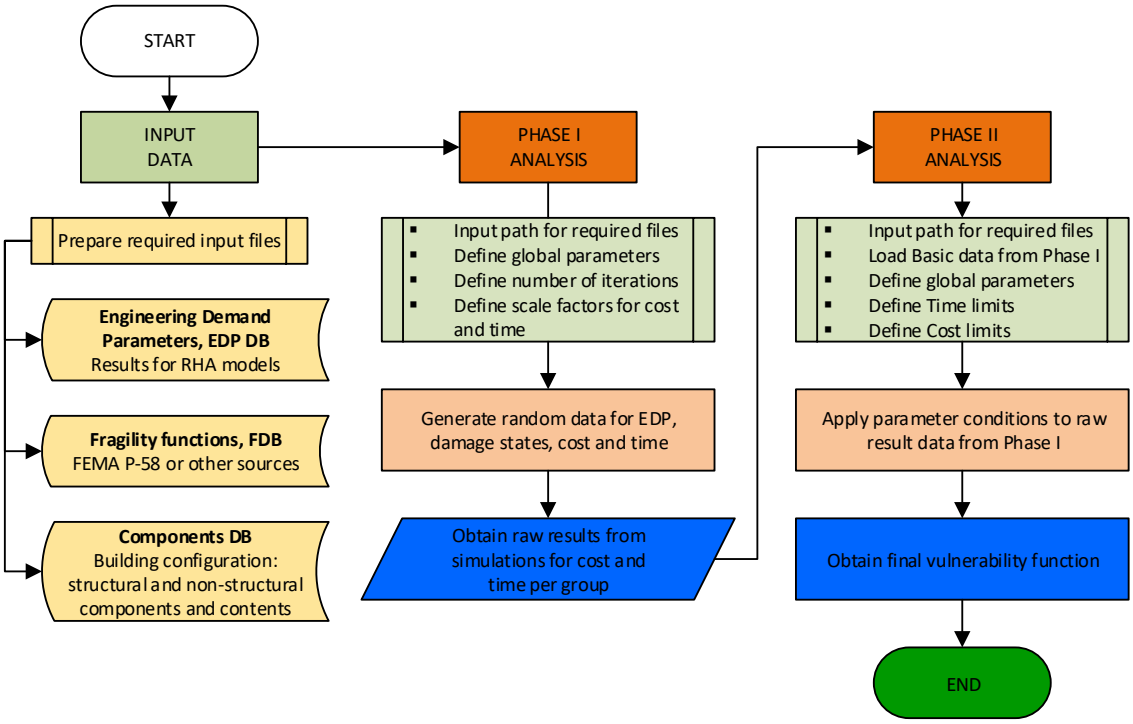


Figure 2 Algorithm for the software approach, (based on Yamin et al. 2017)

1.3. Objectives

The principal objectives of this software are:

- Integrated software to obtain vulnerability functions using an analytical methodology for the hazard risk assessment required by the CAPRA-GIS software.
- Obtain vulnerability functions by rigorously losses calculated using repair and replacement commercial costs. The model considers seismic hazard, demand parameters, damage states, and repair cost and times.
- Estimates integrated damages, costs and time of repair for continuous increasing values of the seismic intensity parameter.
- Considers the repair costs from all structural, non-structural, and content components in the analysis.
- Considers business interruption costs based on the probable downtime due to the repair works.
- Considers results from nonlinear multi-degree-of-freedom dynamic analysis.
- Combines all uncertainties in the seismic hazard, in demand parameters, damage states, and repair costs and times, by means of Monte Carlo simulation techniques.

1.4. Expected results and calculus limitations

This software calculates the vulnerability function trough two phases. The user shall understand the methodology to avoid get wrong results. This software has the following limitations:

- This software only allows to create one vulnerability function at a time.

- This software allows to visualize only the previous graph for comparison purposes.
- The user cannot add, edit, delete or save any field from the files “Component_DB.xlsm”, “Fragility_DB_V3.xlsm” and “EDP_DB.xlsm” other than those fields as specified in section **Error! Reference source not found.**.
- If you are using the “Component_DB.xlsm” file, you must also open the “Fragility_DB_V3.xlsm” file.
- If you prepare the input *.txt file format without using the “Component_DB.xlsm”, “Fragility_DB_V3.xlsm” and “EDP_DB.xlsm”. Those files should have the structure as specified in the section **Error! Reference source not found.**.
- The maximum number of iterations for consideration of uncertainties in model, damage states and cost & time are limited to 10 each one. It also depends on the available RAM capacity where this software is installed.
- This software only considers a maximum of 100 records for the complete intensities scales, used for the response history analysis, *RHA*.
- The *RHA* for nonlinear dynamic analysis are out of the scope of this software.
- The fragility function database included in the “Fragility_DB_V3.xlsm” file can be modified under criteria of the user.
- The maximum number of points to define a new vulnerability function depends on the number of intensities considered in the nonlinear *RHA*.
- This software does not verify if the user is using consisting units among the different parameters that shall be defined.
- This software does not calculate automatic conversion among difference parameters units. The user should be aware that he/she is using the same parameters units as required or defined in this software.

Chapter 2

Software installation

2.1. Minimum installation requirements

The hardware and software requirements for the installation of this software are specified in the following sections.

2.1.1. Minimum hardware requirements

The following are the minimum hardware requirements:

2.1.1.1 Processor and OS

- PC or compatible computer with Pentium III processor (or higher) and processor speed over 1.5 GHz.
- Operating systems: Microsoft XP or Higher.

2.1.1.2 RAM Memory

- Free hard drive capacity of 250 Mb or Higher.
- 512 Mb Extended Memory (RAM).

2.1.2. Software requirements

The following are the minimum software requirements:

- If the computer where this software is going to be installed does not have installed MATLAB Runtime version 9.2 (2017a), please install the MATLAB Runtime version 9.2 (2017a). It can download from: http://www.mathworks.com/products/compiler/mcr/index.html.

2.2. Installation process

This software does not required installation. You must only follow the next steps:

1. Verify that all software requirements are meet before installation. Please see section 2.1.2.
2. Enter in the Windows™ Explorer and select the path where the software package folder is located, then, go to the Application File folder.
3. Run the **FUNVULComponents.exe**; this command starts the programs.

If you cannot run this software or get any error message during the program starts, please send an email with the description to ecapra@uniandes.edu.co.

Chapter 3

Graphical user interface

3.1. General description

This software allows the user to create new vulnerability functions. The methodology used to create new function is presented in section 1.2.

The FUNVUL Components main window is divided in three areas; menu area, parameters area and display area. (see Figure 3).

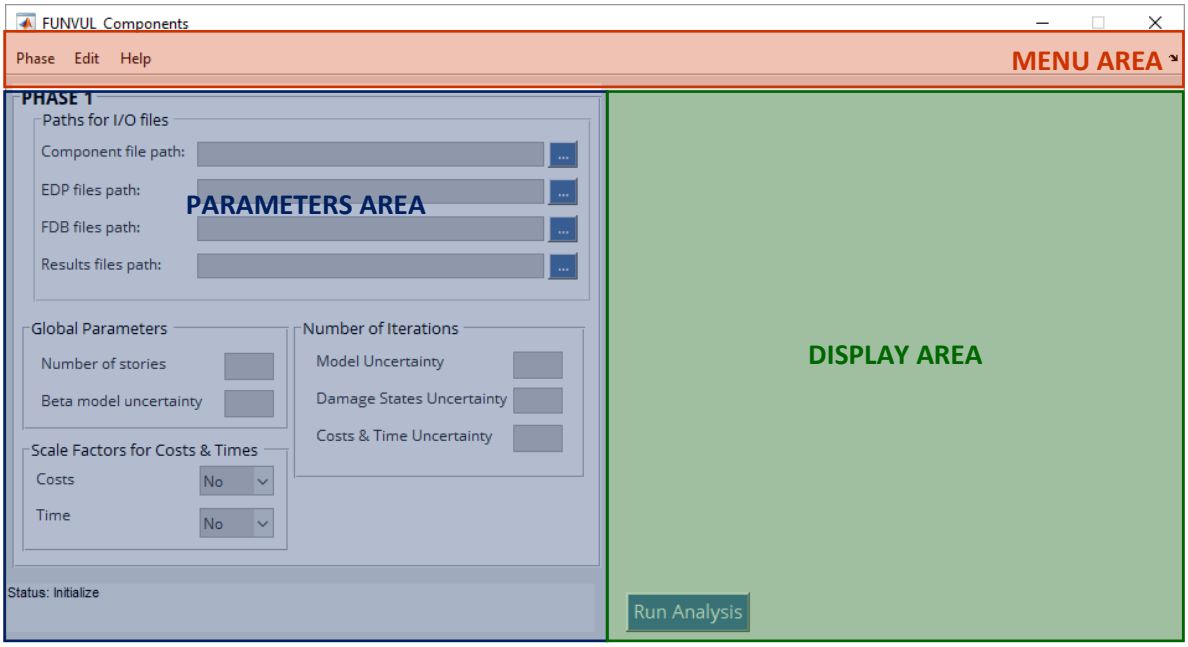


Figure 3 FUNVUL Simplified main window

3.2. Tools and Menus

3.2.1. Menu area

The software menu bar has three drop-down menus to get access at different functions.

- Phase drop-down menu item: includes access to Phase 1 and Phase 2.
- Edit drop-down menu: allows the user to "Clear form Data" and add "Default Values" to the forms fields for each Phase.
- Help drop-down menu: allows the user to get access to the documentation resources of the software, the license and the about information.

3.2.2. Parameters area

This area displays two different forms and a Status text box at the bottom part. Each form depends of the Phase that is under analysis.

3.2.2.1 Phase 1 Form

This form contains the parameters field required to perform the Phase 1 analysis. This form has been divided in four blocks.

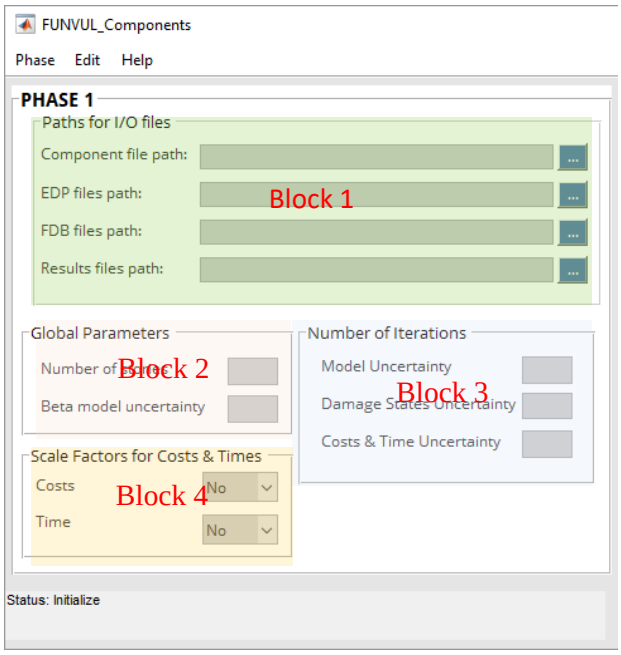


Figure 4 Tab overview for parameters area

Block 1: Paths for I/O files

- **Components file path:** field to define the path where are stored the "Components.txt" file. The values are editable.
- **EDP files path:** field to define the path where are stored the "IML.txt", "Drift.txt", "RDrift.txt", "Accel.txt", "PR_COL.txt" and "PR_BEAM.txt" files. The values are editable.
- **FDB files path:** field to define the path where are stored the "damage_state.txt" and "damage_cost_time.txt" files. The values are editable.
- **Results files path:** field to define the path where are stored the "ParametersPhaseI.txt" and "RF_I.mat" files. The values are editable.

Block 2: Global Parameters

- **Number of stories:** field to define the number of stories of the building.
- **Beta model uncertainty:** field to define the beta model uncertainty.

Block 3: Number of Iterations

- **Model Uncertainty:** field to define the number of iterations for account model uncertainty.
- **Damage States Uncertainty:** field to define the number of iterations for account damage states uncertainty.
- **Cost & Time Uncertainty:** field to define the number of iterations for account cost and time uncertainty.

Block 4: Scale Factors for Costs & Times

- **Costs:** field to define if considers scale economy for repair cost.
- **Time:** field to define if considers scale economy for repair time.

3.2.2.2 Phase 2 Form

This form contains the parameters field required to perform the Phase 2 analysis. This form has been divided in five blocks.

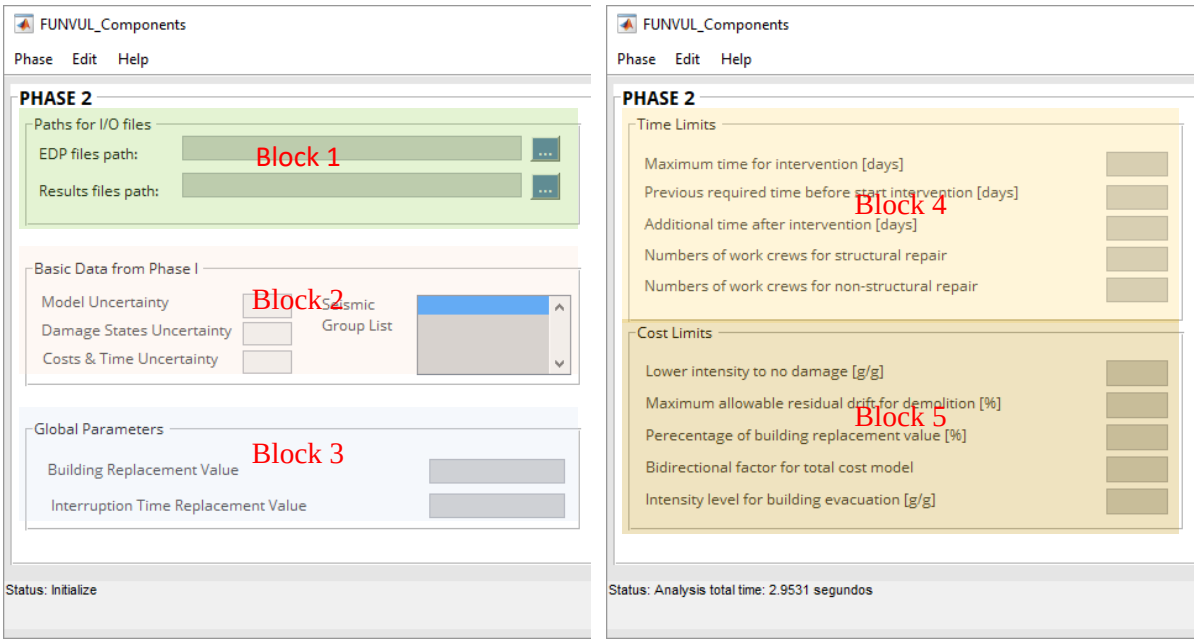


Figure 5 Tab overview for parameters area

Block 1: Paths for I/O files

- **EDP files path:** field to define the path where are stored the "IML.txt", "Drift.txt", "RDrift.txt", "Accel.txt", "PR_COL.txt" and "PR_BEAM.txt" files. The values are editable.
- **Results files path:** field to define the path where are stored the "ParametersPhaseII.txt", "RF_I.mat" and "RF_II.mat" files. The values are editable.

Block 2: Basic Data from Phase I

- **Model Uncertainty:** field with the number of iterations for account model uncertainty. The value is not editable.
- **Damage States Uncertainty:** field with the number of iterations for account damage states uncertainty. The value is not editable.
- **Cost & Time Uncertainty:** field with the number of iterations for account cost and time uncertainty. The value is not editable.
- **Seismic Group List:** field to select the group names for the analysis in the Phase 2.

Block 3: Global Parameters

- **Building Replacement Value:** field to define the building replacement value.
- **Interruption Time Replacement Value:** field to define interruption time replacement value.

Block 4: Time Limits

- **Maximum time for intervention:** field to define the maximum days of time for intervention.

- **Previous required time before start intervention:** field to define the previous requires days of time before start intervention.
- **Additional time after intervention:** field to define the additional days of time after intervention.
- **Number of work crews for structural repair:** field to define the total number of work crews for structural components.
- **Number of work crews for non-structural repair:** field to define the total number of work crews for non-structural components.

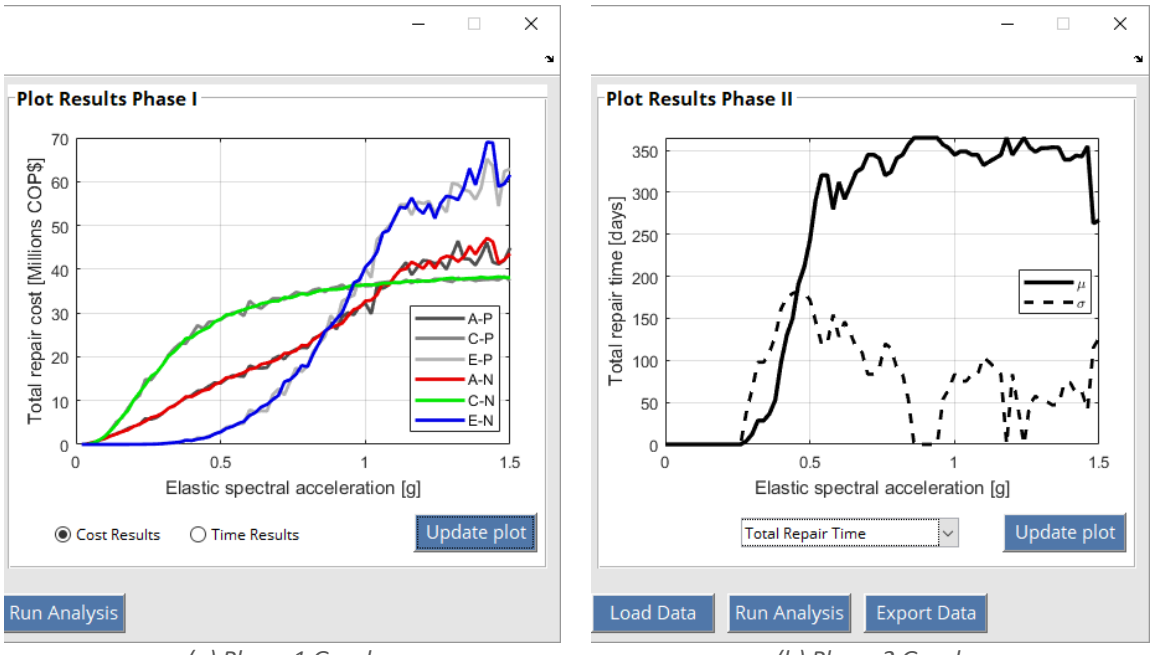
Block 5: Cost Limits

- **Lower intensity to no damage:** field to define the lower intensity for no damage.
- **Maximum allowable residual drift for demolition:** field to define the residual drift for demolition.
- **Percentage of building replacement value:** field to define the maximum percentage of building replacement value.
- **Bidirectional factor for total cost model:** field to account the bidirectional factor for total cost model.
- **Intensity level for building evacuation:** field to define the intensity level for building evacuation.

3.2.3. Display area

The display area allows the user to visualize the results from each one of the phases.

- **Phase 1 Graph:** display the vulnerability raw curve for the three main groups of components for cost or time.
- **Phase 2 Graph:** display the vulnerability curve for the total repair cost, time and normalized cost including business interruption.



(a) Phase 1 Graph *(b) Phase 2 Graph*

Figure 6 Tabs overview for Display area

The function for each button is described below.

- **Run Analysis button:** run the analysis for the active phase.
- **Load Data button:** load data and fills the Basic Data from Phase I variables for Phase 2 form.
- **Export Data button:** export files to format *.txt for the results from Phase 2.
- **Update plot:** update the plot based on the selected option.

3.3. Input parameters setting and data type

The following table specify the input setting and data type for all parameters used in the software. Also, some recommended values are included.

Table 1 Input parameters

Item	Parameter	Format type	Value	Units
1	**PARAMETER AREA – PHASE 1**			
1.1	Component file path	String (see section 4.1.3 for format input file)	-	-
1.2	EDP files path	String (see section 4.1.2 for format input file)	-	-
1.3	FDB files path	String (see section 4.1.1 for format input file)	-	-
1.4	Results files path	String (see section 5.1 for format output file)	-	-
1.5	Number of stories	Integer	-	-
1.6	Beta model uncertainty	Double	0.1 – 0.5 Default value 0.2	-
1.7	Model Uncertainty	Integer	Default value 10	-
1.8	Damage States Uncertainty	Integer	Default value 10	-
1.9	Cost & Time Uncertainty	Integer	Default value 10	-
1.10	Costs	String	No Yes	-
1.11	Time	String	No Yes	-
2	**PARAMETER AREA – PHASE 2**			
2.1	EDP files path	String (see section 4.1.2 for format input file)	-	-
2.2	Results files path	String (see section 5.2 for format input file)	-	-
2.3	Parameter values Table	String	-	-
2.4	Model Uncertainty	Integer	-	-
2.5	Damage States Uncertainty	Integer	-	-
2.6	Cost & Time Uncertainty	Integer	-	-
2.7	Seismic Group List	String	List	-
2.8	Building Replacement Value	Double	-	Currency Units
2.9	Interruption Time Replacement Value	Double	-	Currency Units
2.10	Maximum time for intervention	Integer	Default value 365	Days
2.11	Previous required time before start intervention	Integer	Default value 30	Days

Item	Parameter	Format type	Value	Units
2.12	Additional time after intervention	Integer	Default value 30	Days
2.13	Number of work crews for structural repair	Integer	Default value 4	-
2.14	Number of work crews for non-structural repair	Integer	Default value 4	-
2.15	Lower intensity to no damage	Double	Default value 0	g/g
2.16	Maximum allowable residual drift for demolition	Double	0 – 100 Default value 2.5	Percentage
2.17	Percentage of building replacement value	Double	0 – 100 Default value 100	Percentage
2.18	Bidirectional factor for total cost model	Double	Default value 1.5	-
2.19	Intensity level for building evacuation	Double	Default value 1.2	g/g
3	**DISPLAY AREA**			
3.1	Plot Results Phase I	String	Cost Results Time Results	-
3.2	Plot Results Phase II	String	Total Repair Time Total Repair Cost Total Normalized Cost	-
4	**OUTPUT – PHASE 1**			
4.1	*.txt file path	String	-	-
5	**OUTPUT – PHASE 2**			
5.1	*.txt file path	String	-	-

Chapter 4

Setting input data and files

4.1. Input file and file format

This software uses a unique types of input files. Those types are *.txt format files. It can be load it specifying the folder path where they are stored. The required file format structure of each one is presented in the following sections. Please refer to each one of these sections to verify that your input files have the required file format.

4.1.1. Fragility DB files format

There are two files in *.txt format. The first file “damage_state.txt” contains the specification for the fragility function. The second one “damage_cost_time.txt” contains the specification of the cost and time for each fragility function. Those files contain information written in records. Each record corresponds to each fragility functions. It can be read using the Notepad program. Also, those files can be created using the **“Fragility_DB_V3.xlsm”** spreadsheet file. To create those files the user should complete the information in the sheets “damage_state” and “damage_cost_time”. For more detailed information about each field please refer to FEMA P-58 (FEMA 2012).

4.1.2. EDP files format

There is a total of six different required files for EDP that can be obtained from the nonlinear Response History Analysis, RHA. Those files contain information written in records. Each record corresponds to one seismic intensity level. Those files can be created using the **“EDP_DB.xlsm”** spreadsheet file.

4.1.2.1 Seismic record file

The “IML.txt” file contains the information for the seismic records used in the nonlinear RHA. The file has three columns. The first column corresponds to the seismic record group. The second column corresponds to the seismic record name. The third column corresponds to the seismic record intensity. Each record corresponds to each seismic record intensity (see

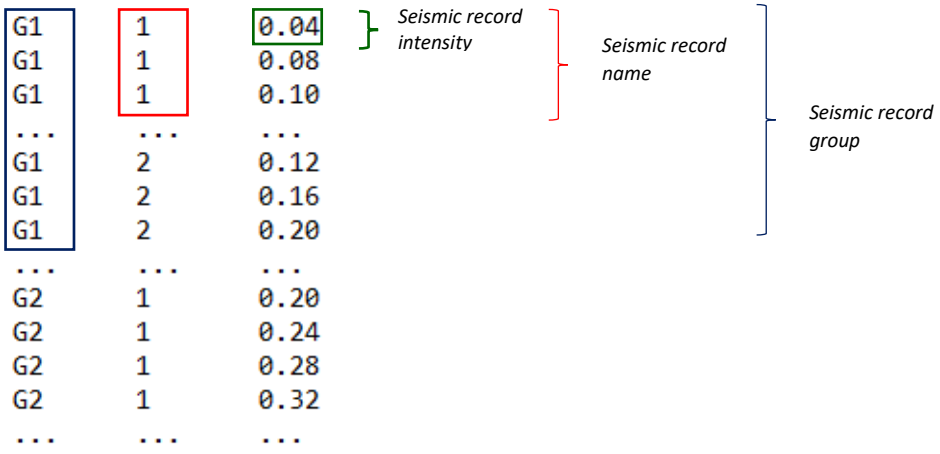


Figure 7).

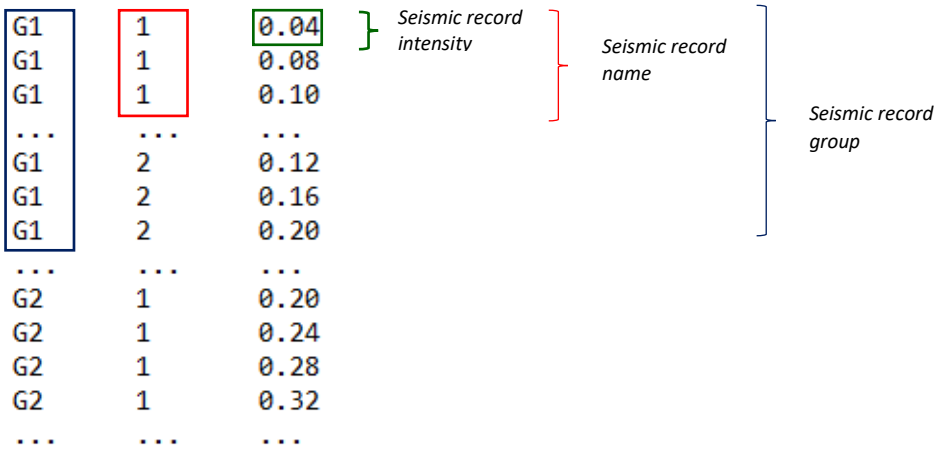


Figure 7 Typical Structure for input IML.txt file

4.1.2.2 Result files

The result files are plain text files that contains result information from the performed nonlinear RHA for each seismic record intensity as specified in the IML.txt file. The total number of columns for each file varies and depends of the result type. Each column is related to each component as defined in the Component DB. There is a total of five result files required. Those files are:

- "Drift.txt": this file contains the maximum inter-story drift ratio obtained from nonlinear RHA performed.
- "RDrift.txt": this file contains the maximum inter-story residual drift ratio obtained from nonlinear RHA performed.
- "Accel.txt": this file contains the maximum story relative acceleration ratio obtained from nonlinear RHA.
- "PR_COL.txt": this file contains the maximum plastic hinge inelastic rotation for columns, obtained from nonlinear RHA performed.
- "PR_BEAM.txt": this file contains the maximum plastic hinge inelastic rotation for beams, obtained from nonlinear RHA performed.

The typical structure of those files is presented below.

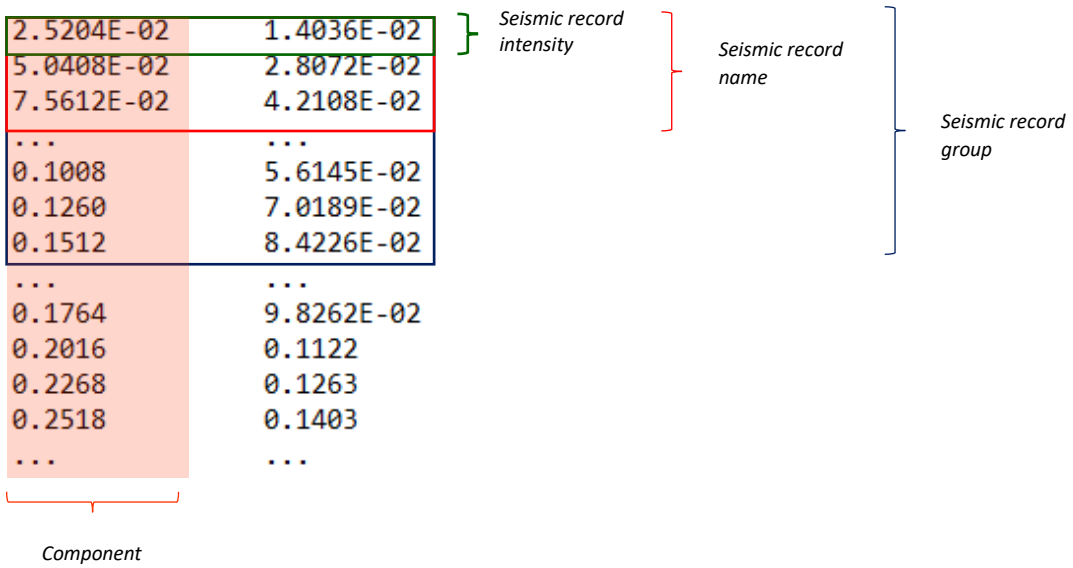


Figure 8 Typical Structure for input results files

4.1.3. Component file format

The "Components.txt" file contains the information for the components that would be considered for the vulnerability analysis. The file format is a plain text with records. Each record corresponds to each component and has the following structure:

- 1st Column: Component Story floor location
- 2nd Column: Component group name
- 3rd Column: Component subgroup name
- 4th Column: Fragility function name
- 5th Column: Component description
- 6th Column: Demand parameter
- 7th Column: Component quantity
- 8th Column: EDP file name
- 9th Column: EDP file column index
- 10th Column: Component correlation

This file can be created using the "Component_DB.xlsm" spreadsheet file.

1	S	S1	B1041.003a	ACI 318 SMF , Conc Col & Bm...	Story Drift Ratio	4	Drift	1	1
1	F	F1	C3032.002a	Suspended Ceiling, SDC C, A...	Peak Floor Acceleration	15	Accel	1	0
1	C	C1	E2022.010a	Fragile Contents, doors, wi...	Story Drift Ratio	3	Drift	1	0
...	...	...	...	...	...	...	...	...	...
2	S	S2	B1041.091a	Non-conforming MF with weak...	Story Drift Ratio	4	Drift	2	1
2	F	F2	C1011.001a	Wall Partition, Type: Gypsu...	Story Drift Ratio	10	Drift	2	0
2	C	C2	E2022.010	Unsecured fragile objects o...	Peak Floor Acceleration	6	Accel	2	0
...	...	...	...	...	...	...	...	...	...

Figure 9 Typical Structure for input component file

Chapter 5

Visualization output files

5.1. Phase 1

This software automatically saves the results from the Phase 1 of the analysis. There are two output files “ParametersPhaseI.txt” and “RF_I.mat”. The first file is a plain text file that contains the input information specified by the user in the Phase I form (see Figure 10). The second file contains the results that will be used for the Phase II analysis.

```
******Path for I/O files******
Component file path: C:\FUNVUL-Components\DB\Tutorial2-3
EDP files path: C:\FUNVUL-Components\DB\Tutorial2-3\EDP_DB
FDB files path: C:\FUNVUL-Components\DB\Tutorial2-3\Fragility_DB
Results files path: C:\FUNVUL-Components\DB\Tutorial2-3\Results_PhaseI
******Global Parameters******
Number of stories: 2
Beta model uncertainty: 2
******Basic Data******
Number of simulations for model uncertainty:10
Number of simulations for damage states uncertainty:  10
Number of simulations for cost & time uncertainty: 10
Do you consider scale factor for cost model?: YES
Do you consider scale factor for time model?: YES
```

Figure 10 Output file “ParametersPhaseI.txt” example

5.2. Phase 2

This software automatically saves the results from the Phase 2 of the analysis. There are output files “ParametersPhaseII.txt” and “RF_II.mat”. The first file is a plain text file that contains the input information specified by the user in the Phase II form (see).

```
******Path for I/O files******
EDP files path: C:\FUNVUL-Components\DB\Tutorial2-3\EDP_DB
Resutls from Phase I files path: C:\FUNVUL-Components\DB\Tutorial2-3\Results_PhaseI
******Basic Data from Phase I******
Number of simulations for model uncertainty:10
Number of simulations for damage states uncertainty:  10
Number of simulations for cost & time uncertainty: 10
******Global Parameters******
Building replacement value: 100000000
Interruption time replacement value: 500000
******Cost Limits Parameters******
Lower intensity limit to no damage value: 0
Maximum allowable residual drift for demolition value [%]:2.5
Perecentage of building replacement value [%]:  100
Bidirectional factor for total cost model value: 1.5
Intensity level for building evacuation value: 1.2
******Cost Limits Parameters******
Maximum time for intervention value [days]: 365
Previous required time before start intervention value [days]: 30
Additional time after intervention value [days]: 30
Numbers of work crews for structural repair: 4
Numbers of work crews for non-structural repair: 4
```

Figure 11 Output file example

Additional to those files the user can export four plain text files with the results from the Phase 2 analysis. Those files are:

- “CostmodelResults.txt”: file that contains the total cost information for each seismic intensity. It has five columns: intensity, mean, standard deviation, percentile 95th and percentile 5th (See Figure 12).

- "TimemodelResults.txt": file that contains the total cost information for each seismic intensity. It has five columns: intensity, mean, standard deviation, percentile 95th and percentile 5th (See Figure 12).
- "FVU_Results.txt": file with the vulnerability function data. It has three columns: intensity, mean and standard deviation (See Figure 13).
- "FVUSimplified_Results.txt": file with the vulnerability function data. It has the same structure that the input*.txt file format for FUNVUL-Simplified (See Figure 14).

Intensity	Mean	Standard deviation	percentile 95	percentile 5
0.00	0.00	0.00	0.00	0.00
0.02	9409.19	132919.38	0.00	0.00
0.04	7780391.86	32637842.98	86060416.45	0.00
0.06	8590714.83	32497929.81	88386808.31	0.00
0.08	10312835.30	32228123.71	97753640.78	0.00
0.10	19550873.17	43712922.20	150000000.00	0.00
0.12	21782878.02	43221131.98	150000000.00	619101.36
0.14	24677566.14	42609186.17	150000000.00	1564421.90
0.16	27700323.44	41994951.50	150000000.00	2594106.40
0.18	30422986.90	41402381.98	150000000.00	3676724.50
0.20	34563587.54	40607596.79	150000000.00	5543504.14
...	...	...	...	...

Figure 12 Output file Cost/time Results example

Intensity	Mean	Standard deviation
0.0000	0.0000	0.0000
0.0200	0.0001	0.0009
0.0400	0.0519	0.2176
0.0600	0.0573	0.2167
...	...	...

Figure 13 Output file FVU Results example

76				
0.0000	0.0000	0.0000	0.0000	0.0000
0.0200	0.0001	0.0000	0.0000	0.0000
0.0600	0.0573	0.0469	0.0000	0.0000
0.1000	0.1303	0.0849	0.0000	0.0000
0.1400	0.1452	0.0830	0.0000	0.0000
...	...	...	...	...

Figure 14 Output file FVU Simplified Results example

5.3. Error file

This software generates automatically an error file when the analysis cannot be conducted. The user shall review this file in order to know the errors. The file name is "error.dat" and has a complete list of the errors. It can be open using any text editor.

The following figure presents an example of the content of this file.

```
You must define a valid directory for PDS Data!
You must define a valid directory for get and save Results Data!
The Building replacement value must be positive!
The Interruption time replacement value must be positive!
The value of Lower intensity limit to no damage must be zero or greater than zero!
The value of Maximum allowable residual drift for demolition must be greater than zero!
The Perecentage of building replacement value must be greater than zero!
The value of Bidirectional factor for total cost model must be greater than zero!
The value of Intensity level for building evacuation must be greater than zero!
The value of Maximum time for intervention must be greater than zero!
The value of Previous required time before start intervention must be greater than zero!
The value of Additional time after intervention must be greater than zero!
The value of Numbers of work crews for structural repair must be greater than zero!
The value of Numbers of work crews for non-structural repair must be greater than zero!
```

Figure 15 Output file example

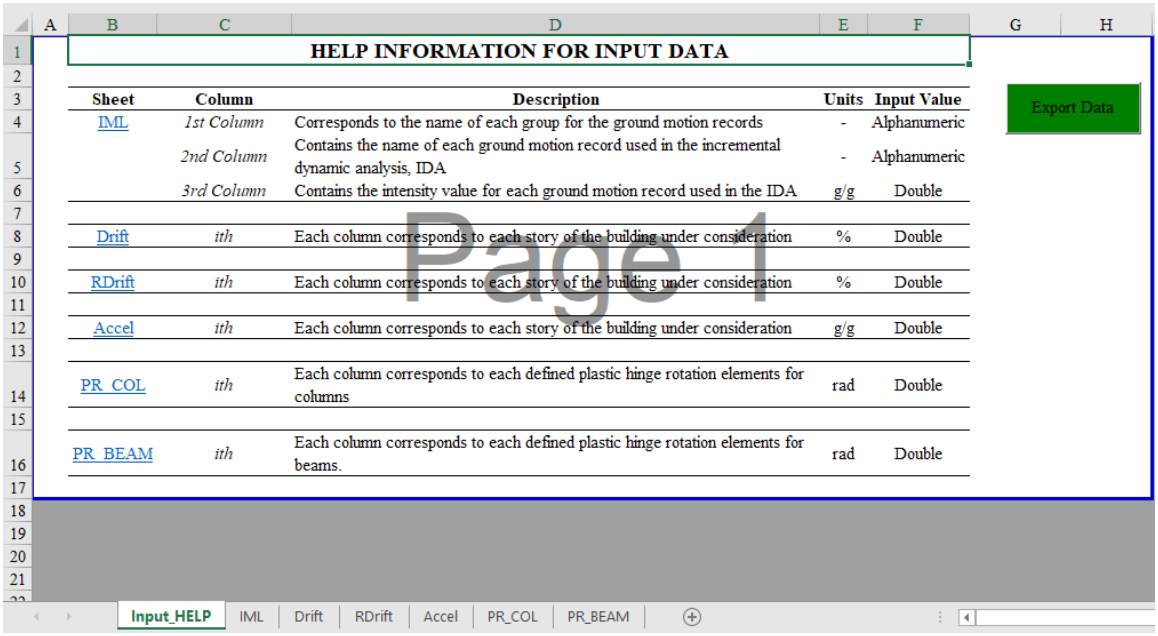
Chapter 6

Step-by-step tutorial

6.1. Tutorial 1: Setting up the input files

This tutorial shows you how create and setup of the files required to perform an analysis using FUNVUL-Components. The step you must follows are the followings:

1. **Setting up the results for the Engineering Demand Parameters, EDP**
   a. Open the folder where do you download the software. Go to **FUNVUL-Components\DB\SETUP**. Open the file **EDP_DB.xlsm**. You will get the following window.



HELP INFORMATION FOR INPUT DATA

Export Data

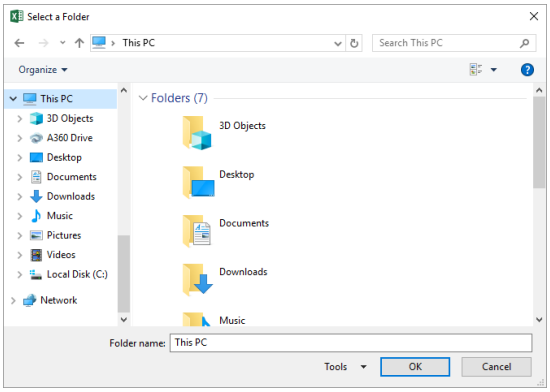
Sheet	Column	Description	Units	Input Value
IML	*1st Column*	Corresponds to the name of each group for the ground motion records	-	Alphanumeric
	2nd Column	Contains the name of each ground motion record used in the incremental dynamic analysis, IDA	-	Alphanumeric
	3rd Column	Contains the intensity value for each ground motion record used in the IDA	g/g	Double
Drift	*ith*	Each column corresponds to each story of the building under consideration	%	Double
RDrift	*ith*	Each column corresponds to each story of the building under consideration	%	Double
Accel	*ith*	Each column corresponds to each story of the building under consideration	g/g	Double
PR_COL	*ith*	Each column corresponds to each defined plastic hinge rotation elements for columns	rad	Double
PR_BEAM	*ith*	Each column corresponds to each defined plastic hinge rotation elements for beams.	rad	Double

Input_HELP | IML | Drift | RDrift | Accel | PR_COL | PR_BEAM

   b. You must fill out or copy and paste your results to each of the EDP sheets. The order of the data is explained in the "**Input_HELP**" sheet. It is highly recommended that all sheets have the same number of rows.
   c. You must fill out of the EDP sheet information. You can copy and paste the results from other sources. For this tutorial, open the file **EDPSampleData.xlsx** (This file is stored in the **Components\DB\Tutorial1** path) and copy the information to the sheets in the **EDP_DB.xlsm** as follows:

EDP	Copy from sheet (EDPSampleData.xlsx)	Paste to sheet (EDP_DB.xlsm)
Intensity level	IML_SAMPLE	IML
Inter-story drift	Drift_SAMPLE	Drift
Residual inter-story drift	RDrift_SAMPLE	RDrift
Story relative acceleration	Accel_SAMPLE	Accel
Plastic hinge inelastic rotation for columns, or other as required per user.	PR_COL_SAMPLE	PR_COL
plastic hinge inelastic rotation for beams, or other as required per user.	PR_BEAM_SAMPLE	PR_BEAM

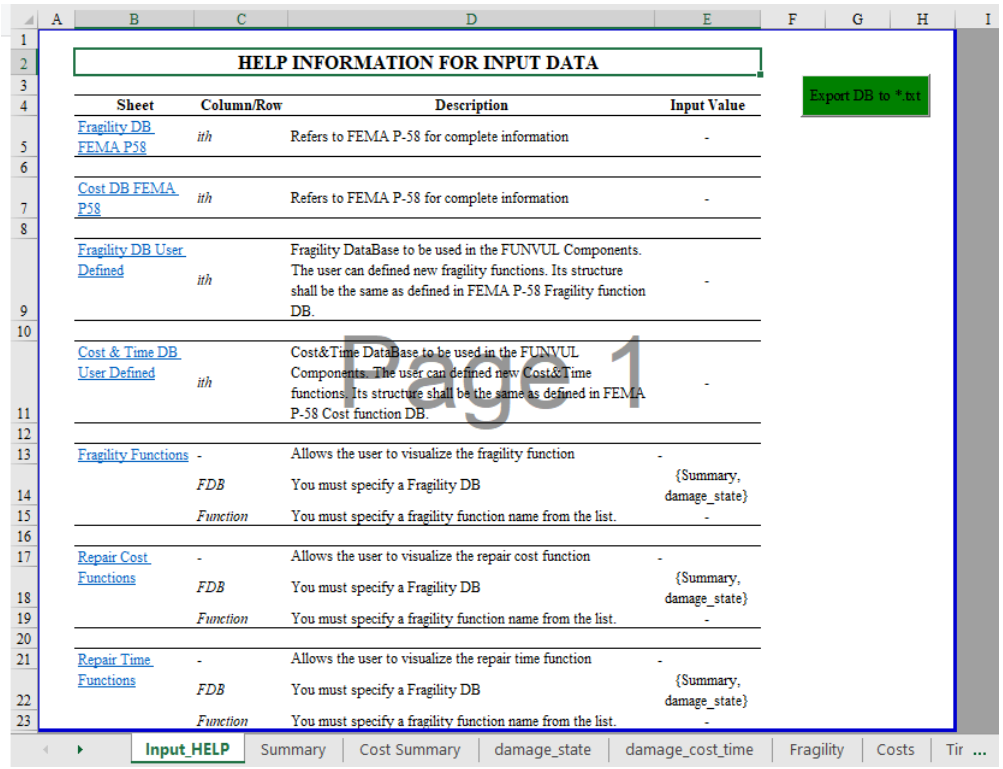
d. After you finished to copy the data from **EDPSampleData.xlsx** to **EDP_DB.xlsm.** You must click on the **"Export Data" button**. This will open a window asking you for the directory where the EDP files will be saved. Please specify a valid path, then click on "OK" button.



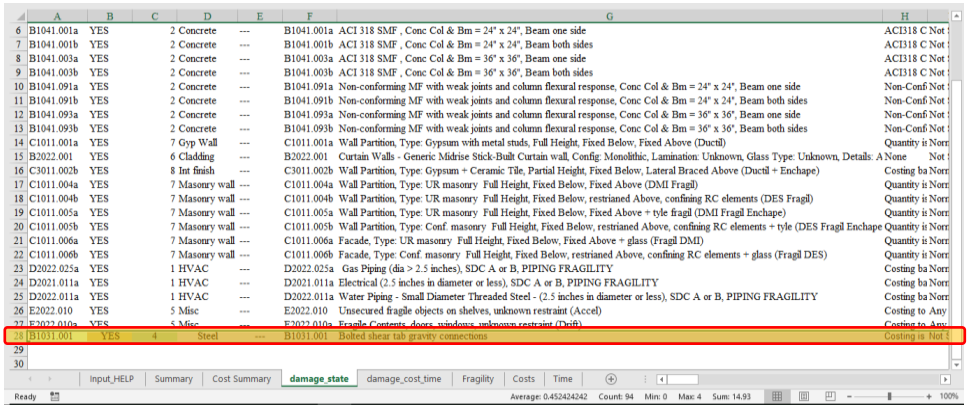
e. Finally, close the both files and then, go to the path that you specify and review that the files as listed in section 4.1.2 are in this path. Also, you can compare your results files with the files stored in the **FUNVUL-Components\DB\Tutorial1\ Results_Step_1** path**.**

2. **Setting up the Fragility Database.**

a. Open the folder where do you download the software. Go to **FUNVUL-Components\DB\SETUP**. Open the file **Fragility_DB_V3.xlsm**. You will get the following window.



b. Please read all the information given in the "Input_HELP" sheet. If you are an advance user or you want to edit the fragility functions, please refer to FEMA P-58.
c. In the **Fragility**, **Costs** and **Time** sheets you can visualize all the information related with the fragility functions available in this file.
d. For this tutorial, it will be only added one fragility function to User Defined DB from FEMA P-58 DB, just for illustrative purpose. For this copy the entire row for the B1031.001 fragility function from the **Summary** sheet to **damage_state** sheet. Paste the data at the following row (Row 28).
e. Repeat the same process with for the information from **Cost Summary sheet** to **damage_cost_time** sheet. At the end you will get the following:

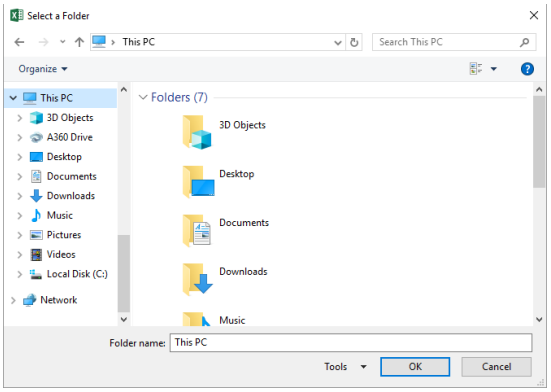


	A	B	C	D	E	F	G	H
6	B1041.001a	YES		2 Concrete	---	B1041.001a	ACI 318 SMF , Conc Col & Bm = 24" x 24", Beam one side	ACI318 C Not
7	B1041.001b	YES		2 Concrete	---	B1041.001b	ACI 318 SMF , Conc Col & Bm = 24" x 24", Beam both sides	ACI318 C Not
8	B1041.003a	YES		2 Concrete	---	B1041.003a	ACI 318 SMF , Conc Col & Bm = 36" x 36", Beam one side	ACI318 C Not
9	B1041.003b	YES		2 Concrete	---	B1041.003b	ACI 318 SMF , Conc Col & Bm = 36" x 36", Beam both sides	ACI318 C Not
10	B1041.091a	YES		2 Concrete	---	B1041.091a	Non-conforming MF with weak joints and column flexural response, Conc Col & Bm = 24" x 24", Beam one side	Non-Confo Not
11	B1041.091b	YES		2 Concrete	---	B1041.091b	Non-conforming MF with weak joints and column flexural response, Conc Col & Bm = 24" x 24", Beam both sides	Non-Confo Not
12	B1041.093a	YES		2 Concrete	---	B1041.093a	Non-conforming MF with weak joints and column flexural response, Conc Col & Bm = 36" x 36", Beam one side	Non-Confo Not
13	B1041.093b	YES		2 Concrete	---	B1041.093b	Non-conforming MF with weak joints and column flexural response, Conc Col & Bm = 36" x 36", Beam both sides	Non-Confo Not
14	C1011.001a	YES		7 Gyp Wall	---	C1011.001a	Wall Partition, Type: Gypsum with metal studs, Full Height, Fixed Below, Fixed Above (Ductil)	Quantity is Norr
15	B2022.001	YES		6 Cladding	---	B2022.001	Curtain Walls - Generic Midrise Stick-Built Curtain wall, Config: Monolithic, Lamination: Unknown, Glass Type: Unknown, Details: A	None Not
16	C3011.002b	YES		8 Int finish	---	C3011.002b	Wall Partition, Type: Gypsum + Ceramic Tile, Partial Height, Fixed Below, Lateral Braced Above (Ductil + Enchape)	Costing ba Norr
17	C1011.004a	YES		7 Masonry wall	---	C1011.004a	Wall Partition, Type: UR masonry Full Height, Fixed Below, Fixed Above (DMI Fragil)	Quantity is Norr
18	C1011.004b	YES		7 Masonry wall	---	C1011.004b	Wall Partition, Type: UR masonry Full Height, Fixed Below, restriained Above, confining RC elements (DES Fragil)	Quantity is Norr
19	C1011.005a	YES		7 Masonry wall	---	C1011.005a	Wall Partition, Type: UR masonry Full Height, Fixed Below, Fixed Above + tyle fragil (DMI Fragil Enchape)	Quantity is Norr
20	C1011.005b	YES		7 Masonry wall	---	C1011.005b	Wall Partition, Type: Conf. masonry Full Height, Fixed Below, restriained Above, confining RC elements + tyle (DES Fragil Enchape	Quantity is Norr
21	C1011.006a	YES		7 Masonry wall	---	C1011.006a	Facade, Type: UR masonry Full Height, Fixed Below, Fixed Above + glass (Fragil DMI)	Quantity is Norr
22	C1011.006b	YES		7 Masonry wall	---	C1011.006b	Facade, Type: Conf. masonry Full Height, Fixed Below, restriained Above, confining RC elements + glass (Fragil DES)	Quantity is Norr
23	D2022.025a	YES		1 HVAC	---	D2022.025a	Gas Piping (dia > 2.5 inches), SDC A or B, PIPING FRAGILITY	Costing ba Norr
24	D2021.011a	YES		1 HVAC	---	D2021.011a	Electrical (2.5 inches in diameter or less), SDC A or B, PIPING FRAGILITY	Costing ba Norr
25	D2022.011a	YES		1 HVAC	---	D2022.011a	Water Piping - Small Diameter Threaded Steel - (2.5 inches in diameter or less), SDC A or B, PIPING FRAGILITY	Costing ba Norr
26	E2022.010	YES		5 Misc	---	E2022.010	Unsecured fragile objects on shelves, unknown restraint (Accel)	Costing to Any
27	E2022.010a	YES		5 Misc	---	E2022.010a	Fragile Contents, doors, windows, unknown restraint (Drift)	Costing to Any
28	B1031.001	YES	4	Steel	---	B1031.001	Bolted shear tab gravity connections	Costing is Not
29								
30								

Input_HELP | Summary | Cost Summary | damage_state | damage_cost_time | Fragility | Costs | Time

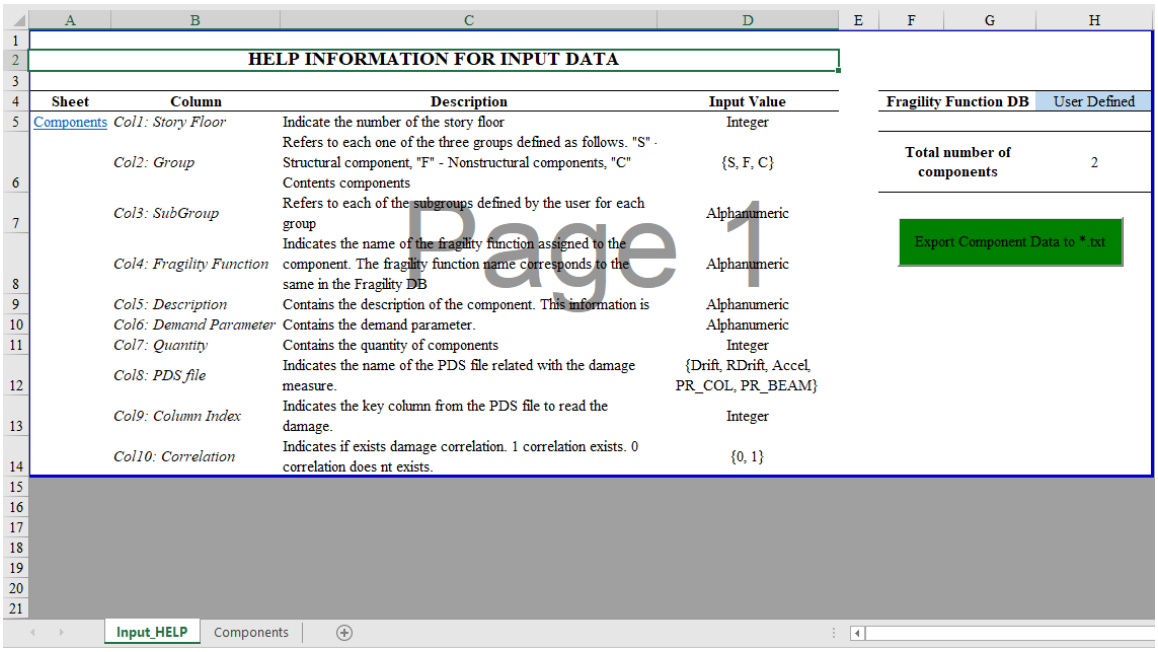
Ready — Average: 0.452424242 Count: 94 Min: 0 Max: 4 Sum: 14.93 — 100%

f. Finally go to the **Input_HELP** sheet and then click on **"Export DB to *.txt" button**. This will open a window asking you for the directory where the Fragility DB files will be saved. Please specify a valid path, then click on "OK" button.



g. Finally, close the file and then, go to the path that you specify and review that the files as listed in section 4.1.1 are in this path. Also, you can compare your results files with the files stored in the **FUNVUL-Components\DB\Tutorial1\ Results_Step_2** path**.**

3. **Setting up the component files.**
   a. Open the folder where do you download the software. Go to **FUNVUL-Components\DB\SETUP**. Open the files **Component_DB.xlsm** and **Fragility_DB_V3.xlsm**. You will get the following window.



HELP INFORMATION FOR INPUT DATA

Sheet	Column	Description	Input Value
Components	*Col1: Story Floor*	Indicate the number of the story floor	Integer
	Col2: Group	Refers to each one of the three groups defined as follows. "S" - Structural component, "F" - Nonstructural components, "C" Contents components	{S, F, C}
	Col3: SubGroup	Refers to each of the subgroups defined by the user for each group	Alphanumeric
	Col4: Fragility Function	Indicates the name of the fragility function assigned to the component. The fragility function name corresponds to the same in the Fragility DB	Alphanumeric
	Col5: Description	Contains the description of the component. This information is	Alphanumeric
	Col6: Demand Parameter	Contains the demand parameter.	Alphanumeric
	Col7: Quantity	Contains the quantity of components	Integer
	Col8: PDS file	Indicates the name of the PDS file related with the damage measure.	{Drift, RDrift, Accel, PR_COL, PR_BEAM}
	Col9: Column Index	Indicates the key column from the PDS file to read the damage.	Integer
	Col10: Correlation	Indicates if exists damage correlation. 1 correlation exists. 0 correlation does nt exists.	{0, 1}

Fragility Function DB	User Defined
Total number of components	2

Export Component Data to *.txt

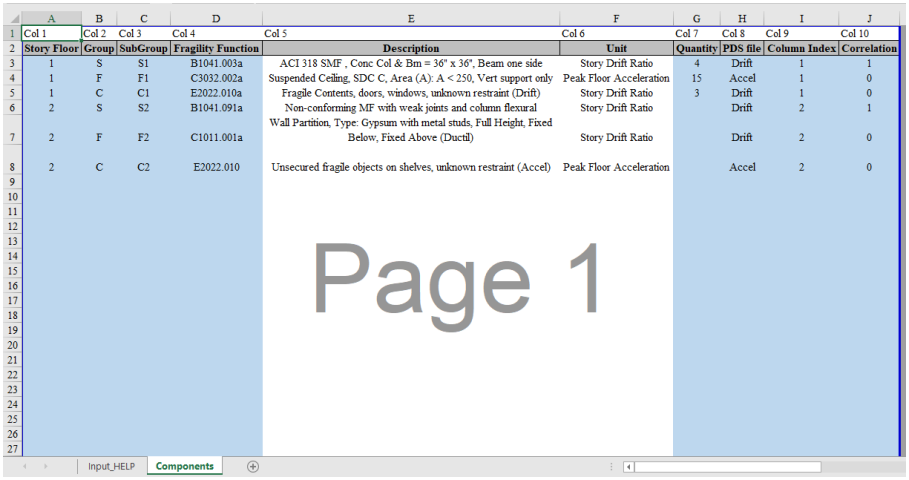
Page 1

Input_HELP | Components

   b. Before to continue, please read all the information given in the "**Input_HELP**" sheet.
   c. In the cell **H5** in the "**Input_HELP**" sheet you can specify the Fragility function DB. Keep in mind that this software uses only the User Defined DB, the FEMA P-58 is just for reference (Refer to step 2 for additional information).
   d. Go to the "**Components**" sheet. Each row represents a component, for additional information refer to section 4.1.3.Then input the following data:

Parameter	Row 3	Row 4	Row 5	Row 6	Row 7	Row 8
Story floor	1	1	1	2	2	2
Group	S	F	C	S	F	C
Subgroup	S1	F1	C1	S2	F2	C2
Fragility Function	B1041.003a	C3032.002a	E2022.010a	B1041.091a	C1011.001a	E2022.010
Quantity	4	15	3	4	10	6
EDP_file	Drift	Accel	Drift	Drift	Drift	Accel
Column Index	1	1	1	2	2	2
Correlation	1	0	0	1	0	0

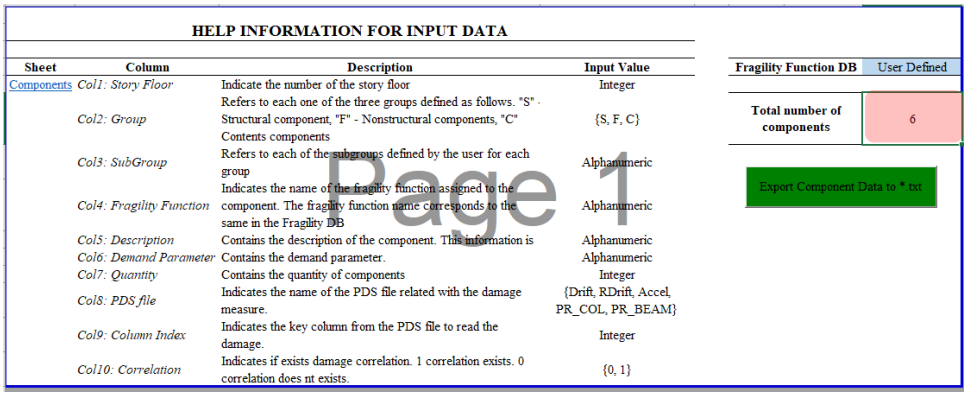
At the end you will get the following:



	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10
2	Story Floor	Group	SubGroup	Fragility Function	Description	Unit	Quantity	PDS file	Column Index	Correlation
3	1	S	S1	B1041.003a	ACI 318 SMF , Conc Col & Bm = 36" x 36", Beam one side	Story Drift Ratio	4	Drift	1	1
4	1	F	F1	C3032.002a	Suspended Ceiling, SDC C, Area (A): A < 250, Vert support only	Peak Floor Acceleration	15	Accel	1	0
5	1	C	C1	E2022.010a	Fragile Contents, doors, windows, unknown restraint (Drift)	Story Drift Ratio	3	Drift	1	0
6	2	S	S2	B1041.091a	Non-conforming MF with weak joints and column flexural	Story Drift Ratio		Drift	2	1
7	2	F	F2	C1011.001a	Wall Partition, Type: Gypsum with metal studs, Full Height, Fixed Below, Fixed Above (Ductil)	Story Drift Ratio		Drift	2	0
8	2	C	C2	E2022.010	Unsecured fragile objects on shelves, unknown restraint (Accel)	Peak Floor Acceleration		Accel	2	0

Input_HELP | Components

e. Now go to "**Input_HELP**" sheet. Then verify that the total number of components given in the cell **H6** is 6.



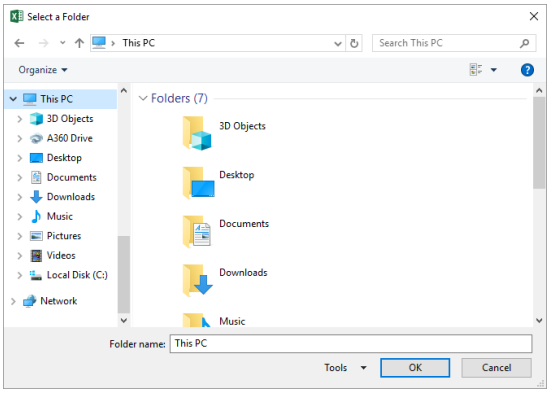
HELP INFORMATION FOR INPUT DATA

Sheet	Column	Description	Input Value
Components	*Col1: Story Floor*	Indicate the number of the story floor	Integer
	Col2: Group	Refers to each one of the three groups defined as follows. "S" - Structural component, "F" - Nonstructural components, "C" Contents components	{S, F, C}
	Col3: SubGroup	Refers to each of the subgroups defined by the user for each group	Alphanumeric
	Col4: Fragility Function	Indicates the name of the fragility function assigned to the component. The fragility function name corresponds to the same in the Fragility DB	Alphanumeric
	Col5: Description	Contains the description of the component. This information is	Alphanumeric
	Col6: Demand Parameter	Contains the demand parameter.	Alphanumeric
	Col7: Quantity	Contains the quantity of components	Integer
	Col8: PDS file	Indicates the name of the PDS file related with the damage measure.	{Drift, RDrift, Accel, PR_COL, PR_BEAM}
	Col9: Column Index	Indicates the key column from the PDS file to read the damage.	Integer
	Col10: Correlation	Indicates if exists damage correlation. 1 correlation exists. 0 correlation does nt exists.	{0, 1}

Fragility Function DB	User Defined
Total number of components	6

Export Component Data to *.txt

f. Then click on **"Export Component Data to *.txt" button**. This will open a window asking you for the directory where the Fragility DB files will be saved. Please specify a valid path, then click on "OK" button.

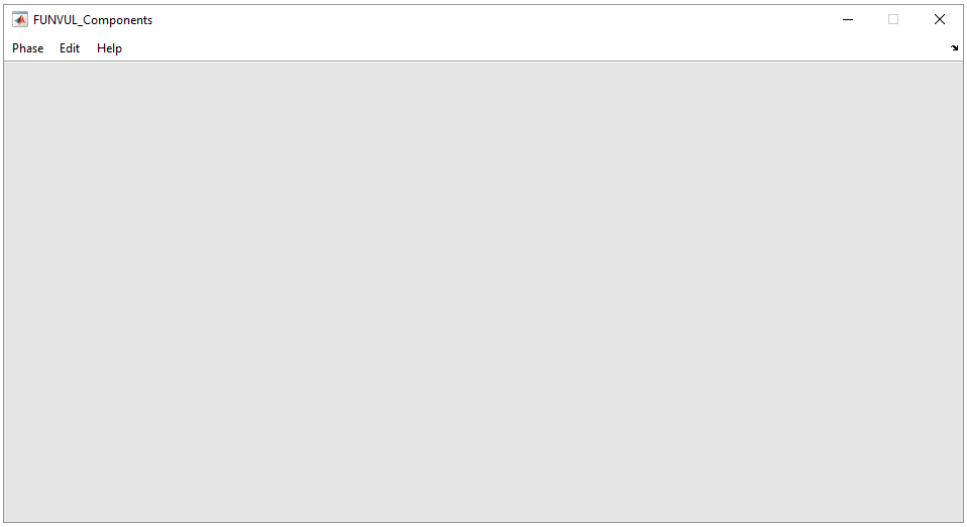


g. Finally, close the file and then, go to the path that you specify and review that the file as listed in section 4.1.3 are in this path. Also, you can compare your results files with the files stored in the **FUNVUL-Components\DB\Tutorial1\ Results_Step_3** path**.**

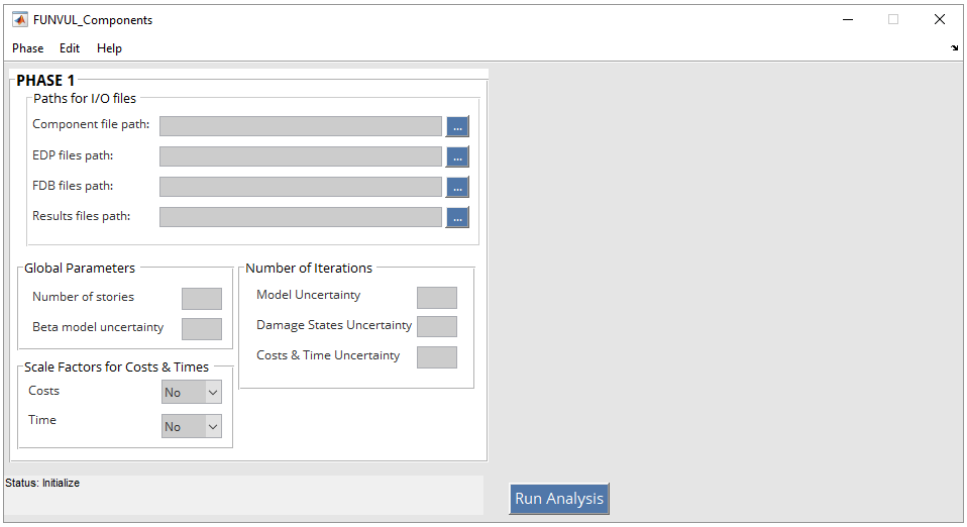
6.2. Tutorial 2: Phase 1

This tutorial shows you how to obtain the results from Phase 1 to create the vulnerability function. The step you must follows are the followings:

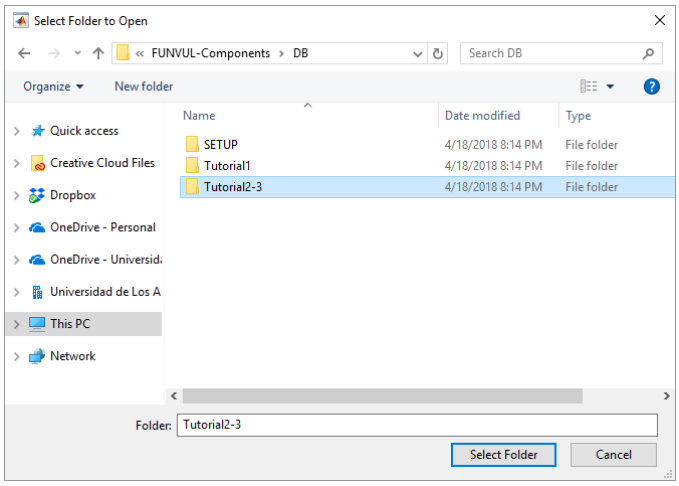
1. Open the **FUNVUL Components** software. For this click on FUNVULComponents.exe file in the path **FUNVUL-Components\Software**. Wait until the program is loaded completely. Once the program is loaded completely you will get the following window:



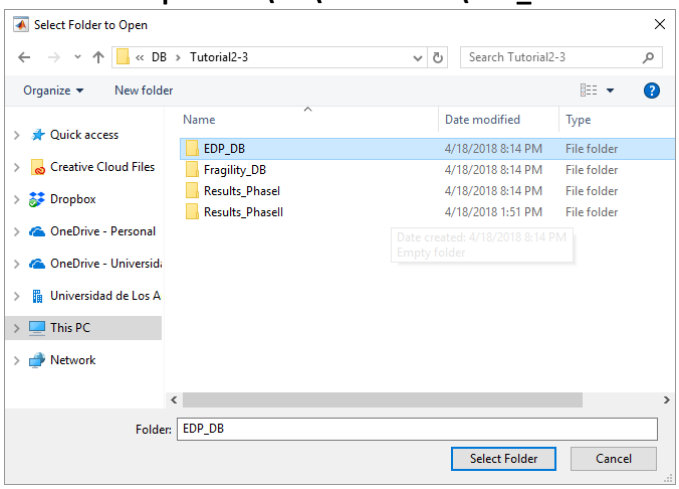
2. Go to and click on **Phase\Phase 1** on the Menu. It will display the following:



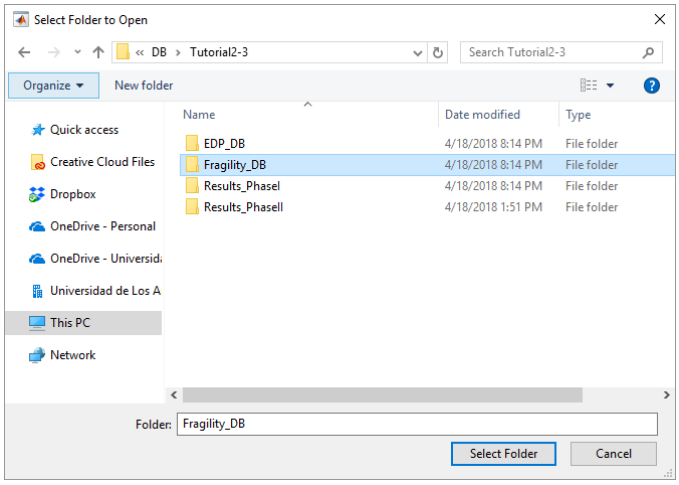
3. Specify the component file: For this click on the **"…"** button that is close to the input field Component file path. Then a new window will be opened. In this window select the folder **FUNVUL-Components\ FUNVUL-Components\DB\Tutorial2-3**.



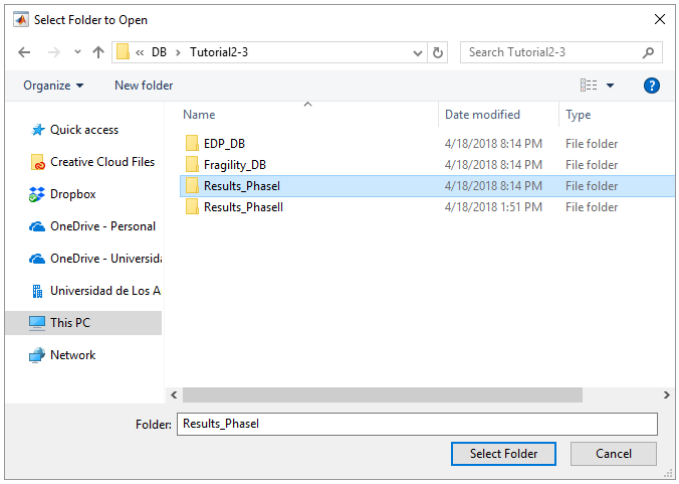
4. Specify EDP DB: For this click on the **"…"** button that is close to the input field EDP files path. Then a new window will open. In this window select the folder **FUNVUL-Components\ FUNVUL-Components\DB\Tutorial2-3\EDP_DB**.



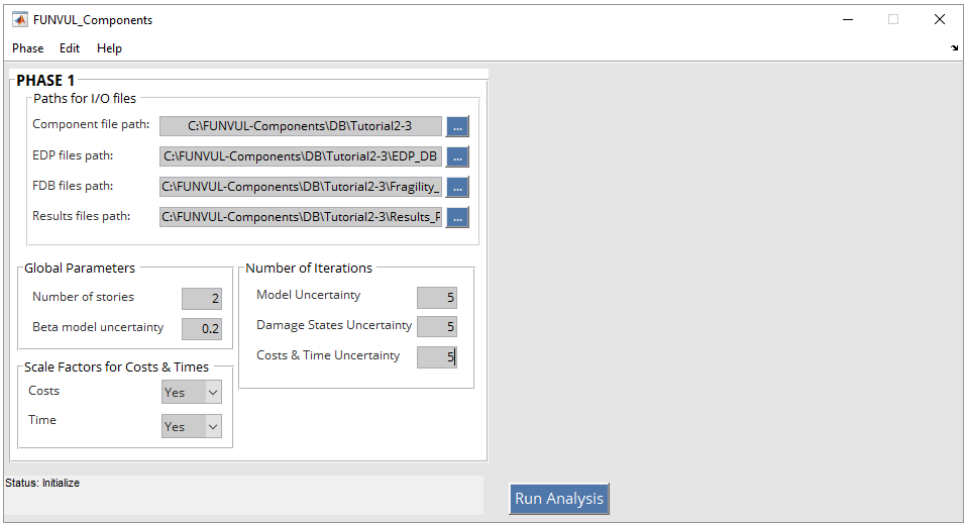
5. Specify Fragility function DB: For this click on the **"…"** button that is close to the input field FDB files path. Then a new window will open. In this window select the folder **FUNVUL-Components\ FUNVUL-Components\DB\Tutorial2-3\Fragility_DB**.



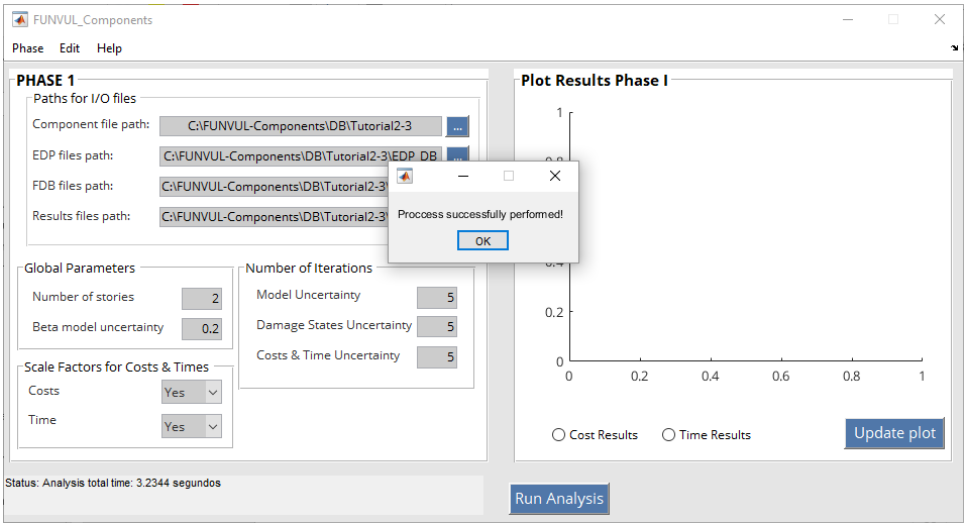
6. Specify Results path: For this click on the **"…"** button that is close to the input field FDB files path. Then a new window will open. In this window select the folder **FUNVUL-Components\ FUNVUL-Components\DB\Tutorial2-3\Results_Phase1**.



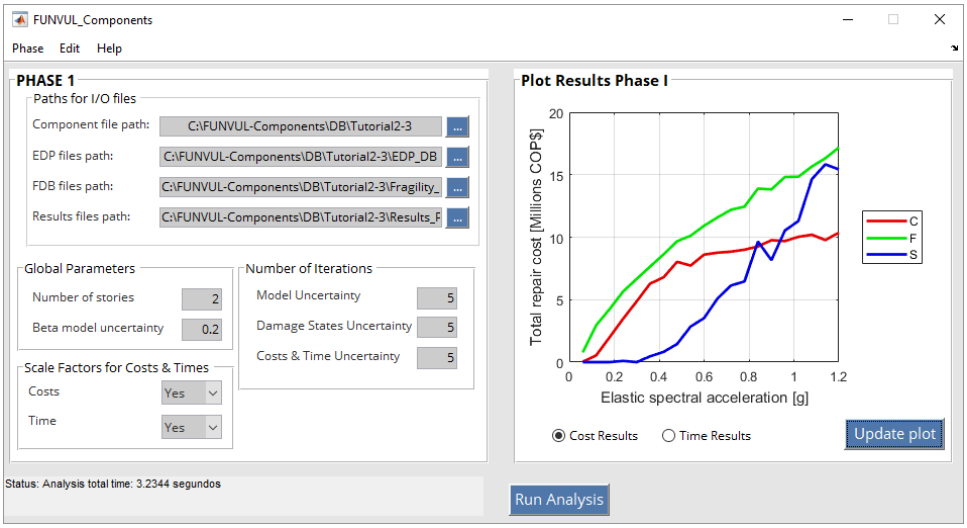
7. In the input box for number of stories please input the value **2**.
8. To specify the other input parameters, please click on **Edit\Default Values**. After that, it will display the following:



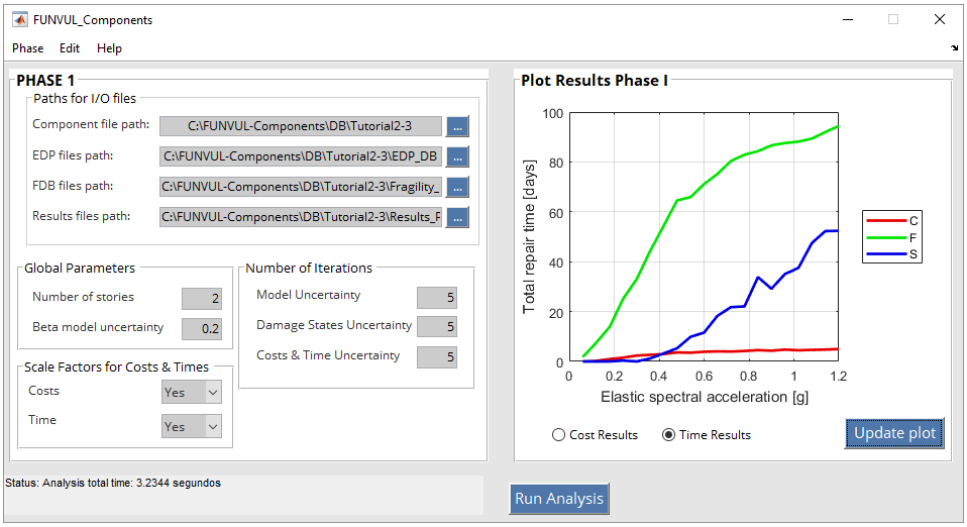
9. Now click on the **Run Analysis button**. Wait until the program finished the analysis. IT will be display the following windows:



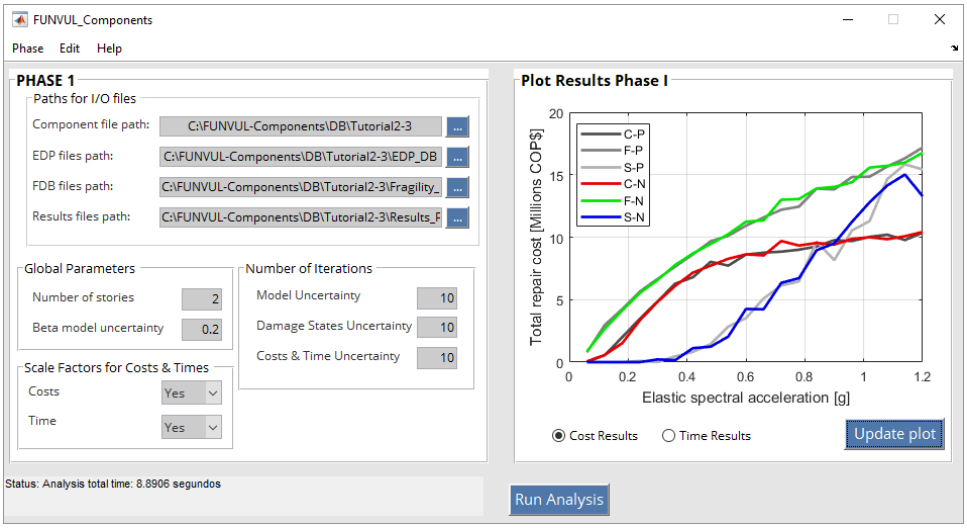
10. Click on the **OK button**.
11. To visualize Cost results please select in the graph area the "**Cost Results**" radio button. Then click on the "**Update plot**" button. After that, you will get the following.



12. To visualize Time results please select in the graph area the "**Time Results**" radio button. Then click on the "**Update plot**" button. After that, you will get the following.



13. Now modify the number of iterations for all three inputs box to 10. Then click on “Run Analysis” button. Then visualize the cost results (repeat the process in step 11). You will get the following results:

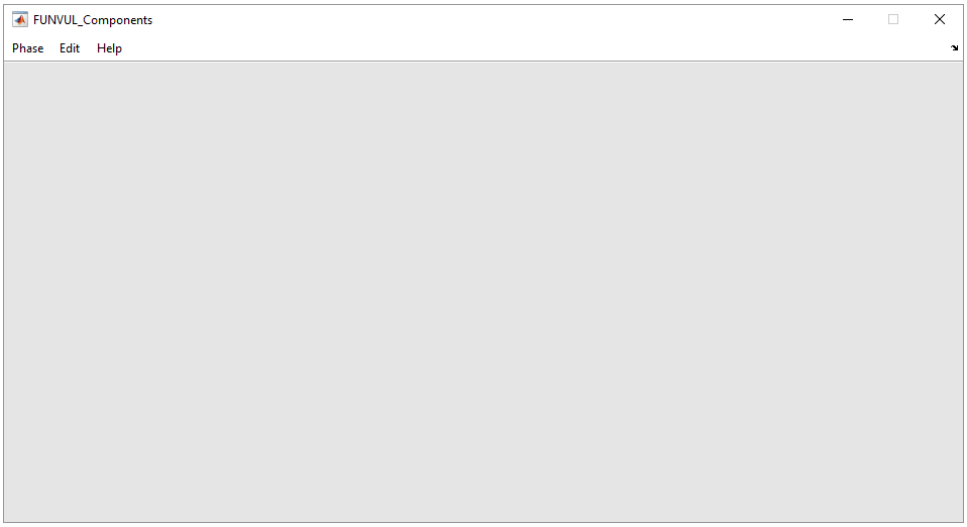


It displays the previous iteration in gray scale. With this you can compare between two analyses.

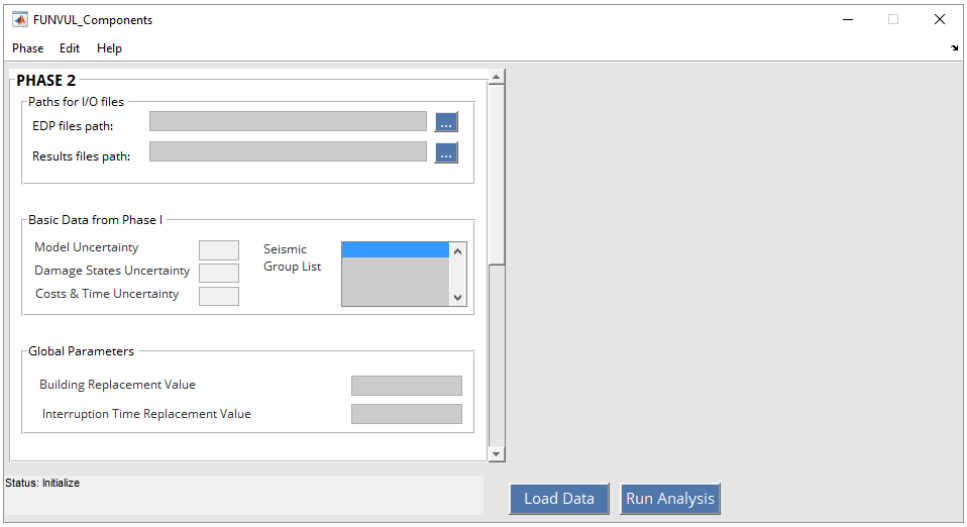
6.3. Tutorial 3: Phase 2

This tutorial shows you how to obtain the results from Phase 2 to obtain the final vulnerability function. The step you must follows are the followings:

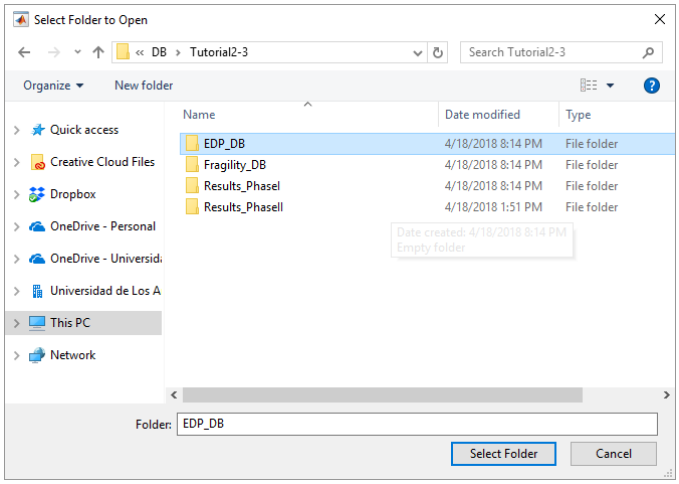
1. Open the **FUNVUL Components** software. For this click on FUNVULComponents.exe file in the path **FUNVUL-Components\Software**. Wait until the program is loaded completely. Once the program is loaded completely you will get the following window:



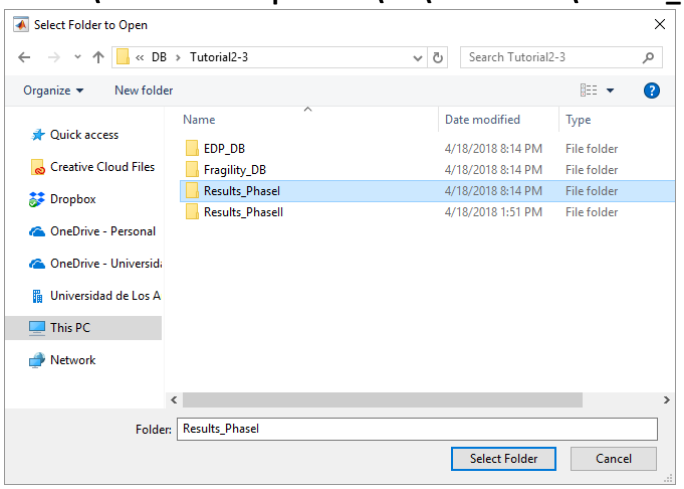
2. Go to and click on **Phase\Phase 2** on the Menu. It will display the following:



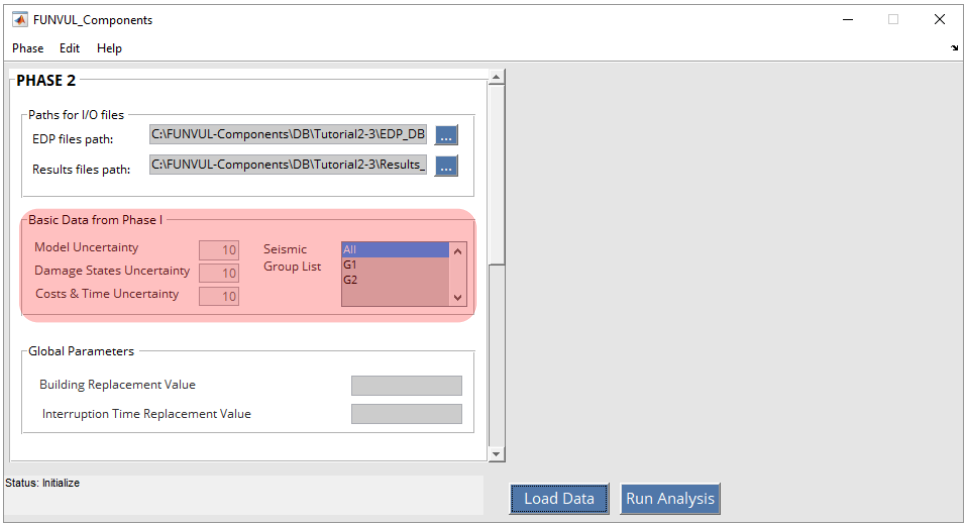
3. Specify EDP DB: For this click on the **"…"** button that is close to the input field EDP files path. Then a new window will open. In this window select the folder **FUNVUL-Components\ FUNVUL-Components\DB\Tutorial2-3\EDP_DB**.



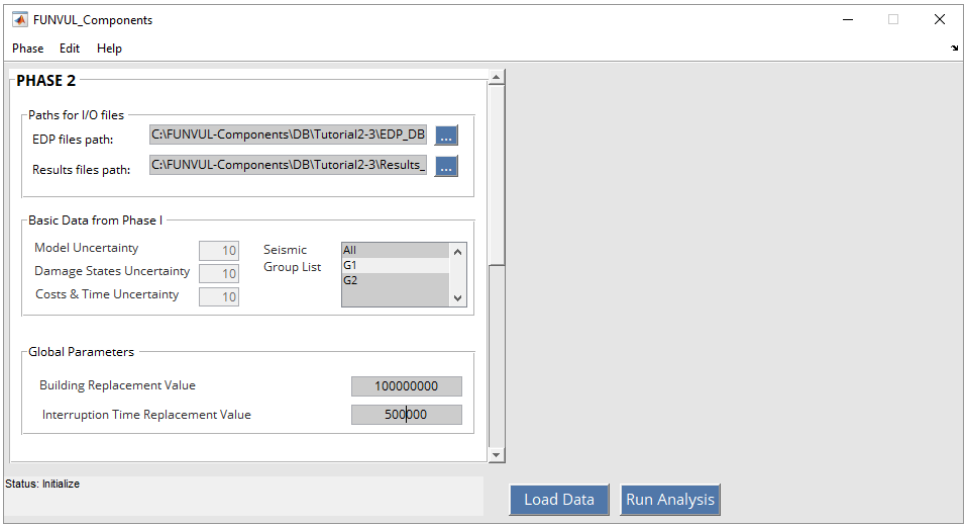
4. Specify Results path from Phase I: For this click on the **"…"** button that is close to the input field FDB files path. Then a new window will open. In this window select the folder **FUNVUL-Components\ FUNVUL-Components\DB\Tutorial2-3\Results_PhaseI**.



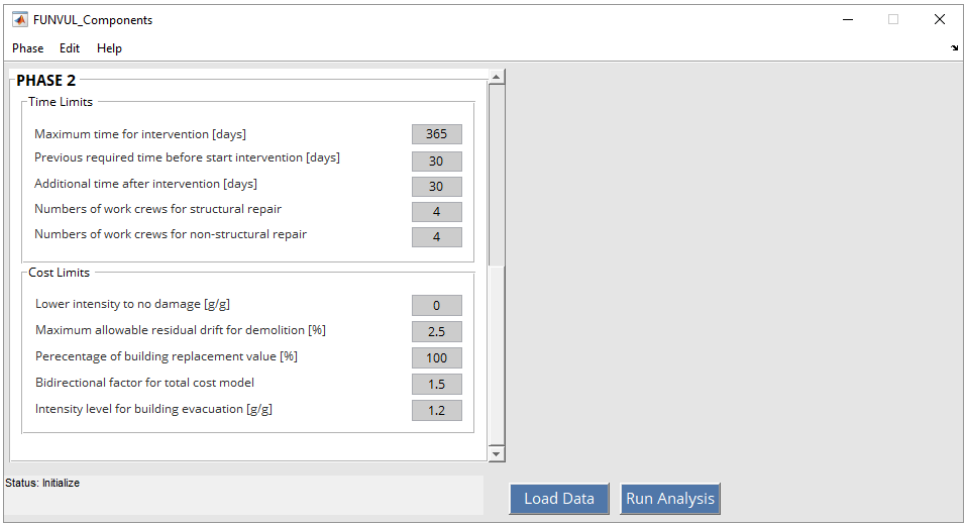
5. Click on the "**Load Data**" **button**. Once the process has be finished it will fill out the data "**Basic Data from Phase I**", the number of iterations and the seismic group list will be updated. In the Seismic Group List you can select which groups will be included for the analysis. It will display the following results:



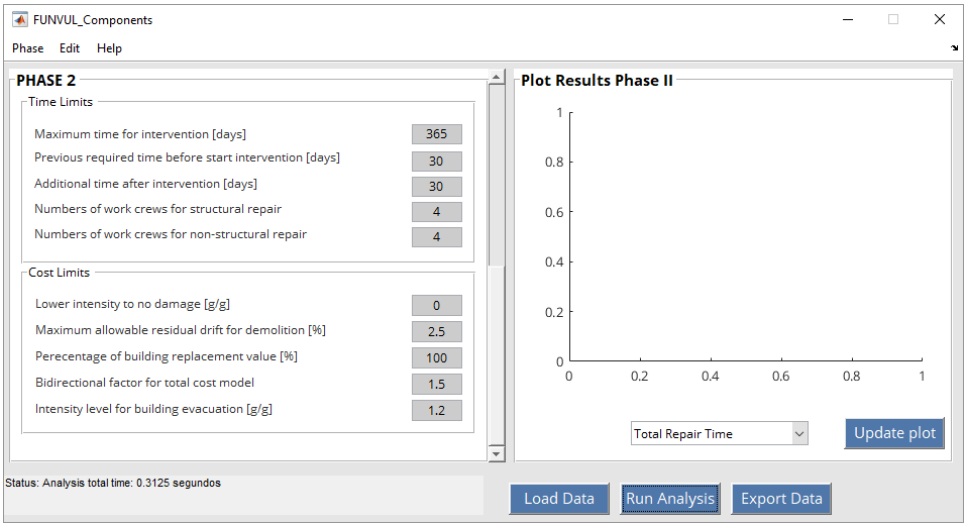
6. Select **G1** from the **Seismic Group List**.
7. Specifying the **Global Parameters**. Input the following values:
   Building Replacement Value: 100,000,000 (you must avoid use any digit grouping symbol).
   Interruption Time Replacement Value: 500,000 (you must avoid use any digit grouping symbol).



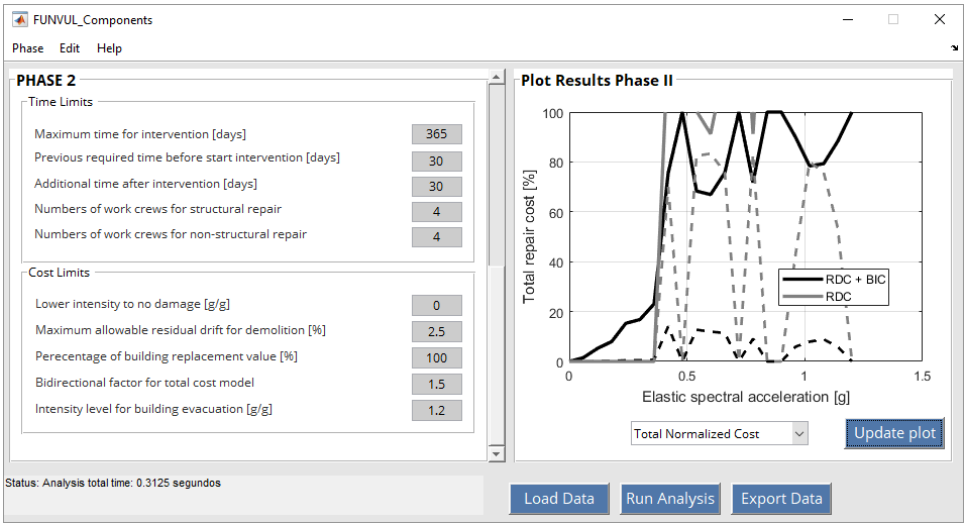
8. Click on the slide bar. Then to specify the additional input parameters, click on **Edit\Default Values**. After that, it will display the following:



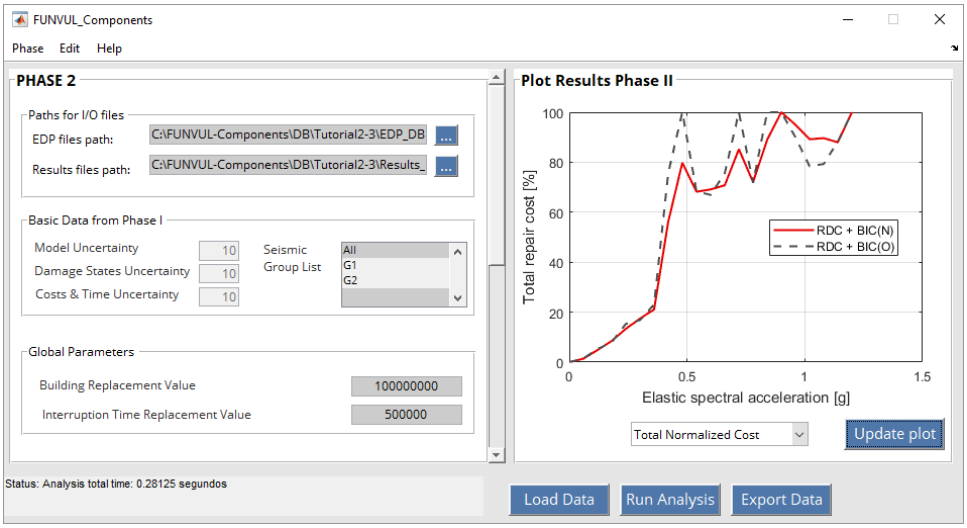
9. Now click on the **Run Analysis button**. Wait until the program finished the analysis. IT will be display the following windows:



10. To visualize results you can select one option from the drop-down list. For this case select "**Total Normalized Cost**". Then click on the "**Update plot**" button. After that, you will get the following.

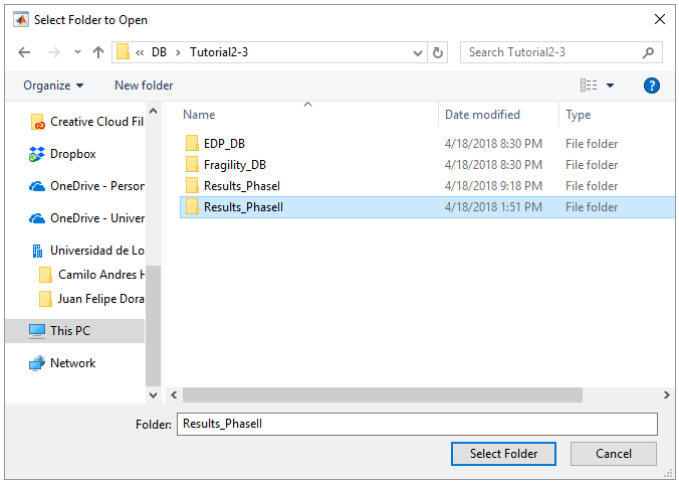


11. Now select **G1 and G2** from the Seismic Group List. Then click on "**Run Analysis**" button. Then visualize the total normalized cost results (repeat the process in step 10). You will get the following results:

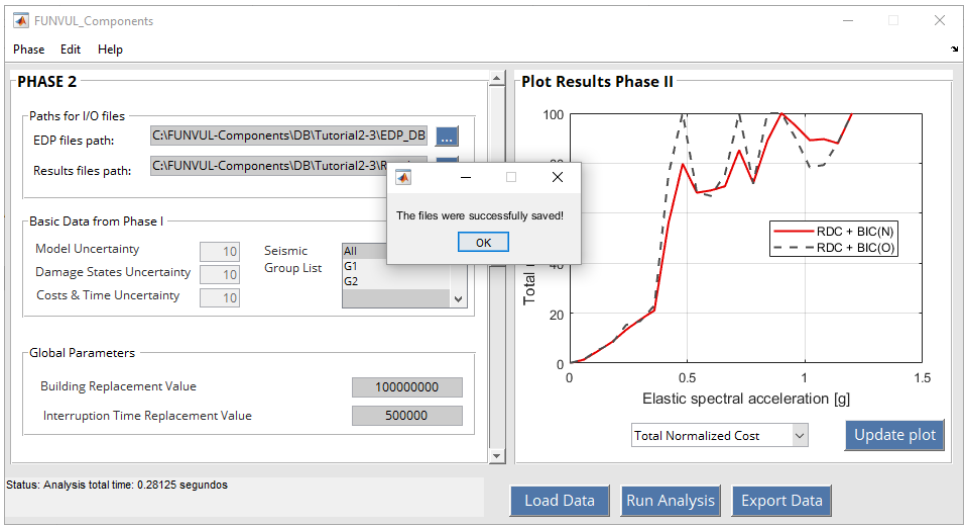


It displays the previous iteration in gray scale. With this you can compare between two analyses.

12. Finally, click on the Export Data button. You will export the results from Phase II to a editable txt formats as specified in the section 5.2. A new window will be open. You must select the path where it will be stored the files. Select the **C:\FUNVUL-Components\DB\Tutorial2-3\Results_PhaseII**.



After you select the folder, it will display a new window with the message that "The files were successfully saved!". Then click on OK button.



13. Now go to the **C:\FUNVUL-Components\DB\Tutorial2-3\Results_PhaseII** path. You will find the five files are specified in the section 5.2.

Chapter 7

Problems and errors

The main problems and errors produced during the use of this software can be related to the followings issues.

Error Message	Description	Solution
Your computer does not have installed the MATLAB Runtime version 9.2 (R2017a)	The MATLAB Runtime is not installed and ensure you have installed version 9.2 (R2017a)	See instructions in section 2.1.2
You must select a valid directory!	This occur when you do not specify a valid path.	Select or specify a valid path.
The Components.txt file does not exist!	This occur when the required file does not exist in the Component Path.	Verify that the file is stored at this path.
You must define a valid directory for Component Data!	This occur when you do not specify a valid path.	Select or specify a valid path.
The IML.txt file does not exist!	This occur when the required file does not exist in the EDP DB Path.	Verify that the file is stored at this path.
The Drift.txt file does not exist!	This occur when the required file does not exist in the EDP DB Path.	Verify that the file is stored at this path.
The RDrift.txt file does not exist!	This occur when the required file does not exist in the EDP DB Path.	Verify that the file is stored at this path.
The Accel.txt file does not exist!	This occur when the required file does not exist in the EDP DB Path.	Verify that the file is stored at this path.
The PR_COL.txt file does not exist!	This occur when the required file does not exist in the EDP DB Path.	Verify that the file is stored at this path.
The PR_BEAM.txt file does not exist!	This occur when the required file does not exist in the EDP DB Path.	Verify that the file is stored at this path.
You must define a valid directory for EDP Data!	This occur when you do not specify a valid path.	Select or specify a valid path.
The damage_state.txt file does not exist!	This occur when the required file does not exist in the FDB Path.	Verify that the file is stored at this path.
The damage_cost_time.txt file does not exist!	This occur when the required file does not exist in the FDB Path.	Verify that the file is stored at this path.
You must define a valid directory for Fragility Specification Data!	This occur when you do not specify a valid path.	Select or specify a valid path.
You must define a valid directory for save Results Data!	This occur when you do not specify a valid path.	Select or specify a valid path.
You must define a numeric value greater than 0 for number of stories!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of stories!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of beta uncertainty model!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of beta uncertainty model	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of iterations for model uncertainty!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of iterations for model uncertainty!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of iterations for damage state uncertainty!	The input value is wrong.	Refers to Table 1. For format type and valid values.

Error Message	Description	Solution
You must define a numeric value greater than 0 for number of iterations for damage state uncertainty!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of iterations for cost & time model uncertainty!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a numeric value greater than 0 for number of iterations for cost & time model uncertainty!	The input value is wrong.	Refers to Table 1. For format type and valid values.
You must define a valid directory for obtain and save Results Data!	This occur when you do not specify a valid path.	Select or specify a valid path.
The Building replacement value must be positive!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The Interruption time replacement value must be positive!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Lower intensity limit to no damage must be zero or greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Maximum allowable residual drift for demolition must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The Percentage of building replacement value must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Bidirectional factor for total cost model must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Intensity level for building evacuation must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Maximum time for intervention must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Previous required time before start intervention must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Additional time after intervention must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Numbers of work crews for structural repair must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.
The value of Numbers of work crews for non-structural repair must be greater than zero!	The input value is wrong.	Refers to Table 1. For format type and valid values.

If you get any other error from those listed above, please send an email to ecapra@uniandes.edu.co. Please include a short description of the error.

Chapter 8

References

FEMA. 2012. Next-Generation Methodology for Seismic Performance Assessment of Buildings. Report No. FEMA P-58. Prepared by the Applied Technology Council (ATC) for the Federal Emergency Management Agency, Washington, D.C.

Yamin, Luis E., Alvaro Hurtado, Raul Rincon, Juan F. Dorado, and Juan C. Reyes. 2017. "Probabilistic seismic vulnerability assessment of buildings in terms of economic losses." *Engineering Structures* 138:308-323. doi: http://dx.doi.org/10.1016/j.engstruct.2017.02.013.