The Resilience and Disaster Recovery (RDR) Tool Suite

Quick Start Guide: Getting Started with RDR Version 2024.2

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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 Guide walks users through installation of the Tool Suite and an initial RDR scenario to confirm successful installation. It is complemented by the RDR Tool Suite Technical Documentation, User Guide, Reference Scenario Library, and Run Checklist.

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1 Installation

1.1 Software Requirements

Required software to run the Resilience and Disaster Recovery (RDR) Tool Suite:

1. Conda dependency management system[1] (see footnote for installation link)
2. Tableau Reader v. 2020.3 or later[2] (see footnote for installation link) or Tableau Desktop full version (any license level)
3. (Optional) ArcGIS Pro or ArcGIS v 10.x with Spatial Analyst extension (if using RDR Exposure Analysis Tool or certain other helper tools) (see User Guide for more details)
4. The RDR Tool Suite

The RDR Tool Suite is written in Python 3.11[3] and R 4.4.1, [4] and requires an installation of the dependency management system conda, which will handle the installation of both Python and R. For this installation process, we recommend Anaconda or Miniconda,[5] which is a miniature version of Anaconda that only includes conda, its dependencies, and Python. It is highly recommended that the user install Anaconda (or Miniconda) at "`C:\Users\%USERNAME%\Anaconda3`", where `%USERNAME%` is the user's computer username, as this is the default setup for the RDR Tool Suite. Note that Python will be automatically installed with conda if using Anaconda or Miniconda and R will be installed when setting up the RDR conda environment (Section 1.3). Neither needs to be installed separately by the user.

1.2 Software Installation

The RDR Tool Suite can be downloaded from the RDR repository on GitHub (https://volpeusdot.github.io/RDR-Public). To download, follow the instructions in the "Installation and Usage" section; these instructions are reproduced here. The User Guide also contains installation troubleshooting tips. A video demo for how to install the RDR Tool Suite is also available on the Volpe Center YouTube channel.

1. To install the RDR Tool Suite, navigate to the RDR repository on GitHub: https://github.com/VolpeUSDOT/RDR-Public
2. Click the green Code dropdown button and select "Download Zip".
3. Extract the contents into a directory on your local machine. It is highly recommended that the user extract the file contents into a directory located at "`C:\GitHub\RDR`", though the tool suite will work regardless of directory location. The user should keep track of their specific directory file path, as it is needed to edit the batch files used to execute the RDR Tool Suite.
    - Note: On some systems, the RDR directory may need to be renamed from RDR-Public-main. The downloaded files may also be extracted into a subfolder; if so, move all extracted files up one directory level.

[1] Conda. [Online]. User Guide: Installation. Accessed 26 July 2022 from https://docs.conda.io/projects/conda/en/latest/user-guide/install/.
[2] Tableau Reader. [Online]. Accessed 26 July 2022 from https://www.tableau.com/products/reader
[3] Python. [Online]. Download. Accessed 26 July 2022 from https://www.python.org/downloads/
[4] R. [Online]. The R Project for Statistical Computing. Accessed 26 July 2022 from https://www.r-project.org/
[5] Anaconda. [Online]. Documentation: Installation. Accessed 26 July 2022 from https://docs.anaconda.com/anaconda/install/

- Ensure that the first layer inside your RDR directory includes subfolders called "`documentation`", "`helper_tools`", "`metamodel_py`", and "`scenarios`". Figure 1 shows the correct setup of the RDR directory structure. The User Guide provides explanations of the directory folders and files.

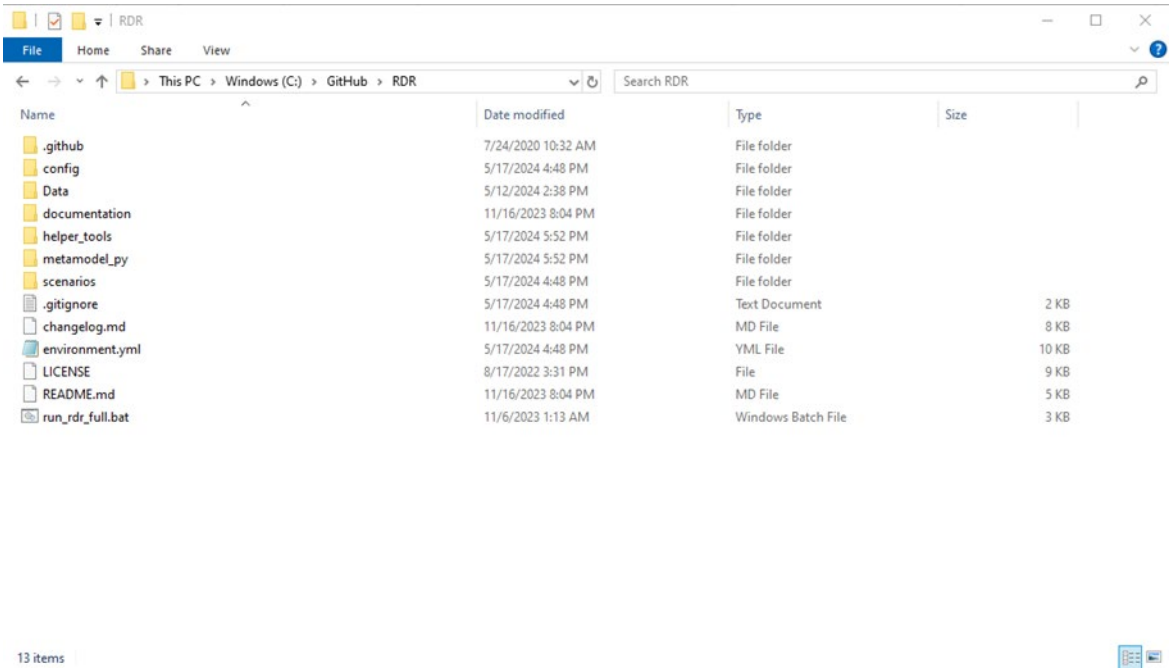


Figure 1: RDR Directory Structure

1.3 Software Configuration

The RDR Tool Suite is run from a custom conda environment, detailed in the '`environment.yml`' file seen in Figure 1. The '`environment.yml`' file lists the specific Python and R dependencies and versions used by the tool suite. In order to run the RDR Tool Suite, the user first needs to create the conda environment from the '`environment.yml`' file:

1. Open an Anaconda Prompt terminal window. Searching for "Anaconda Prompt" in the Start menu should locate the application.
2. In the Anaconda Prompt terminal window, navigate to the location of the RDR directory containing the '`environment.yml`' file using the "`cd`" command:
    - `cd C:\GitHub\RDR`

    In the above command, replace "`C:\GitHub\RDR`" with the full file path location of the user's RDR directory if it is not `C:\GitHub\RDR`.
3. Run the following commands in the terminal window:
    - `conda env create -f environment.yml`
    - `conda info --envs`

    Note that there is one hyphen in "`-f`" in the first command and two hyphens in "`--envs`" in the second command.

4. The second command in step 3 should output a list of available conda environments in the terminal window. Check that an environment named "RDRenv" shows up as an available environment.
5. (Optional) If the user is updating an existing installation of the RDR environment or for some reason the "RDRenv" conda environment is not functioning as expected, remove the environment using the following command, then start again at step 2. Refer to the conda documentation[6] for details.

   - `conda env remove --name RDRenv`

   Note that there are two hyphens in "`--name`".

Once the conda environment has been created following the steps laid out above, the user is ready to run the Quick Start example. The Quick Start example will confirm that the user correctly installed the RDR Tool Suite on their machine and provides a walkthrough of key components of the tool.

2 Running the Quick Start Example

The RDR directory contains a suite of Quick Start and Reference Scenario examples using sample data provided with the RDR Tool Suite. The sample input files, network data, and batch files for the scenario examples are located in the "`scenarios`" folder shown in Figure 1. To run Quick Start 1, follow the steps in the subsequent section. A video demo of how to run Quick Start 1 can also be found on the Volpe Center YouTube channel.

2.1 Quick Start 1: Running the RDR ROI Analysis Tool

Purpose: Quick Start 1 presents a simple RDR run with a small scenario space and demonstrates how to run a resilience return on investment (ROI) analysis, using the RDR Metamodel and the RDR ROI Analysis Tool.

Instructions: Quick Start 1 is run via the batch file '`run_rdr_full.bat`' in the "`scenarios\qs1_sioux_falls`" subfolder. Before running Quick Start 1, the user needs to confirm the environment variables of the batch file are correct for the user's setup (see explanation below). In addition, the user should confirm the configuration file ('`QS1.config`') points to the correct input and output folder paths for the Quick Start. Open the batch file and configuration file in a text editor (e.g., Notepad++) to view and edit the environment variables and parameters.

The user should be able to run the batch file once they have confirmed the `PATH` and `PYTHON` environment variables in the batch file are correct (see Section 4 of the User Guide for more details on how to locate your RDR conda environment and Python executable), without needing to change the path to the configuration file, also located in the "`scenarios\qs1_sioux_falls`" subfolder, 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 Quick Start 1 configuration file, the `RDR` and `CONFIG` environment variables in the Quick Start 1 batch file, and the `cd` change directory command in the batch file.

[6] Conda. [Online]. User Guide: Managing environments. Accessed 26 July 2022 from https://docs.conda.io/projects/conda/en/latest/user-guide/tasks/manage-environments.html

To run the batch file, either drag and drop the batch file into a terminal window (e.g., Command Prompt) and press Enter or double-click on 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. If the user would like to redirect the terminal window output to a text file instead, they should use the command "`run_rdr_full.bat > myoutput.txt 2>&1`" when in the Quick Start 1 subfolder. Instead of printing to the terminal window, logging statements will be stored in the designated text file. Detailed logging is also provided in the "`logs`" subfolder of the output data folder specified in the configuration file. The batch file will complete a full run of the RDR Metamodel and ROI Analysis Tool, including eight runs of the AequilibraE core model, and should take about one minute. A full description of the analysis is below, including the expected results.

At the conclusion of the run, a Tableau workbook with Quick Start 1 results will automatically open.

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 two-way 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.

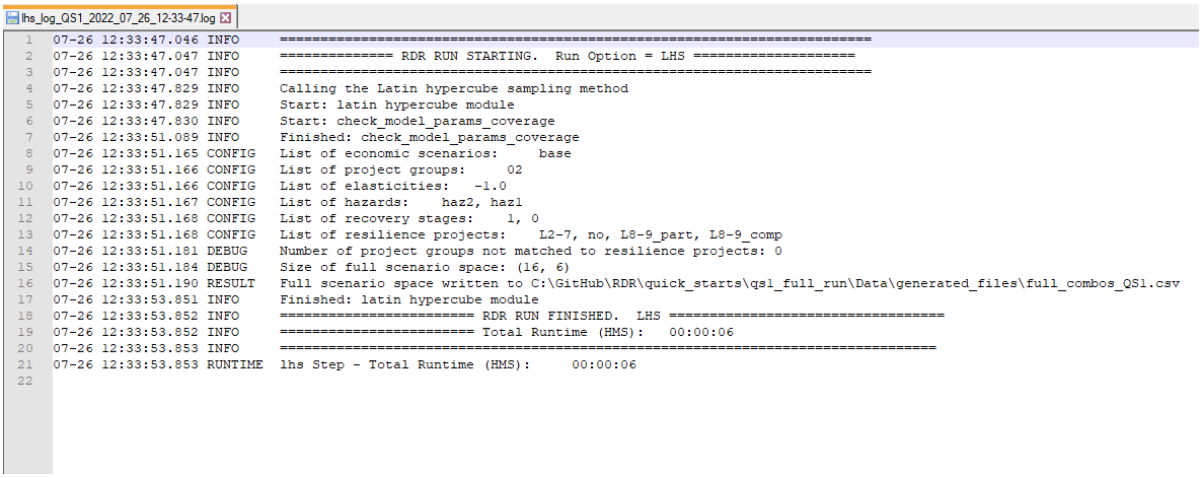
As seen in the configuration file, this analysis specifies eight AequilibraE core model runs ('lhs_sample_target' parameter is set to 8 in the configuration file). The minimum number of core model runs is four since that is the maximum number of possible values for an uncertainty parameter (there are four 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 multitarget Gaussian regression model ('multitarget') 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 for roadways adapted from Pregnolato et al. for the exposure to disruption calculation, the default depth-damage function for roadways 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 four days and a maximum duration of eight days, with two hazard recovery cases (four days and eight days) and a hazard recession period specified to be four 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 2023 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 in the output directory (e.g., "`generated_files`") 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 1: 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 '`Model_Parameters.xlsx`' file 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 Regret 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.

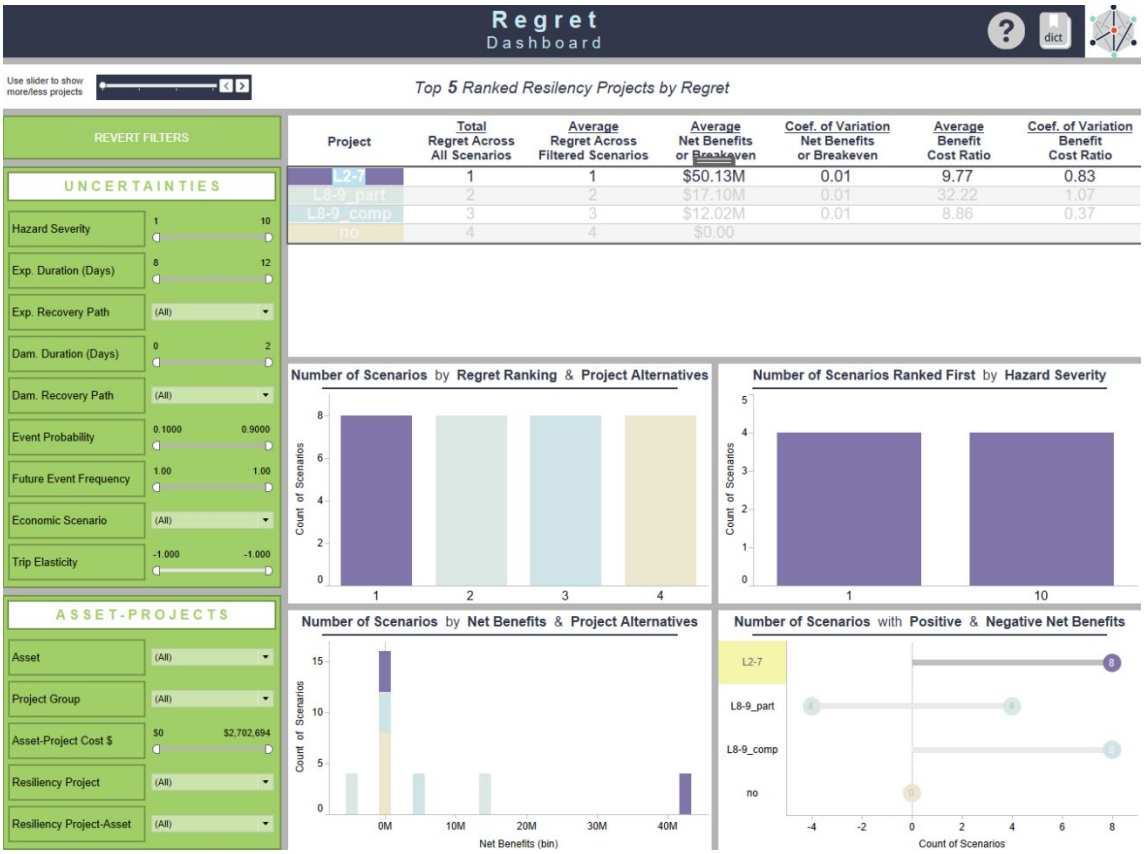


Figure 2: Summary Dashboard for Quick Start 1

The Regret dashboard shows that Project 'L2-7' is ranked first by overall regret across all scenarios in the scenario space. Project 'L8-9_part' is ranked second and Project 'L8-9_comp' 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 all eight scenarios.

3 Next Steps

Now that the user has confirmed successful installation of the RDR Tool Suite on their machine, they can begin to explore further examples and conduct their own custom analyses. The Reference Scenario Library contains six additional examples of RDR scenarios, including demonstrations of the RDR Benefits Analysis Tool and preparation/incorporation of a transit network. Documentation on how to configure components of the tool suite to set up a new scenario can be found in the User Guide, including best practices for file management. For documentation of the models and technical specifications of the RDR Tool Suite, please reference the Technical Documentation. 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. To conduct their own custom analyses, the user will need to create all required input files detailed in the Run Checklist for their specific application/network before they can run the tool. The RDR User Interface and the scenario input validation helper tool aid the user in configuring their custom analysis and validating scenario input data is correct and sufficient to run a custom analysis.