Planned Resource Optimization Model with Experimental Design (PROM-WED)

USER MANUAL

UNITED STATES NAVY
CHIEF OF NAVAL OPERATIONS

NPS
PRAESTANTIA PER SCIENTIAM
1909

SEED
Simulation Experiments & Efficient Designs
Center for Data Farming
Naval Postgraduate School
Table of Contents

I. What is PROM-WED
II. Output Options
III. Step-by-step instructions to run PROM-WED
IV. Guidelines for analysis of PROM-WED data in JMP
V. Example Test Cases
NOTICE:

The user is cautioned that PROM-WED has not undergone formal verification and validation testing, and comes without any warranty. Informal testing confirms the outputs from PROM-WED match the output from the legacy PRO model.
I. WHAT IS PROMWED

PROM-WED embeds the legacy PRO model within a data farming environment. The foundation of PROM-WED's data farming wrapper is the nearly orthogonal Latin hypercube (NOLH). The NOLH design of experiment (DOE) builds experimental designs that efficiently and effectively explore the solution space. This good space-filling capability means that uncertainties and fluctuations in input variables along with multivariable interactions are adequately investigated.

The 33 and 129 point NOLH designs makeup PROM-WED's data farming wrapper. The 33-point NOLH DOE tests each variable at 33 levels and grows data for 33 legacy PRO model runs, whereas the 129-point NOLH DOE tests each variable at 129 levels and grows data for 129 legacy PRO model runs. PROM-WED's graphical user interface (GUI) allows users to easily enter a range of values for each input variable into the NOLH DOE worksheet, regardless of their level of knowledge or familiarity with data farming or DOE techniques.

A completed PROM-WED excursion grows a data set of either 33 or 129 data points. Automatically generated sensitivity analysis provides users with a basic risk assessment picture focused on the decision variables. Further insights into variable interactions and effects of input variables can be easily explored using commercial statistics software package. PROM-WED transforms the legacy PRO model into a resource that N1 can use to gain robust insights into the optimal allocation of recruiting resources.
II. OUTPUT OPTIONS

PROM-WED provides users with decision support capabilities to analyze the data grown by each excursion. PROM-WED offers two decision support capabilities: (A) automatically generated analysis, and (B) data generated for further analysis requiring a statistical software package.

A. Automatically Generated Analysis

PROM-WED’s “Decision Support Analysis” for the traditional run option provides users with a broad understanding of how variability in decision variables, controllable policy changes, and uncontrollable market factors affect the total cost of recruiting. This type of analysis would be appropriate for testing excursions during a time constrained meeting, working group, or whenever basic analysis needs to be generated quickly.

An example of PROM-WED’s automatically generated analysis follows.
Traditional Run: 33 Design Points

Mean Total Cost of Recruiting over FYDP

- Confidence High
- Mean
- Confidence Low

PROMWED Excursion versus Program of Record

Scenario

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</table>
B. JMP Analysis

Analysts will need to use a statistical software package to take full advantage of the data grown by PROM-WED. Therefore, data produced by PROM-WED is designed to be easily uploaded into a software package, such as JMP.

The following are examples of insights gained through analysis of PROM-WED data in JMP.

1. Partition Tree

Over 80 percent of variance in the total cost of recruiting is explained by the amount of funds allocated to advertising.
2. **Stepwise Regression**

The total cost of recruiting can be formulated into a stepwise regression model:

<table>
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<th>Prediction Expression</th>
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<td>150.980052850998</td>
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<tr>
<td>+ 0.02553596931337 * NCO</td>
</tr>
<tr>
<td>+ -24.593679044673 * Unemployment</td>
</tr>
<tr>
<td>+ -550.34801858165 * Relative Pay</td>
</tr>
<tr>
<td>+ ( NCO - 35000.0620155039 ) * ( Relative Pay - 1 ) * -0.1270005027034</td>
</tr>
<tr>
<td>+ ( NCO - 35000.0620155039 ) * ( NCO - 35000.0620155039 ) * 0.00000304992539</td>
</tr>
<tr>
<td>+ ( Relative Pay - 1 ) * ( Relative Pay - 1 ) * 1882.37625427676</td>
</tr>
</tbody>
</table>

3. **Contour Plots**

The contour plot indicates that nearly half of the solution space supports a low advertising budget, represented by the dark blue region. The cost of advertising substantially increases when relative pay favors the civilian sector and the accession mission is high, represented by the red region. Once relative pay exceeds approximately
1.00, changes in the new accession mission have little to no effect on the amount of resources allocated to advertising.
III. STEP-BY-STEP INSTRUCTIONS TO RUN PROM-WED

Step 1: Unzip the “PROM-WED.zip” file, and save the “PROM-WED.xlsm” file and “NOLH.xls” file in the same folder. This folder is where the output file generated by PROM-WED will be saved following the PROM-WED excursion.

Step 2: Open the PROM-WED file, and ensure the “Enable Content” button is selected.
The first time you open PROM-WED, the NOLH.xls file link needs to be updated. To do this, select the “Edit Links...” button.

To update the NOLH.xls file, click on the “Change Source…” button.

A file search window will pop-up. Navigate to the folder where you saved the files after unzipping them. Select the “NOLH.xls” file, and click on the “OK” button.
The “Edit Links” window will pop-up. Once the “NOLH.xls” worksheet’s status updates to “OK,” click on the “Close” button.

**Step 3:** Open the PROM-WED file, and select the “PROM-WED” button to open the GUI.
**Step 4:** Select the appropriate starting fiscal year (FY) from the drop-down list. The current version of the legacy PRO model is set at a FY 2015 start.
Step 5: To constrain a decision variable, select it from the list, and click “Fix DV” button.
The default data from the legacy PRO Model will automatically populate the “Design of Experiments Table.”
**Step 6:** Input the range of values for the decision variable in the “Design of Experiments Table.” Input the low value of the range in the “Low Level” text box for each FY, and the high value of the range in the “High Level” text box for each FY. In this example, the number of recruiters is tested from 2,500 to 3,500 for each FY.

Each year can be tested using different ranges. For example, to represent a smaller recruiter force in FY 2021, the range could be inputted as 2,000 to 2,700.

If you want to constrain the decision variable at the default value populated by the legacy PRO model, select the “Fix Value” button. By selecting “Fix Value,” the default values for the decision variable in the “Design of Experiments Table” are deposited into the NOLH worksheet for each FY. This decision variable is now moved to the “Fixed Decision Variables” list, and the “Design of Experiments Table” is cleared. (If this is your course of action, continue to Step 8.)

If you want to constrain the decision variable at one number that is different than the default value populated by the legacy PRO model, the same number has to be inputted into the “Low Level” and “High Level” text boxes. For example, if you want to constrain the number of recruiters in FY 2021 to 2700, then you would enter 2700 in both the “Low Level,” and “High Level” text boxes.
**Step 7:** Once the “Design of Experiments Table” is fully populated with the low and high levels for each FY, select the decision variable from the “Input Values” box, and click on the “Set Range” button.
By selecting “Set Range,” the low and high values entered for this decision variable in the “Design of Experiments Table” are deposited into the NOLH worksheet for each FY. This decision variable is now moved to the “Fixed Decision Variables” list, and the “Design of Experiments Table” is cleared.
**Step 8**: Follow Steps 5-7 to fix any other decision variables.

Reminders:

- If you constrain a decision variable to a number other than the default values populated from the legacy PRO model, as mentioned earlier enter the same number into the low and high level text boxes, and select the “Set Range” button when complete.

- Since the PRO model solves an optimization problem, ensure that at least one of the following decision variables: Recruiters, Advertising or Enlistment Bonus (EB) remain in a “float” status. In this example, only the number of recruiters are fixed.
Step 9: Once all decision variables that need to be fixed are fixed, gears shift to the market factors. The “Market Factors” list includes all market factors (relative pay, QMA and unemployment rate) and policy factors (percentage of high quality recruits (TSC I-IIIA), percentage of recruits with a high school diploma (HSDG), and NCO). Each market factor, from relative pay to NCO, must either be fixed at one value, or a range of values needs to be entered.

Similar to how decision variables are fixed, select “Relative Pay” from the list of market factors, and select the “Add MF” button.
The default data from the legacy PRO Model automatically populates in the “Design of Experiments Table.”
**Step 10**: Input the range values for the market factor in the “Design of Experiments Table.” Input the low value of the range in the “Low Level” text box for each FY, and the high value of the range in the “High Level” text box for each FY.

In this example, the relative pay is tested from 0.8 to 1.2 for each FY. Clicking the “Set Range” button deposits the low and high values entered for this market factor into the NOLH worksheet for each FY.
This market factor is now moved to the “Varied Market Factors” list, and the “Design of Experiments Table” is cleared.

Step 11: Work through each “Market Factor” in the list, from “Relative Pay” to “NCO” following Steps 9-10.

Note that each year can be tested using a different range of values for the market factors. For example, an annual decrease of 10,000 QMA can be entered as shown in the figure below.

If you want to constrain the market factor at one number different than what is populated by the legacy PRO model, the same number has to be inputted into the “Low Level” and “High Level” text boxes. Then select the “Set Range” button.
To constrain the market factor at the value automatically populated in the “Design of Experiments Table,” select the market factor from the “Input Values” box, and click on the “Fix Value” button.
Step 12: Work through all seven market factors until they are all accounted for. A market factor is accounted for once it appears in either the “Varied Market Factors,” or “Fixed Market Factors” lists.
Step 13: Select “Traditional Run” under “Select Run Type.” (Currently, only the Traditional Run option is operational).

Automatically Generated Decision Support:

The “33 Design Points” option is well suited for the automatically generated decision support analysis. The “129 Design Points” option can also be used, but it will take additional time to run (approximately 10 minutes versus 2-3 minutes). The “129 Design Points” option grows more data, resulting in a narrower 95% confidence interval.

Analysis in JMP:

The “129 Design Points” option is intended to be used for further analysis in a commercial statistical software package, such as JMP.
**Step 14:** To save PROM-WED output to a separate .xls file for analysis in JMP, select the “Include output for analysis in JMP” box. This will save the PROM-WED output as a .xls file in the same folder that the PROM-WED model was saved in.
Step 15: Once the run options are set, select the “NOLH Run” button. A message will pop-up providing an estimated wait time for the PROM-WED excursion. Click “OK.”

![Image of Planned Resource Optimization with Experimental Design (PROM-WED) interface](image)

Step 16: When the PROM-WED excursion is complete, the automatically generated decision support analysis will appear (this is true for both the 33 and 129 point designs). If you selected the option to output PROM-WED data for analysis in JMP, the .xls file named “PROMWED_Output129.xls” will appear in the folder that your PROM-WED model is saved in.

![Image of file explorer showing PROMWED_Output129.xls](image)

Please be aware that each 129 design point output file will be named “PROMWED_Output129.xls.” It is recommended that you rename the file before running another PROM-WED excursion.
IV. GUIDELINES FOR ANALYSIS OF PROM-WED DATA IN JMP

Using JMP Pro 12, the following section provides a tutorial on analysis techniques for PROM-WED output. Steps 1-5 explain how to upload and prepare the data for analysis in JMP, followed by guidance on how to conduct various analysis techniques.

Analysis Techniques:
   A. Oneway Analysis of Total Cost of Recruiting by FY
   B. Explore Outliers from the Oneway Analysis Graph
   C. Select one FY to Analyze
   D. Distribution
   E. Partition Trees
   F. Stepwise Regression Model
   G. Scatterplot Matrix
   H. Contour Plot

Step 1: To load the PROM-WED data into JMP, select the folder icon.
**Step 2:** Select the output data of interest, select the “Best Guess” option, and click “Open.”

![Image of file browser with selected file and options]

**Step 3:** Select the “Import” button.

![Image of Data Preview window with selected worksheet and import button highlighted]
The PROM-WED output data should appear in a table, as shown below:

![Table Example]

**Step 4:** Change the FY column from “continuous” to “nominal” data, by right-clicking on the blue triangle next to “FY,” and select “nominal” from the drop-down menu.

![Dropdown Menu Example]
The blue triangle next to FY will change to a red bar chart icon when JMP changes its classification to nominal data.

The data is now ready to be analyzed.
A. Oneway Analysis of Total Cost of Recruiting by FY

Step 1: To create an oneway analysis of total cost of recruiting by FY graph, select “Analyze” from the ribbon, and select “Fit Y by X.”
Step 2: Select “Total Cost of Recruiting” from the list of columns, and select the “Y, Response” button.

“Total Cost of Recruiting” should now appear in the “Y, Response” box.
Step 3: Select “FY” from the list of columns, and select the “X, Factor” button.

“FY” should now appear in the “X, Factor” box.
Step 4: Click-on the “OK” button to generate the graph of FY by total cost of recruiting.

Step 5: To add boxplots on the data for each FY, select the red triangle in the upper left hand corner of the graph. From the drop-down menu, select “Quantiles.”
B. Explore Outliers from the Oneway Analysis Graph

Step 1: Hover your mouse over a data point of interest to retrieve information regarding that point.
Clicking on the data point on the graph will highlight it within the greater data set. Understanding the input variables can help explain why the total cost of recruiting was unusually high for this data point.

Step 2: To explore a group of outliers, lasso the data points of interest by creating a box around the data points with your mouse. Lassoing the data points will automatically select these data points within the greater data set.
**Step 3:** The selected data points can be further analyzed on their own. Right-click on “Selected.”

Then choose “Data View” from the drop down menu.
This will create a separate data table with just the outliers.
C. Select one FY to Analyze

To focus analysis on one specific FY, the other six FYs must be hidden and excluded. In this example, FY 2017 is the FY of interest. FYs 2015, 2016, 2018, 2019, 2020, and 2021 will be hidden and excluded.

**Step 1:** To exclude FY 2015 and 2016, select on the first row of FY 2015 data in the furthest column to the left. Hold the “shift” keyboard button.
Step 2: Scroll down to the last row of FY 2016 data (which appears in row “258”). Click on the “258” cell in the furthest column to the left.

Step 3: Right-click on the selected rows, and choose “Hide and Exclude” from the drop down menu.
You should now see a "no" symbol next to each row of data from FY 2015 and 2016.

**Step 4:** Follow steps 1-3 to hide and exclude data from FY 2018, 2019, 2020 and 2021. Row 388 is the first row of data for FY 2018.
D. Distribution

The distribution of the total cost of recruiting for FY 2017 is explored. This technique can be applied to any of the output variables to better understand its distribution and possible spread values.

**Step 1:** Select “Analyze” from the ribbon, and select “Distribution” from the drop down menu.
Step 2: Select “Total Cost of Recruiting” from the list of columns, and click on the “Y, Columns” button. The distribution for Total Cost of Recruiting will appear.

Step 3: To rotate the distribution to appear horizontal, click on the red triangle in the upper left hand corner of the graph, and select “Stack” from the drop down menu.
E. Partition Trees

The partition tree on total cost of recruiting will be explored. The partition tree is a useful method that can help provide insights into variable interactions.

Step 1: To create a partition tree, select “Analyze” from the ribbon. Then choose “Modeling,” and “Partition” from the drop down menus.
Step 2: Select “Total Cost of Recruiting” from the list of columns, and click on the “Y, Response” button.

Step 3: Select each decision variable (Advertising, EB, Education Incentive, Total Recruiters) from the list of columns, then click on the “X, Factor” button.
Step 4: Click on the “OK” button.

The partition tree window will pop-up with just the parent node.
Step 5: To make the first split on “Total Cost of Recruiting,” click on the “Split” button.

Continue to split, by clicking the “Split” button. If you want to undo a split, click on the “Prune” button. A “Training” $R^2$ value of 0.80 is an adequate threshold to achieve. In this case, disregard the “Validation” $R^2$ value.
F. Stepwise Regression Model

To develop a model for the total cost of recruiting, stepwise regression is used to determine the beta estimates to fit a model.

**Step 1:** Select “Analyze” from the ribbon, then “Fit Model” from the drop down menu.

**Step 2:** Select “Total Cost of Recruiting” from the list of columns, and click on the “Y” button.
Step 3: While holding the Ctrl key, select each market factor that was varied in the PROM-WED excursion.

Select the right corner of the “Macros” button (i.e. the arrow), and select “Factorial to degree” from the drop-down menu.
This will add all main effect and two-way interactions.

Again, while holding the Ctrl key, select each market factor that was varied in the PROM-WED excursion. Select the right corner of the “Macros” button (i.e. the arrow), and select “Polynomial to degree” from the drop-down menu. This will add all second degree polynomial interactions.
Step 4: From the “Personality” drop-down menu, select “Stepwise.”

Step 5: Ensure that the “Keep dialog open” box is checked, and click the “Run” button.
Step 6: The “Stepwise Regression Control” window will appear. Press the “Go” button.
Step 7: Once settled, select the “Run Model” button.
The “Report: Fit Model” window will appear.

At this point, you can decide if you would like to make manual adjustments to the stepwise regression. For example, the interactions between unemployment rate and relative pay, and the new accession mission and unemployment in this example both exhibit low “t Ratio” values.
To remove these terms from the model, return to the “Stepwise Fit” window, and uncheck the terms in the “Entered” column that you would like to remove. Select “Run Model” to fit the new model.

**Step 8:** To graph the “Actual by Predicted” plot, select the red triangle next to “Response Total Cost of Recruiting.” From the drop-down menu, select “Row Diagnostics” and “Plot Actual by Predicted.”
**Step 9:** To fit the prediction model, select the red triangle next to “Response Total Cost of Recruiting.” From the drop-down menu, select “Estimates” then “Show Prediction Expression.”
G. Scatterplot Matrix

Scatterplot matrices can be used to visualize trends when multiple variables are changing.

Step 1: Select “Graph” from the ribbon, then “Scatterplot Matrix” from the drop down menu.
Step 2: To set the Y-axis variables, select “Total Cost of Recruiting” and “Advertising” from the list of columns, and click on the “Y, Columns” button.

Step 3: To set the X-axis variables, select the variables of interest (NCO, Unemployment Rate and Relative Pay in this case), and click on the “X” button.

Step 4: Repeat Step 3 for Unemployment Rate and Relative Pay.
**Step 5:** To generate the scatterplot matrix, click the "OK" button.

**Step 5:** To fit a trend line on the plots, click the red triangle, and select “Fit Line” from the drop down menu.
H. Contour Plots

Step 1: Select “Graph” from the ribbon, then “Contour Plot” from the drop down menu.
Step 2: To set “Total Cost of Recruiting” as the variable represented by the color scale, select “Total Cost of Recruiting” from the list of columns, and click the “Y” button.

Step 3: To set “Relative Pay” as the x-axis, select “Relative Pay” from the list of columns, and click the “X” button.
Step 3: To set the new accession mission (NCO) as the y-axis, select “NCO” from the list of columns, and click the “X” button.

Step 4: Select the “Fill Areas” box, then click the “OK” button to generate the contour plot.
V. EXAMPLE TEST CASES

Two test case examples are provided to demonstrate PROM-WED’s capabilities.

A. Effect of Economic Uncertainties

What is the optimal allocation of recruiting resources that is robust to a broad range of economic uncertainties?

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<th>Value High</th>
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<td>2,500 recruiters</td>
<td>3,500 recruiters</td>
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<td>Market Factor</td>
<td>Unemployment Rate</td>
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<td>8.0%</td>
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<td>Market Factor</td>
<td>Relative Pay</td>
<td>0.80</td>
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<tr>
<td>Policy Factor</td>
<td>Recruiting Mission (NCO)</td>
<td>30,000 recruits</td>
<td>40,000 recruits</td>
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</table>

B. Effect of Legalization of Marijuana Test Case:

What is the optimal allocation of recruiting resources if the Navy desires to increase the percentage of high quality recruits from 70 percent to 85 percent? Due to uncertainties in the current fiscal environment, the unemployment rate may fluctuate between 4 to 8 percent and the ratio of relative pay may vary between 0.8 and 1.2. In addition, since marijuana has been legalized for recreational use in many states nationwide, drug-use amongst 18-24 year-olds is expected to increase. An increase in drug-use means less young adults qualify for military service. This test case models the effect of an annual decrease of 10,000 qualified military available due to pre-service drug-use.

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<tr>
<th>Variable Type</th>
<th>Variable Name</th>
<th>Value Low</th>
<th>Value High</th>
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<td>Decision Variable</td>
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<td>3,500 recruiters</td>
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<tr>
<td>Market Factor</td>
<td>Unemployment Rate (UE)</td>
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<td>Market Factor</td>
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<td>85%</td>
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<td>1.2</td>
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<td>Market Factor</td>
<td>Qualified Military Available (QMA)</td>
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<tr>
<td>Policy Factor</td>
<td>Recruiting Mission (NCO)</td>
<td>30,000 recruits</td>
<td>40,000 recruits</td>
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Cumulative Effect of Decrease in QMA

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