Chapter 264

Response Surface Designs

Introduction

Response-surface designs are the only designs provided that allow for more than two levels. There are two general types of response-surface designs. The central-composite designs give five levels to each factor. The Box-Behnken designs give three levels to each factor.

The Central-Composite designs build upon the two-level factorial designs by adding a few center points and star points. A factor's five values are: -*a*, -1, 0, 1, and *a*. The value of *a* is determined by the number of factors in such a way that the resulting design is orthogonal. For example, if you are going to use either four or five factors, the value of *a* is 2.00.

The actual values of the levels are determined from these five values as follows:

1. The low-level value is assigned to -1.
2. The high-level value is assigned to 1.
3. The average of these two values is assigned to 0.
4. The values of -*a* and *a* are used to find the minimum and the maximum values.

For example, suppose we entered 50 for the low-level and 60 for the high level. Further, suppose there were four factors in the experiment. The levels would be

Coded Level	Actual Level
-***a***	45
-1	50
0	55
1	60
a	65

The values of *a* depend on the number of factors in the design:

Factors	Value of ***a***
2	1.41
3	1.73
4	2.00
5	2.00
6	2.24

The Box-Behnken designs have two differences from the central-composite designs. First, they usually use fewer runs. Second, they only use three levels while the central-composite designs use five.

The actual values of the levels are determined in the same manner as the central-composite designs, except that the value of *a* is ignored.

Procedure Options

This section describes the options available in this procedure.

Design Tab

This panel specifies the parameters that will be used to create the design values.

Experimental Setup

Design Type

Specify whether to generate a *central-composite* or a *Box-Behnken* design. This selection controls the number of runs generated as well as the block size (if a blocking variable is present).

Sort Order

The order of the generated rows. The rows may be in random or standard order.

- **Random**
  The rows are randomly ordered (random blocks and random rows within blocks). Use this option when the order of application to experimental units is governed by the row number.

- **Standard**
  The rows are not randomly ordered. Instead, they are placed in standard order. Use this option when you want to quickly see the structure of the design.

Experimental Setup – Factor Values

Factor Values

Each factor has three or five possible values (levels). The values associated with -1 and 1 are entered here.

If a Box-Behnken design was selected, the resulting three values will be -1,0,1. For example, if you entered 10 20 here, the resulting values would be 10, 15, and 20.

If a central-composite design was selected, the resulting five values will be -*a*, -1, 0, 1, *a*. For example, if you had four factors and entered 50 60 here, the resulting values would be 45, 50, 55, 60, and 65.

These are the values that will be written to the database. You can only use numeric values.

Data Storage

Store Data with the Dataset

Check this box to generate the design data on the dataset. The data will be identical to the design data generated on the output window.

Block Column

The variable to contain the block identification numbers. The blocks are numbered from one to B, where B is the number of blocks. This variable is optional. If this option is left blank, no blocks will be generated.

First Factor Column

This is where the group of variables that is to contain your design begins. The K-1 variables after this variable are also filled with data. The number of variables used is determined by the number of Factor Values boxes that contain data. Up to six variables may be used.

Warning: The program fills these variables with data, so any previous data will be lost.

Example 1 – Response Surface Design

This section presents an example of how to generate an experimental design using this program. **CAUTION: since the purpose of this routine is to generate (not analyze) data, you should always begin with an empty dataset.**

In this example, we will show you how to generate a three-factor central composite design with blocks. You may follow along here by making the appropriate entries or load the completed template **Example 1** by clicking on Open Example Template from the File menu of the Response Surface Designs window.

1 Open a new (empty) dataset.

- From the File menu of the NCSS Data window, select New.
- Click the **Ok** button.

2 Open the Response Surface Designs window.

- Using the Analysis menu or the Procedure Navigator, find and select the **Response Surface Designs** procedure.
- On the menus, select **File**, then **New Template**. This will fill the procedure with the default template.

3 Specify the design parameters.

- On the Response Surface Designs window, select the **Design** tab.
- Select **Central-Composite** in the **Design Type** list box.
- Select **Standard** in the **Sort Order** list box.
- Set **three** of the **Factor Values** boxes equal to **-1 1**.
- Check the box **Store Data with the Dataset.**
- Enter **1** in the **Block Column** box.
- Enter **2** in the **First Factor Column** box.

4 Run the procedure.

- From the Run menu, select **Run Procedure**. Alternatively, just click the green Run button.

Three-Factor Response-Surface Design

C1	C2	C3	C4
1	-1	-1	-1
1	1	-1	-1
1	-1	1	-1
1	1	1	-1
1	-1	-1	1
1	1	-1	1
1	-1	1	1
1	1	1	1
1	0	0	0
1	0	0	0
1	0	0	0
2	-1.73	0	0
2	1.73	0	0
2	0	-1.73	0
2	0	1.73	0
2	0	0	-1.73
2	0	0	1.73
2	0	0	0
2	0	0	0
2	0	0	0

Note that there are three replicates of the center points in each block. Note the star points represented by -1.73 and 1.73.