The Resilience and Disaster Recovery Tool Suite

Quick Start Tutorial Version 2022.1

Volpe Project: OS20A121

Final Report — August 2022

VNTSC-OST-22-03

DOI: 10.21949/1527574

Prepared for:

United States Department of Transportation
Office of Research, Development, and Technology
Washington, D.C.

The Federal Highway Administration
Office of Natural Environment
Washington, D.C.

Recommended citation:

Jonathan Badgley, Daniel Flynn, Olivia Gillham, Michelle Gilmore, Kristin C. Lewis (Project Manager), Alexander Oberg, Gretchen Reese, Scott Smith, Kevin Zhang. The Resilience and Disaster Recovery Tool Suite: Quick Start Tutorial Version 2022.1. Volpe National Transportation Systems Center, Cambridge, MA, 2022. DOI: 10.21949/1527574

Notice

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE August 2022	3. REPORT TYPE AND DATES COVERED Tutorial (6/2021-8/2022)

4. TITLE AND SUBTITLE The Resilience and Disaster Recovery Tool Suite: Quick Start Tutorial Version 2022.1	5a. FUNDING NUMBERS OS20A121
6. AUTHOR(S) Jonathan Badgley, Daniel Flynn, Olivia Gillham, Michelle Gilmore, Kristin C. Lewis (Project Manager), Alexander Oberg, Gretchen Reese, Scott Smith, Kevin Zhang	5b. CONTRACT NUMBER 693JK421NT800008
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation John A Volpe National Transportation Systems Center 55 Broadway, Cambridge, MA 02142-1093	8. PERFORMING ORGANIZATION REPORT NUMBER VNTSC-OST-22-03
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) US Dept. of Transportation Office of Research, Development and Technology 1200 New Jersey Ave, SE, Washington, DC 20590	10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOI: 10.21949/1527574
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public at https://volpeusdot.github.io/RDR-Public.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Volpe developed the Resilience and Disaster Recovery (RDR) Tool Suite in support of the USDOT Office of Research, Development and Technology in collaboration with the Federal Highway Administration's Office of Natural Environment. The RDR Tool Suite enables transportation practitioners to assess the return-on-investment of resilient infrastructure across a range of potential hazard conditions to help prioritize resilience investments. This Quick Start Tutorial guides users through a suite of example RDR scenarios to confirm successful installation and demonstrate RDR functionality. It is complemented by the RDR Tool Suite Technical Document, User Guide, and Run Checklist.

14. SUBJECT TERMS	15. NUMBER OF PAGES 12 16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)

Prescribed by ANSI Std. 239-18

298-102

Contents

1 Quick Start Tutorial: Running the RDR Tool Suite 5
1.1 Quick Start 1: Running the RDR Metamodel and ROI Analysis Module together 6
1.2 Quick Start 2: Running the RDR ROI Analysis Module separately 9
1.3 Quick Start 3: Expanding the scenario space and using existing core model runs 11

1 Quick Start Tutorial: Running the RDR Tool Suite

This document walks through a suite of quick start analyses using sample data provided with the RDR Tool Suite. Each quick start analysis provides an example of one way the user can conduct an RDR run: Quick Start 1 corresponds to a full run (Section 3.1 of the User Guide), Quick Start 2 corresponds to an analysis run (Section 3.2 of the User Guide), and Quick Start 3 corresponds to an additional run (Section 3.3 of the User Guide). All three quick starts use a toy road network for demonstration purposes, and their input data can be used as templates for custom scenarios the user may wish to run. The sample input files, network data, and batch files for the Quick Start examples are included with the code download from the RDR repository on GitHub (https://volpeusdot.github.io/RDR-Public). The RDR Technical Document, User Guide, and a Scenario Run Checklist can also be found on GitHub in the "`documentation`" folder.

Installation instructions for the RDR Tool Suite can be found in the User Guide, as well as documentation on how to configure components of the tool suite to set up a new scenario. For documentation of the models and technical specifications of the RDR Tool Suite, please reference the Technical Document. The user is also encouraged to use the Scenario Run Checklist as a final comprehensive list of input data elements to double-check before running a new scenario.

The RDR directory should contain a "`quick_starts`" subfolder. Inside the "`quick_starts`" subfolder should be a set of three Quick Start examples, as seen in Figure 1; each example is detailed in a subsequent section. The Quick Start examples are constructed to be run sequentially, and each example demonstrates a different aspect of the RDR Tool Suite functionality.

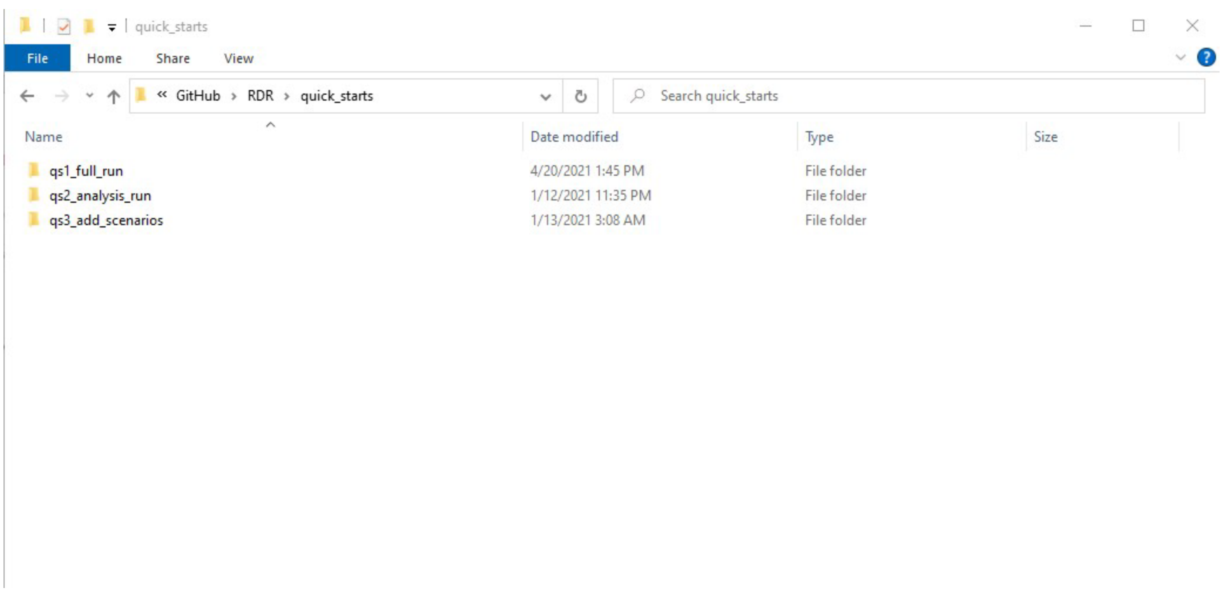


Figure 1: Quick Start Folder Structure

Each Quick Start example includes a batch file, a configuration file, and the required input files to run the analysis. In order to run each Quick Start example, the user needs to confirm the configuration file points to the correct input and output folder paths for the Quick Start example. In addition, the user should confirm the environment variables of the batch file are correct for the user's setup (as described in Section 3 of the User Guide). These sample Quick Start scenarios can be used to verify the RDR Tool Suite installation is fully functional, as well as provide examples of input and output files for reference.

1.1 Quick Start 1: Running the RDR Metamodel and ROI Analysis Module together

Purpose: Quick Start 1 presents a simple analysis with a small scenario space and demonstrates how to run a full run of the RDR Tool Suite, including the RDR Metamodel and the RDR ROI Analysis Module.

Instructions: To run the Quick Start 1 scenario, execute the batch file `'run_rdr_full.bat'` in the `"quick_starts\qs1_full_run"` subfolder. The run will complete a full run of the RDR Tool Suite, including 6 runs of AequilibraE, and should take about 1 minute. A full description of the analysis is below, including the expected results.

The user should be able to run the batch file once they have modified the `PATH` and `PYTHON` environment variables in the batch file, without needing to change the configuration file as long as the user's RDR directory is located at `"C:\GitHub\RDR"`; otherwise the user will also need to modify the 'input_dir' and 'output_dir' parameters in the configuration file, the `RDR` and `CONFIG` environment variables in the batch file, and the `cd` change directory command in the batch file. The batch file is set to pause at the end of the run so the user can see the terminal window output.

Input Data: As seen in the `'Model_Parameters.xlsx'` input file, Quick Start 1 executes an ROI analysis considering 3 potential resilience projects (a highway project completely mitigating hazard exposure on 2 network links labeled 'L2-7', a highway project completely mitigating hazard exposure on 2 network links labeled 'L8-9_comp', and a highway project mitigating hazard exposure up to 1.5 feet on the same 2 network links labeled 'L8-9_part'), plus the baseline scenario with no resilience investment, within 1 project group (given the arbitrary value '02'). (Note that this example uses only one project group—if the user does not have multiple network files associated with different project groups, they can group all resilience projects in one project group labeled with an arbitrary value.) The resilience projects 'L8-9_comp' and 'L8-9_part' both cover the same asset (the link from Node 8 to Node 9) but mitigate different levels of hazard exposure at different project costs.

There are 2 possible flooding hazard events ('haz1' represents a 10-year river flooding event and 'haz2' represents a 1-year river flooding event) and 2 possible recovery stages for each hazard event (labeled 0 for the initial hazard severity and 1 for an intermediate hazard recession stage). There is only one possible future economic scenario (labeled 'base') and one possible trip loss elasticity (-1) to consider.

As seen in the configuration file, this analysis specifies 6 AequilibraE core model runs ('lhs_sample_target' parameter is set to 6 in the configuration file). The minimum number of core model runs is 4 since that is the maximum number of possible values for an uncertainty parameter (there are 4 possible values for 'Resiliency Projects' including the baseline scenario). AequilibraE is set to use the shortest path algorithm ('SP') to create core model outputs. The RDR Metamodel is set to use a simple regression model ('base') to expand the core model runs to cover the entire scenario space.

Also seen in the configuration file, this Quick Start example uses the default depth-disruption function adapted from Pregnolato et al. for the exposure to disruption calculation, the default depth-damage function adapted from Simonovic et al. for the exposure to damage calculation, and default repair cost and repair time look-up tables located in the `"config"` subfolder of the RDR directory. Resilience project disruption and damage mitigation is user-specified through the 'Exposure Reduction' column in the project table input CSV file to allow for partial mitigation modeling.

Additional parameters for the recovery module specify a minimum initial hazard event duration of 4 days and a maximum duration of 8 days, with two hazard recovery cases (4 days and 8 days) and a hazard recession period specified to be 4 days.

The ROI analysis is run for an analysis period of 2020 to 2045, with base year core model runs specified for 2017, a future year indicated as 2045, and costs all in 2018 dollars. Other parameters are found in the configuration file (discounting factor, vehicle occupancy rate, etc.) and the user inputs file (1 and 1.001 event frequency factors).

Results: The user should examine the log files in the "`logs`" folder and the output report in the "`Reports`" folder generated by the run to check that it completed successfully. The log files are also useful to understand more about what happens within each module. Every module creates its own log file with informational messages and any errors encountered during the run. Figure 2 shows the log file for the 'lhs' module.

```
lhs_log_QS1_2022_07_26_12-33-47.log
07-26 12:33:47.046 INFO     =========================================================================
07-26 12:33:47.047 INFO     ============== RDR RUN STARTING.  Run Option = LHS ====================
07-26 12:33:47.047 INFO     =========================================================================
07-26 12:33:47.829 INFO     Calling the Latin hypercube sampling method
07-26 12:33:47.829 INFO     Start: latin hypercube module
07-26 12:33:47.830 INFO     Start: check_model_params_coverage
07-26 12:33:51.089 INFO     Finished: check_model_params_coverage
07-26 12:33:51.165 CONFIG   List of economic scenarios:     base
07-26 12:33:51.166 CONFIG   List of project groups:     02
07-26 12:33:51.166 CONFIG   List of elasticities:   -1.0
07-26 12:33:51.167 CONFIG   List of hazards:    haz2, haz1
07-26 12:33:51.168 CONFIG   List of recovery stages:    1, 0
07-26 12:33:51.168 CONFIG   List of resilience projects:    L2-7, no, L8-9_part, L8-9_comp
07-26 12:33:51.181 DEBUG    Number of project groups not matched to resilience projects: 0
07-26 12:33:51.184 DEBUG    Size of full scenario space: (16, 6)
07-26 12:33:51.190 RESULT   Full scenario space written to C:\GitHub\RDR\quick_starts\qs1_full_run\Data\generated_files\full_combos_QS1.csv
07-26 12:33:53.851 INFO     Finished: latin hypercube module
07-26 12:33:53.852 INFO     ======================== RDR RUN FINISHED.  LHS ==================================
07-26 12:33:53.852 INFO     ======================== Total Runtime (HMS):   00:00:06
07-26 12:33:53.853 INFO     =================================================================================
07-26 12:33:53.853 RUNTIME  lhs Step - Total Runtime (HMS):     00:00:06
```

Figure 2: Log file for 'lhs' module for Quick Start 1

The report summarizes the outputs of the run. It is divided into six possible sections: (1) scenario, which notes the Run ID and RDR version for the run, (2) total runtime, which reports runtimes for each module, (3) results, which lists off output files, their locations, and the modules they were created by, (4) config, which specifies the configuration parameters for the run, (5) error, which lists all error messages if any, (6) warning, which lists all warning messages, if any, created by the modules.

The main output files are the XLSX file '`tableau_input_file_QS1.xlsx`' that can be analyzed using data analysis software like Excel and the Tableau workbook '`tableau_dashboard.twbx`' of dashboard reports (found in a timestamped "`tableau_report`" subfolder of the "`Reports`" subfolder of the output directory). The HTML file '`rdr_Metamodel_Regression_QS1.html`' provides details and evaluation of fit for the regression module of the RDR Metamodel. The uncertainty parameters specified in the '`UserInputs.xlsx`' for the ROI analysis lead to 32 total uncertainty scenarios, as seen in the '`uncertainty_scenarios.csv`' output file. The economic analysis output for these uncertainty scenarios can be seen in Figure 3 in the Summary dashboard of the Tableau data visualization. Note that net benefits and benefit-cost ratios may not exactly match due to the randomness of the Latin hypercube sampling module.

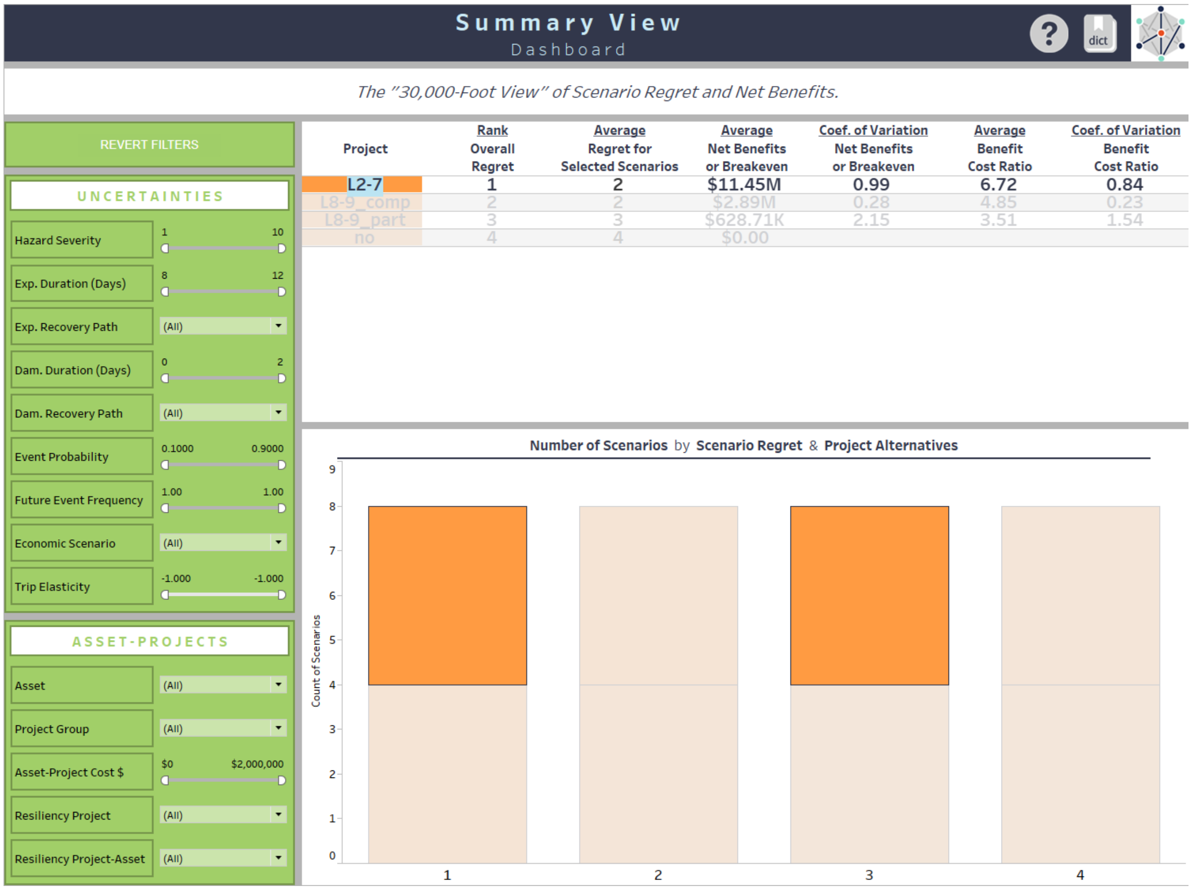


Figure 3: Summary Dashboard for Quick Start 1

The Summary dashboard shows that Project 'L2-7' is ranked first by overall regret across all scenarios in the scenario space. Project L8-9_comp is ranked second and Project 'L8-9_part' is ranked third, with the no-action baseline scenario ranked last with zero net benefits. The 'L2-7' project, which has the best overall regret ranking, is highlighted. The bar graph highlights that the 'L2-7' project has regret ranking of 1 in four scenarios and regret ranking of 3 in four scenarios.

1.2 Quick Start 2: Running the RDR ROI Analysis Module separately

Purpose: In this Quick Start example, the user can test out a series of analysis runs, changing the subset of uncertainty scenarios analyzed and/or other user parameters (recovery and ROI analysis parameters in the configuration file), using the regression model that has already been built during the RDR Metamodel run in Quick Start 1. This example shows how the user can run several other analyses by only changing the configuration file and the user inputs file, without re-fitting the regression model.

Instructions: Because Quick Start 2 relies on the regression model built in Quick Start 1, the user first needs to **manually copy over the regression model output file**, `'Metamodel_scenarios_SP_futureyear_QS1.csv'`, **from the output data folder of Quick Start 1** (e.g., `"C:\GitHub\RDR\quick_starts\qs1_full_run\Data\generated_files"`) **to the output data folder for each of the three Quick Start 2 examples** (e.g., `"C:\GitHub\RDR\quick_starts\qs2_analysis_run\Example_A\Data\generated_files"`), and **rename the file with the correct Run ID** (e.g., `'Metamodel_scenarios_SP_futureyear_QS2ExA.csv'`). The user will need to manually create the output data folder (`"generated_files"` subfolder) for each of the three Quick Start 2 examples before copying over the regression model file. If changes are made to Quick Start 1, the user must manually re-copy the regression model file into the output data folder (`"generated_files"` subfolder) for each of the three examples before re-running the analysis-only Quick Start 2 runs in order for changes to propagate in the Quick Start 2 outputs.

The `'run_rdr_analysis.bat'` files for each example need to be edited to reference the user's paths to the corresponding Python and RDR code files, as noted in Section 3 of the User Guide.

To run the examples in Quick Start 2, execute the batch file `'run_rdr_analysis.bat'` within each of the three subfolders. Each run should take <1 minute.

Input Data: There are three examples to run within Quick Start 2:

Example A runs an analysis on a subset of uncertainty scenarios, as specified in the user input file, limited to one hazard event ('haz1'), one event frequency factor (1.001), and 2 projects ('L2-7' and 'L8-9_comp').

Example B changes parameters of the recovery module to analyze more hazard recovery cases (minimum duration of 2 days, maximum duration of 8 days, 4 hazard recovery cases, and hazard recovery period of 50% of initial hazard event duration). The user should also note that they can change parameters for the ROI analysis in the [analysis] subsection of the configuration file in the same manner as to how recovery parameters were modified in this example. Note that the ROI analysis parameter 'vot_per_hour' does impact link tolls in the AequilibraE core model used to build the regression model.

Example C changes how damage metrics are calculated in the economic analysis. Instead of using the default depth-damage function adapted from Simonovic et al. used in Quick Start 1, this example uses a binary exposure-damage calculation ('exposure_damage_approach' parameter is set to 'Binary'). The example continues to use the default repair cost and repair time tables used in Quick Start 1, but the user can modify the configuration file to use a user-defined repair cost table (they need to specify the file path using the 'repair_cost_csv' parameter in configuration file, and do not need to specify 'repair_network_type' parameter anymore) and a user-defined repair time table (they need to specify the file path using the 'repair_time_csv' parameter) in the same manner. (The user should note that they cannot change the exposure-disruption calculation method in an analysis run because that calculation impacts the core model runs used to build the regression model; they would need to execute a full run to re-fit the regression model in this case.)

Results: The user should examine the log files in the “logs” folder and the output report in the “Reports” folder generated by the analysis run to check each run completed successfully.

The main output files are the XLSX file (e.g., ‘tableau_input_file_QS2ExA.xlsx’) and the Tableau workbook ‘tableau_dashboard.twbx’ in a timestamped “tableau_report” subfolder in the “Reports” folder. The uncertainty parameters specified in the ‘UserInputs.xlsx’ for the ROI analysis lead to 6 total uncertainty scenarios for Example A, 64 uncertainty scenarios for Example B, and 32 uncertainty scenarios for Example C, as seen in the corresponding ‘uncertainty_scenarios.csv’ output files. The economic analysis outputs for Example A can be seen in Figure 4 in the Summary dashboard of the Tableau data visualization. The overall regret ranking of the two resilience projects has switched for this more limited scenario space analysis; resilience project ‘L8-9_comp’ now ranks first in all scenarios. Note that net benefits and benefit-cost ratios may not exactly match due to the randomness of the Latin hypercube sampling module.

Figure 4: Summary Dashboard for Quick Start 2 Example A

1.3 Quick Start 3: Expanding the scenario space and using existing core model runs

Purpose: This example completes a full run of the RDR Tool Suite in order to run an ROI analysis with a modified scenario space, as compared to Quick Start 1. Modifying the scenario space requires several additional core model runs for comprehensive coverage, which entails re-running the RDR Metamodel in order to build a new regression model incorporating the new scenario space (e.g., given updated inputs). In addition, this example details how previously run core model runs can be reused for new RDR scenario runs, in the interest of reducing runtime and improving regression fit.

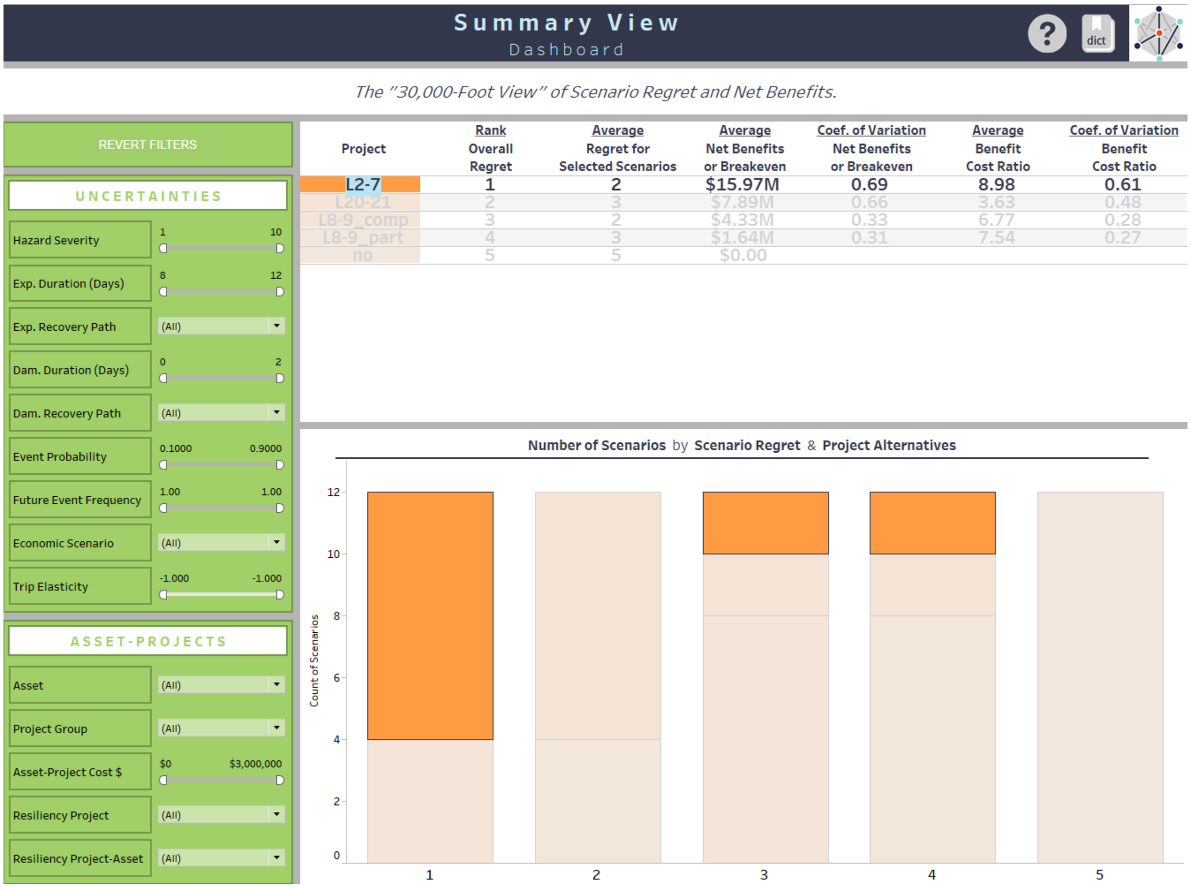
Instructions: To reuse the existing core model runs from Quick Start 1 in this quick start, the user first needs to **manually copy the entire output data folder of Quick Start 1** (e.g., "`C:\GitHub\RDR\quick_starts\qs1_full_run\Data\generated_files`") **from the** "`qs1_full_run`" **folder to the** "`qs3_add_scenarios`" **folder to use as the starting output data folder for Quick Start 3** (e.g., "`C:\GitHub\RDR\quick_starts\qs3_add_scenarios\Data\generated_files`"). In particular, this will pre-populate the core model runs subfolder ("`generated_files\aeq_runs`") with the previously run core model runs. The RDR Tool Suite will automatically add these existing core model runs into the new RDR scenario run. Note that the run ID provided in the Quick Start 3 configuration file is 'QS1', not 'QS3', in order to use the Quick Start 1 core model runs; to use existing runs, the RDR scenarios must have the same run ID.

To run the Quick Start 3 scenario, execute the batch file '`run_rdr_full.bat`' in the "`quick_starts\qs3_add_scenarios`" subfolder. The run should take between 1-2 minutes. Note that the environment variables for the .bat file need to be set to the paths of the user's Python and RDR code and data locations, as noted in Section 3 of the User Guide.

Input Data: The modified scenario space can be seen in the model parameters file across all three tabs. In addition, a new hazard exposure file for the new hazard event is included in the "`Hazards`" subfolder of the input data folder, and a new network attribute file for the new project group is included in the "`Networks`" subfolder of the input data folder. Expansions to the scenario space compared to Quick Start 1 include 1 additional project group (given the arbitrary value '00') with 1 potential resilience project (a highway project completely mitigating hazard exposure on 2 network links labeled 'L20-21'), 1 additional hazard event (given the label 'haz3'), and 1 additional recovery stage (possible recovery stages are 0, 1, and 2). As seen in the configuration file, 12 additional AequilibraE core model runs are specified by the 'lhs_sample_additional_target' parameter to be chosen by the 'lhs' module to supplement the existing 6 core model runs from Quick Start 1. To indicate that this RDR scenario run is using pre-existing core model runs, the 'do_additional_runs' parameter in the configuration file must be set to 'True' and the 'lhs_sample_target' parameter must match the number used in the previous run.

Results: The user should examine the log files in the "`logs`" folder and the output report in the "`Reports`" folder generated by the analysis run to check the run completed successfully.

The main output files are the XLSX file '`tableau_input_file_QS1.xlsx`' (in the output data folder for Quick Start 3, not Quick Start 1) and the Tableau workbook '`tableau_dashboard.twbx`' in a timestamped "tableau_report" subfolder of the "Reports" folder. The uncertainty parameters specified in the '`UserInputs.xlsx`' for the ROI analysis lead to 72 total uncertainty scenarios, as seen in the '`uncertainty_scenarios_QS1.csv`' output file. The economic analysis output for these uncertainty scenarios can be seen in Figure 5 in the Summary dashboard for the Tableau data visualization. Note that net benefits and benefit-cost ratios may not exactly match due to the randomness of the Latin hypercube sampling module.



Project	Rank Overall Regret	Average Regret for Selected Scenarios	Average Net Benefits or Breakeven	Coef. of Variation Net Benefits or Breakeven	Average Benefit Cost Ratio	Coef. of Variation Benefit Cost Ratio
L2-7	1	2	$15.97M	0.69	8.98	0.61
L20-21	2	3	$7.89M	0.66	3.63	0.48
L8-9_comp	3	2	$4.33M	0.33	6.77	0.28
L8-9_part	4	3	$1.64M	0.31	7.54	0.27
no	5	5	$0.00			

Figure 5: Summary Dashboard for Quick Start 3

The new resilience project added in Quick Start 3, ‘L20-21’, ends up with the second-best overall regret ranking among projects. Project ‘L2-7’ remains the best-ranked project overall, with the top regret ranking in eight of the 12 scenarios analyzed.

Exercises: The user is encouraged to test out other modified scenario spaces in this Quick Start example by editing the model parameters input file. Several potential input files are included: network attribute files for a new project group labeled ‘00’ with corresponding resiliency projects ‘L20-21’, ‘L6-8’, ‘L10-16’, ‘L10-17’, ‘L15-19’, ‘L20-21’, and ‘L20-22’ (all highway projects completely mitigating hazard exposure on 2 links); and an exposure analysis file for a new hazard event ‘haz3’, representing a different 1-year river flooding event. The user can also analyze different possible values for trip loss elasticity.