

品質與可靠度工程實驗室

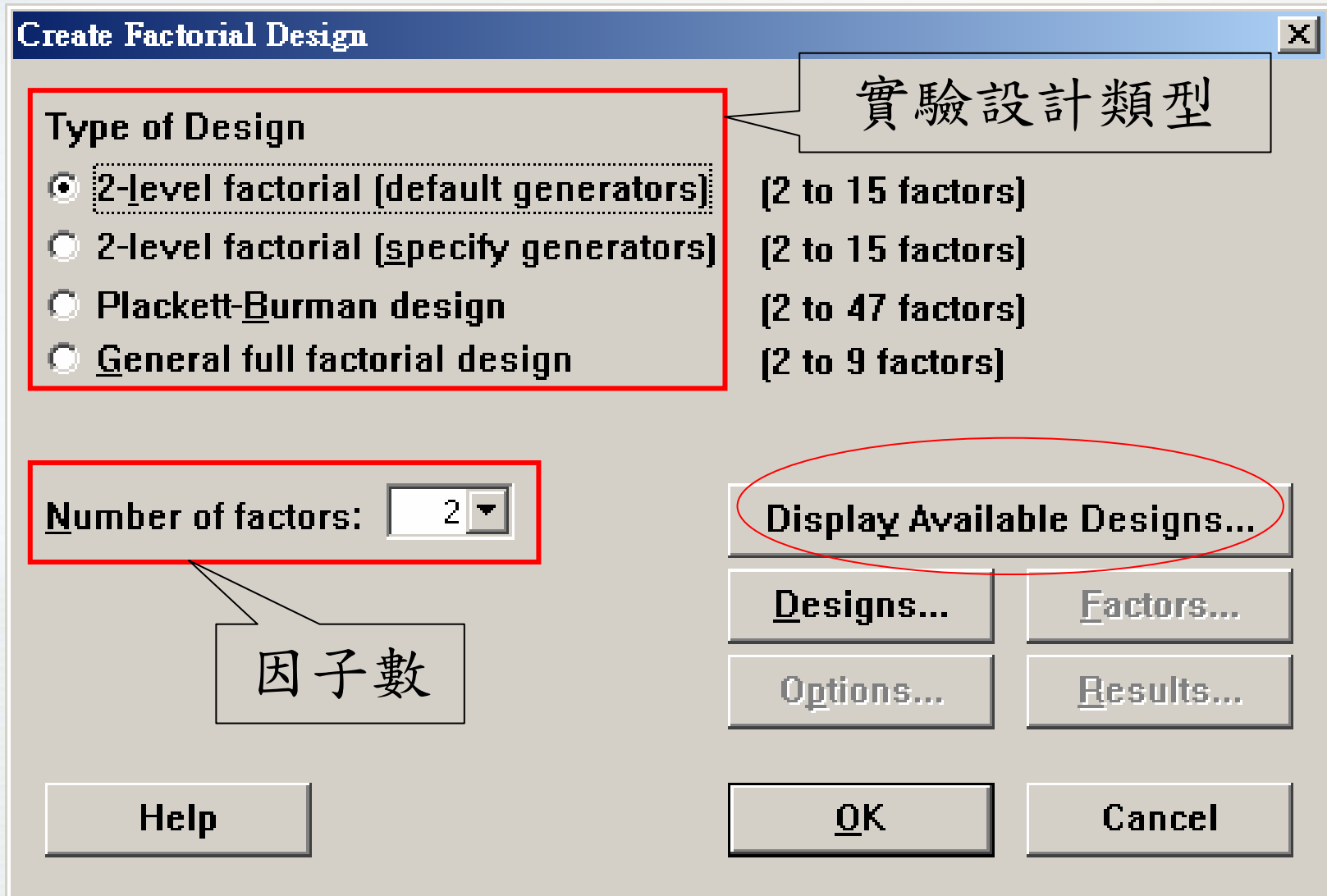
Quality and Reliability Engineering Lab.

因子實驗設計分析-Minitab操作

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產生實驗規劃表

- Stat → DOE → Factorial → Create Factorial Design



產生實驗規劃表-預設產生器

- 顯示兩因子兩水準各種實驗解析度

Create Factorial Design

Type of Design

- 2-level factorial [default generator]
- 2-level factorial [specify generator]
- Plackett-Burman design
- General full factorial design

Number of factors:

2

Create Factorial Design - Display Available Designs

Available Factorial Designs (with Resolution)

	Factors														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
4	Full	III													
8		Full	IV	III	III	III									
16			Full	V	IV	IV	IV	III	III	III	III	III	III	III	
32				Full	VI	IV	IV	IV	IV	IV	IV	IV	IV	IV	
64					Full	VII	V	IV	IV	IV	IV	IV	IV	IV	
128						Full	VIII	VI	V	V	IV	IV	IV	IV	

Available Resolution III Plackett-Burman

Factors	Runs	Factors	Runs	Factors	Runs
2-7	8,12,16,20,....,48	20-23	24,28,32,36,....,48	36-39	40,44,48
8-11	12,16,20,24,....,48	24-27	28,32,36,40,44,48	40-43	44,48
12-15	16,20,24,28,....,48	28-31	32,36,40,44,48	44-47	48
16-19	20,24,28,32,....,48	32-35	36,40,44,48		

Help

OK

Display Available Designs...

Designs...

Factors...

Options...

Results...

Help

OK

Cancel

產生實驗規劃表-預設產生器

Create Factorial Design - Designs

全因子或部分因子實驗

Designs	Runs	Resolution	2^{k-p}
Full factorial	4	Full	$2^{**}2$

實驗次數

解析度

2的k-p次實驗

Create Factorial Design

Type of Design

- 2-level factorial (default)
- 2-level factorial (specify)
- Plackett-Burman design
- General full factorial de

Number of center points: 0

[per block]
中心點實驗次數
(for corner points only)

Number of replicates: 1

重複實驗次數

Number of blocks: 1

區集數

Number of factors: 2

Help OK Cancel

Designs... Factors...
Options... Results...
OK Cancel

Help

產生實驗規劃表-自定產生器

Create Factorial Design

Type of Design

- 2-level factorial (default generators) [2 to 15 factors]
- 2-level factorial (specify generators) [2 to 15 factors]
- Plackett-Burman design [2 to 47 factors]
- General full factorial design [2 to 9 factors]

Number of factors: 5

Display Available Designs...

Designs... Factors...

Option

Help OK

Create Factorial Design - Designs

Designs	Runs	Resolution	2^{k-p}
1/4 fraction	8	III	2^{5-2}
1/2 fraction	16	V	2^{5-1}
Full factorial	32	Full	2^5

Number of center points: 0 (per block)

Number of replicates: 1 (for corner points only)

Generators...

Help OK Cancel

解析度

2的k-p次
實驗

實驗次數

全因子或部
分因子實驗

中心點實驗次數

區集數

自訂產生器，
見下頁投影片

產生實驗規劃表-自定產生器

Create Factorial Design - Designs - Generators

Add factors to the base design by listing their generators (e.g. F=ABC):

F = ABCDE

新增一個因子來表示高階交互作用

Define blocks by listing their generators (e.g., ABCD):

AB AC

指定交互作用來表示區集

Help

OK

Cancel

Help

OK

Cancel

2**(k-p)

2**(5-2)

2**(5-1)

2**5

ck)

er points only)

Generators...

產生實驗規劃表-自定產生器

修改因子名稱

隨機實驗順序

Create Factorial Design - Factors

Factor	Name	Low	High
A	A	-1	1
B	B	-1	1
C	C	-1	1
D	D	-1	1
E	E	-1	1
F	F	-1	1

Create Factorial Design - Options

Create Factorial Designs - Options

Fold Design

- Do not fold
- Fold on all factors
- Fold just on factor:

Randomize runs

Base for random data generator

Store design in worksheet

Fraction

- Use principal fraction
- Use fraction number:

Help

OK

Cancel

default generators) [2 to 15 factors]
specify generators) [2 to 15 factors]
design [2 to 47 factors]
rial design [2 to 9 factors]

5

Display Available Designs...

Designs

Factors...

Options...

Results...

Help

OK

Cancel

OK

Cancel

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
StdOrder	RunOrder	CenterPt	Blocks	A	B	C	D	E	F						
9	1	1	3	-1	1	-1	-1	-1	1						
11	2	1	3	-1	1	-1	1	1	1						
10	3	1	3	1	-1	1	-1	1	1						
12	4	1	3	1	-1	1	1	-1	1						
14	5	1	4	1	1	1	-1	-1	1						
13	6	1	4	-1	-1	-1	-1	1	1						
15	7	1	4	-1	-1	-1	1	-1	1						
16	8	1	4	1	1	1	1	1	1						
8	9	1	2	-1	-1	1	1	1	1						
6	10	1	2	-1	-1	1	-1	-1	1						
7	11	1	2	1	1	-1	1	-1	1						
5	12	1	2	1	1	-1	-1	1	1						
1	13	1	1	1	-1	-1	-1	-1	1						
3	14	1	1	1	-1	-1	1	1	1						
4	15	1	1	-1	1	1	1	-1	1						
2	16	1	1	-1	1	1	-1	1	1						

F=ABCDE作為
1/2部分因子實驗

由AB AC交互作用
決定4個區集

產生實驗規劃表-Plackett Burman

總實驗次數

中心點實驗次數

Number of runs: 8

Number of center points: 0 (total number)

Number of replicates: 1 (for corner points only)

Help

OK

Cancel

Number of factors: 3

Display Available Designs...

Designs...

Factors...

Options...

Results...

實驗重複次數

Help

Create Factorial Designs - Options

Randomize runs

Base for random data generator

Store design in worksheet

Help

OK

Cancel

隨機實驗順序

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
StdOrder	RunOrder	CenterPt	Blocks	A	B	C									
2	1	1	1	1	1	-1									
4	2	1	1	-1	1	1									
5	3	1	1	1	-1	1									
1	4	1	1	1	-1	-1									
6	5	1	1	-1	1	-1									
8	6	1	1	-1	-1	-1									
3	7	1	1	1	1	1									
7	8	1	1	-1	-1	1									



產生實驗規劃表-通用形式全因子設計

- 可以產生混合水準的實驗規劃

Create Factorial Design - Designs

Factor	Name	Number of Levels
A	A	2
B	B	3
C	C	2

Number of replicates:

1

Block on replicates

給定各因子水準

Help

OK

Cancel

Number of factors:

3

Display Available Designs...

Designs...

Factors...

Options...

Results...

Help

OK

Cancel

產生實驗規劃表-通用形式全因子設計

隨機實驗順序

Create Factorial Design - Factors

Factor	Name	Level Values	Levels
A	A	100 200	2
B	B	1 2 3	3
C	C	High Low	2

Help OK Cancel

Create Factorial Designs - Options

Randomize runs

Base for random data gene

Store design in worksheet

Help OK Cancel

Factorial design (2 to 47 factors)

General full factorial design (2 to 9 factors)

Number of factors: 3

Display Available Designs...

Designs... Factors... Options... Results...

Help OK Cancel

給定因子水準值，可以用文字或數字表示

C1	C2	C3	C4	C5	C6-T	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
StdOrder	RunOrder	Blocks	A	B	C										

8	1	1	200	1	Low
2	2	1	100	1	Low
7	3	1	200	1	High
4	4	1	100	2	Low
11	5	1	200	3	High
12	6	1	200	3	Low
6	7	1	100	3	Low
10	8	1	200	2	Low
5	9	1	100	3	High
9	10	1	200	2	High
1	11	1	100	1	High
3	12	1	100	2	High

以文字表示兩個水準

3個水準

以數字表示兩個水準

自定實驗規劃表

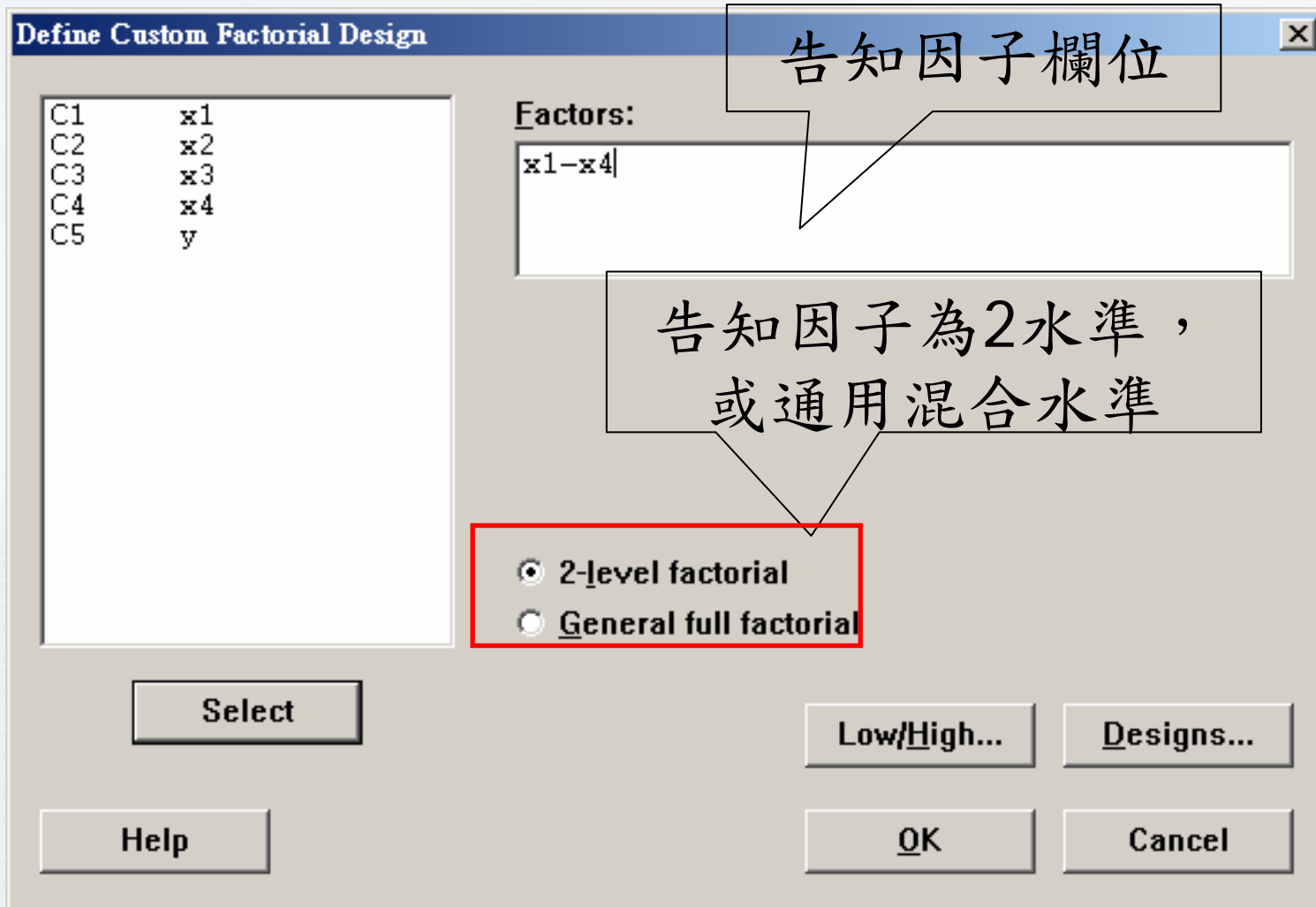
- 輸入一個實驗規劃表與實驗（望大品質特性）結果如右表

x1	x2	x3	x4	y
-1	-1	-1	-1	45
1	-1	-1	-1	71
-1	1	-1	-1	48
1	1	-1	-1	65
-1	-1	1	-1	68
1	-1	1	-1	60
-1	1	1	-1	80
1	1	1	-1	65
-1	-1	-1	1	43
1	-1	-1	1	100
-1	1	-1	1	45
1	1	-1	1	104
-1	-1	1	1	75
1	-1	1	1	86
-1	1	1	1	70
1	1	1	1	96

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
x1	x2	x3	x4	y											
-1	-1	-1	-1	45											
1	-1	-1	-1	71											
-1	1	-1	-1	48											
1	1	-1	-1	65											
-1	-1	1	-1	68											
1	-1	1	-1	60											
-1	1	1	-1	80											
1	1	1	-1	65											
-1	-1	-1	1	43											
1	-1	-1	1	100											
-1	1	-1	1	45											
1	1	-1	1	104											
-1	-1	1	1	75											
1	-1	1	1	86											
-1	1	1	1	70											
1	1	1	1	96											

自定實驗規劃表

- Stat → DOE → Factorial → Define Custom Factorial Design



自定實驗規劃表

Define Custom Factorial Design - Low/High

Low and High Values for Factors

Factor	Name	Low	High
A	x1	-1	1
B	x2	-1	1
C	x3	-1	1
D	x4	-1	1

因子命名和設定

Worksheet Data Are

Coded

Uncoded

Help OK Cancel

Factorial

Low/High... Designs...

Help OK Cancel

自定實驗規劃表

The image shows a software dialog box titled "Define Custom 2-Level Factorial - Design". The dialog has a main area with four sections, each with a red border and a callout box pointing to it:

- Standard Order Column:** The callout box says "給予標準實驗順序欄位". The section contains radio buttons for "Order of the data" (selected) and "Specify by column:" with an empty text box.
- Run Order Column:** The callout box says "給予實際執行實驗順序欄位". The section contains radio buttons for "Order of the data" (selected) and "Specify by column:" with an empty text box.
- Center Points:** The callout box says "給予中心點實驗欄位". The section contains radio buttons for "No Center Points" (selected) and "Specify by column:" with an empty text box.
- Blocks:** The callout box says "給予區集的欄位". The section contains radio buttons for "No blocks" (selected) and "Specify by column:" with an empty text box.

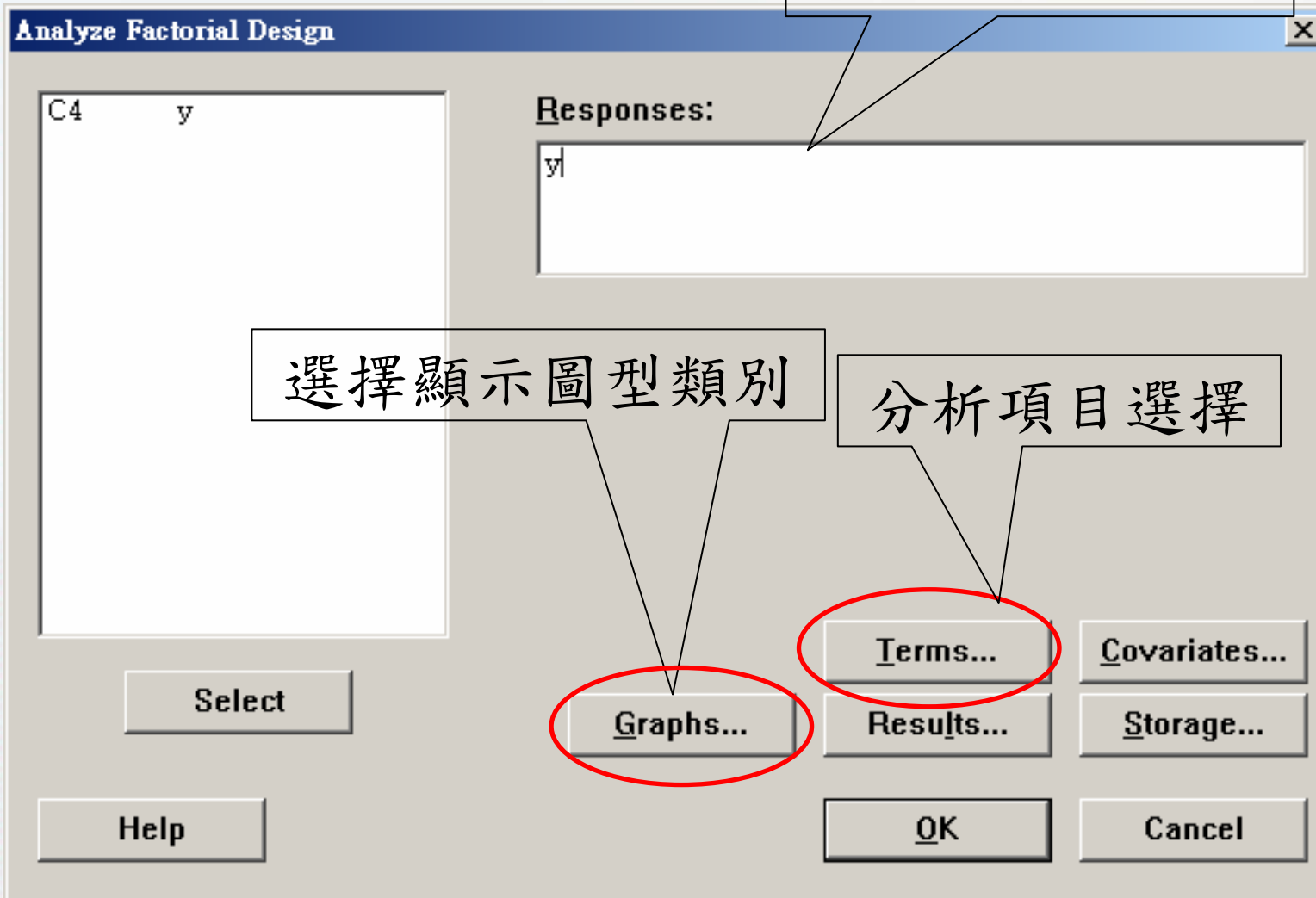
At the bottom of the dialog, there are buttons for "Select", "Help", "OK", "Cancel", "Designs...", and another "OK" and "Cancel" button. A large red text overlay at the bottom reads: "當實驗數據裡沒有這些欄位時，使用預設值即可".

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
x1	x2	x3	x4	y	StdOrder	RunOrder	Blocks	CenterPt							
-1	-1	-1	-1	45	1	1	1	1							
1	-1	-1	-1	71	2	2	1	1							
-1	1	-1	-1	48	3	3	1	1							
1	1	-1	-1	65	4	4	1	1							
-1	-1	1	-1	68	5	5	1	1							
1	-1	1	-1	60	6	6	1	1							
-1	1	1	-1	80	7	7	1	1							
1	1	1	-1	65	8	8	1	1							
-1	-1	-1	1	43	9	9	1	1							
1	-1	-1	1	100	10	10	1	1							
-1	1	-1	1	45	11	11	1	1							
1	1	-1	1	104	12	12	1	1							
-1	-1	1	1	75	13	13	1	1							
1	-1	1	1	86	14	14	1	1							
-1	1	1	1	70	15	15	1	1							
1	1	1	1	96	16	16	1	1							



分析因子設計

- Stat → DOE → Factorial → Analyze Factorial Design
- 延續先前例子



分析因子設計

Analyze Factorial Design - Terms

Include terms in the model up through order:

2

Available Terms:

Selected Terms

A: x1
B: x2
C: x3
D: x4
ABC
ABD
ACD
BCD
ABCD

>

>>

<

<<

Cross

Default

A: x1
B: x2
C: x3
D: x4
AB
AC
AD
BC
BD
CD

1

2

3

4

選擇所要分析的主效應因子與交互作用因子

Include blocks in the model

Include center points in the model

Help

OK

Cancel

Terms...

Covariates...

Results...

Storage...

OK

Cancel

分析因子設計

Fractional Factorial Fit: y versus x1, x2, x3, x4

Estimated Effects and Coefficients for y (coded units)

Term	Effect	Coef	SE Coef	T	P	
Constant		70.063	1.264	55.43	0.000	*
x1	21.625	10.812	1.264	8.55	0.000	*
x2	3.125	1.562	1.264	1.24	0.271	
x3	9.875	4.937	1.264	3.91	0.011	
x4	14.625	7.312	1.264	5.79	0.002	*
x1*x2	0.125	0.062	1.264	0.05	0.962	
x1*x3	-18.125	-9.063	1.264	-7.17	0.001	*
x1*x4	16.625	8.313	1.264	6.58	0.001	*
x2*x3	2.375	1.188	1.264	0.94	0.391	
x2*x4	-0.375	-0.187	1.264	-0.15	0.888	
x3*x4	-1.125	-0.563	1.264	-0.45	0.675	

*表示顯著因子

Analysis of Variance for y (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	4	3155.2	3155.2	788.81	30.86	0.001
2-Way Interactions	6	2447.9	2447.9	407.98	15.96	0.004
Residual Error	5	127.8	127.8	25.56		
Total	15	5730.9				

主效應與二因子
交互作用均顯著

Unusual Observations for y

Obs	y	Fit	SE Fit	Residual	St Resid
13	75.000	69.188	4.192	5.813	2.06R

顯示主效應交互作用圖

- Stat → DOE → Factorial → Factorial Plot

The image shows the Minitab Factorial Plots dialog box and its 'Main Effects' sub-dialog. Red callout boxes with arrows point to specific UI elements, providing Chinese annotations:

- 主效應圖** (Main Effects Plot): Points to the 'Main Effects Plot' checkbox in the 'Factorial Plots' dialog.
- 顯示所選定的因子主效應圖和交互作用圖** (Display selected factor main effects and interaction plots): Points to the 'Interaction Plot' checkbox in the 'Factorial Plots' dialog.
- 指定反應值欄位** (Specify response variable): Points to the 'Responses:' field containing 'y' in the 'Factorial Plots - Main Effects' dialog.
- 設定圖的名稱和各軸的尺度** (Set plot name and axis scales): Points to the 'Options...' button in the 'Factorial Plots - Main Effects' dialog.
- 交互作用圖** (Interaction Plot): Points to the 'Interaction Plot' checkbox in the 'Factorial Plots' dialog.

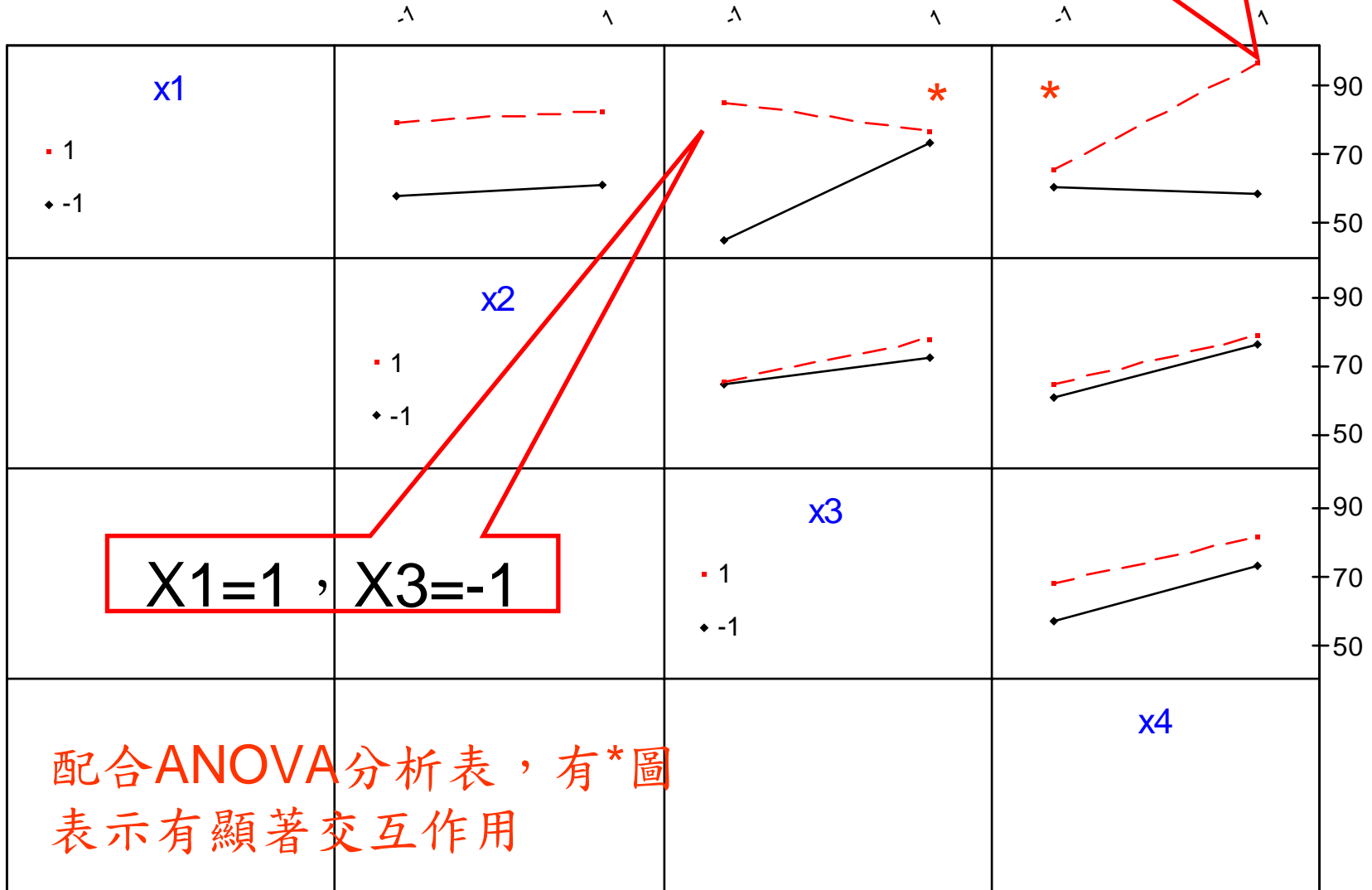
The 'Factorial Plots' dialog includes options for 'Main Effects Plot', 'Interaction Plot', and 'Cube Plot'. The 'Type of Means to Use in Plots' section has radio buttons for 'Data Means' (selected) and 'Fitted Means'. A 'Help' button is at the bottom.

The 'Factorial Plots - Main Effects' dialog shows 'Responses:' as 'y'. The 'Factors to Include in Plots' section has an 'Available:' list (empty) and a 'Selected:' list containing 'A: x1', 'B: x2', 'C: x3', and 'D: x4'. Navigation buttons (>, >>, <, <<) are between the lists. An 'Options...' button is at the bottom right. 'Help', 'OK', and 'Cancel' buttons are at the bottom.

顯示主效應交互作用圖-交互作用圖

Interaction Plot (data means) for y

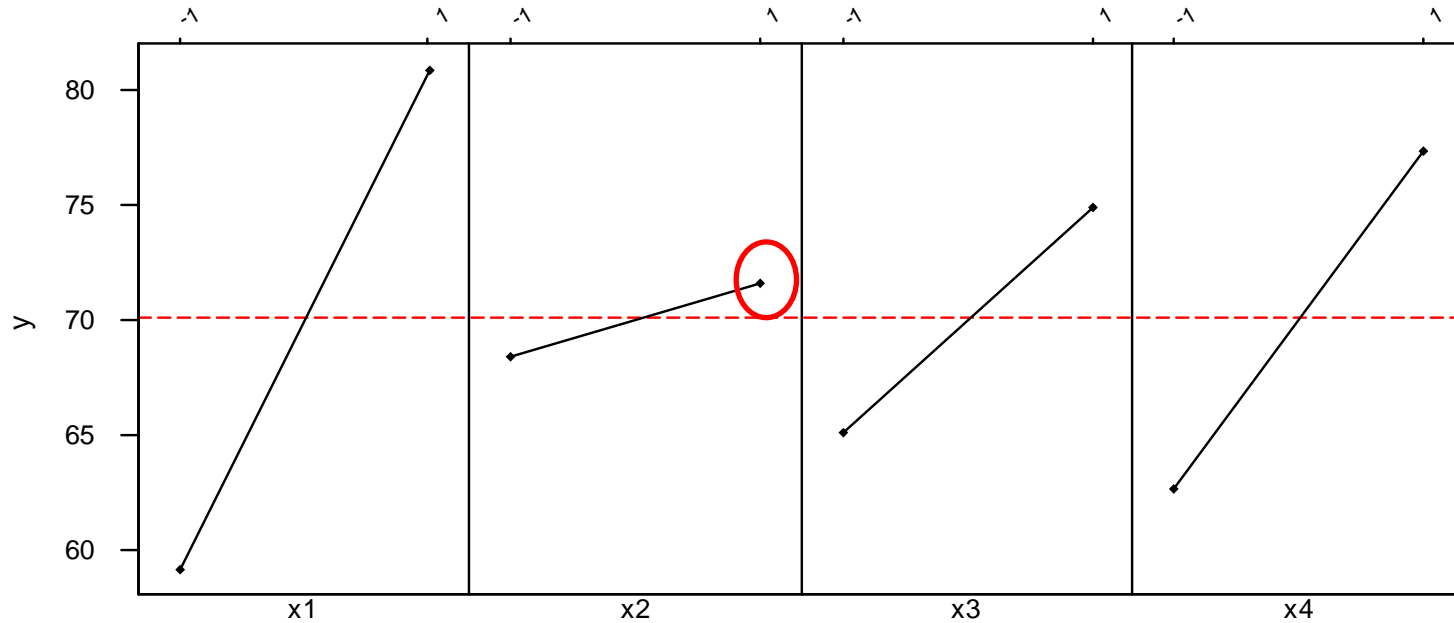
$X1=1, X4=1$



配合ANOVA分析表，有*圖表示有顯著交互作用

顯示主效應交互作用圖-主效應圖

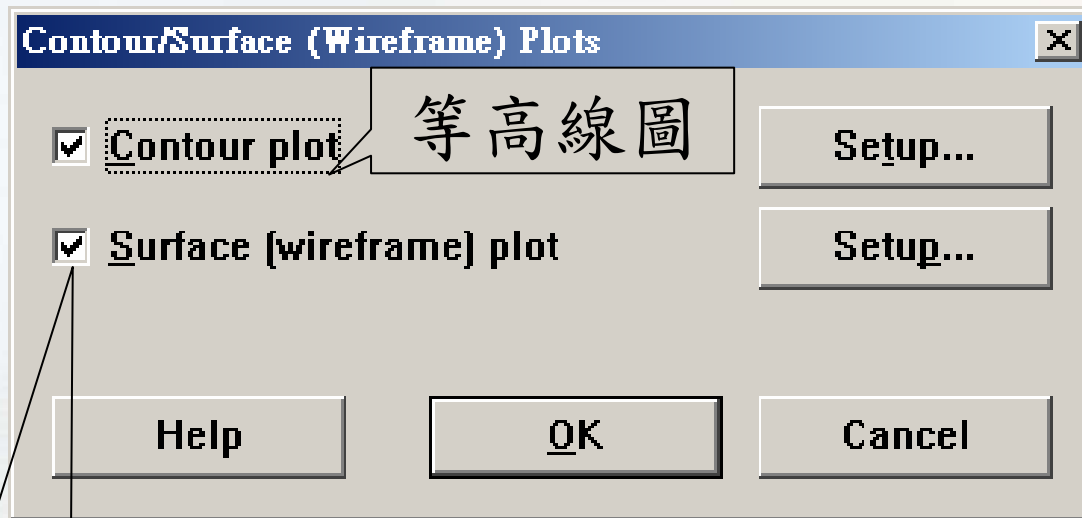
Main Effects Plot (data means) for y



配合ANOVA分析表，X2不顯著，所以水準值的選擇影響不大，若執意要選擇一個水準，則X2=1
搭配交互作用圖結果，最佳參數水準為
X1=1，X2=1，X3=-1，X4=1

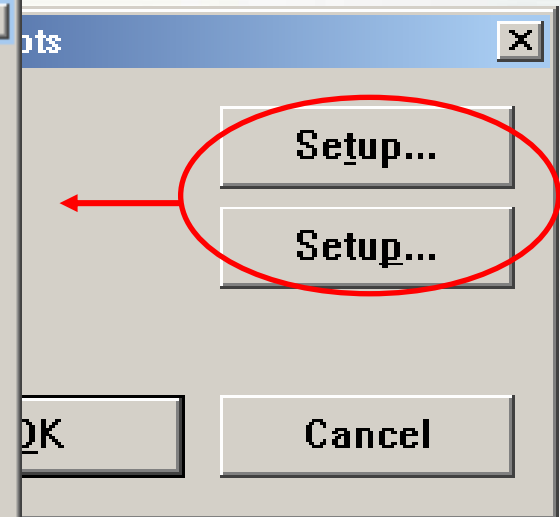
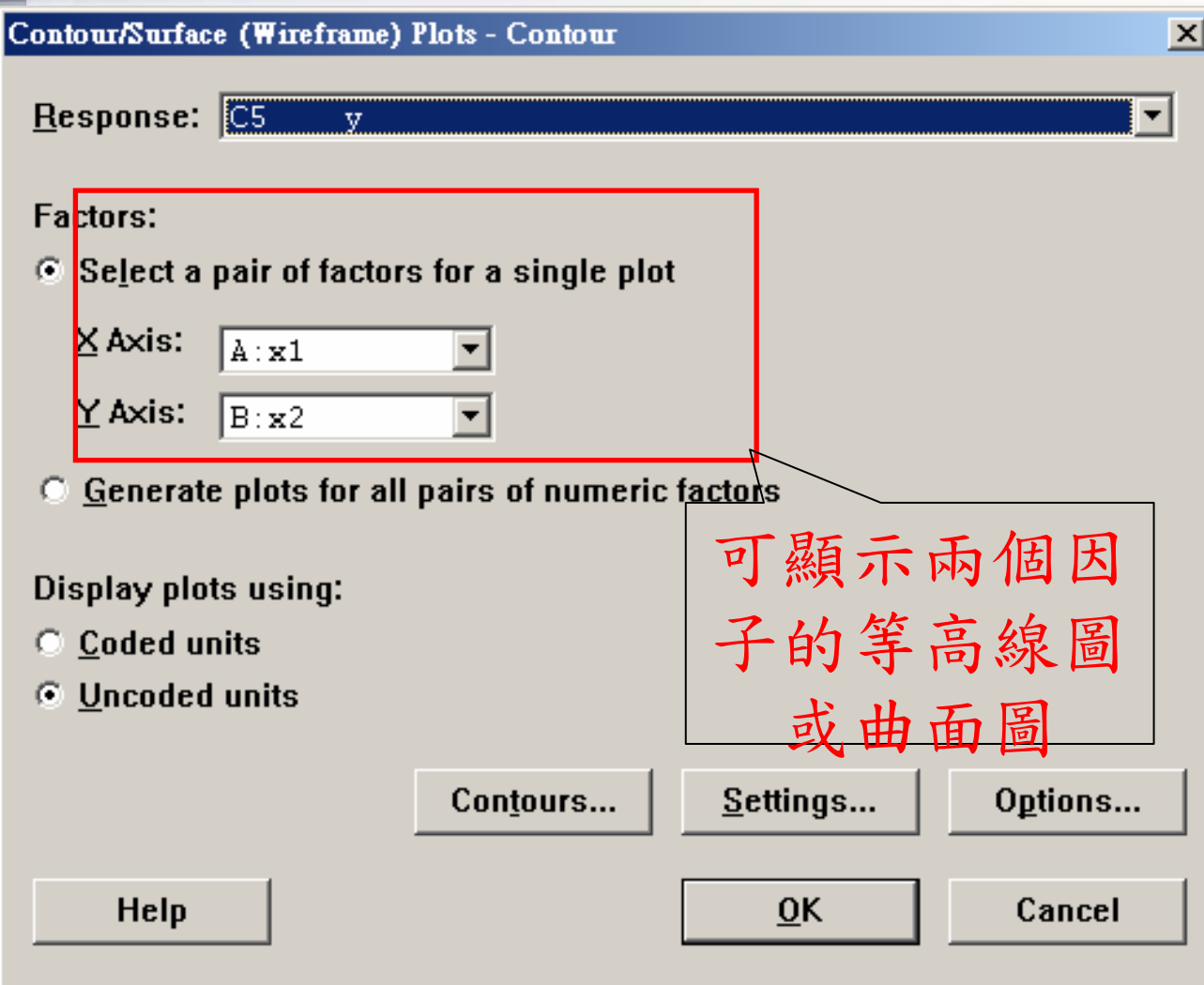
產生反應曲面圖和等高線圖

- 延續先前例子
- Stat → DOE → Factorial → Contour Surface (Wireframe) Plots



曲面圖

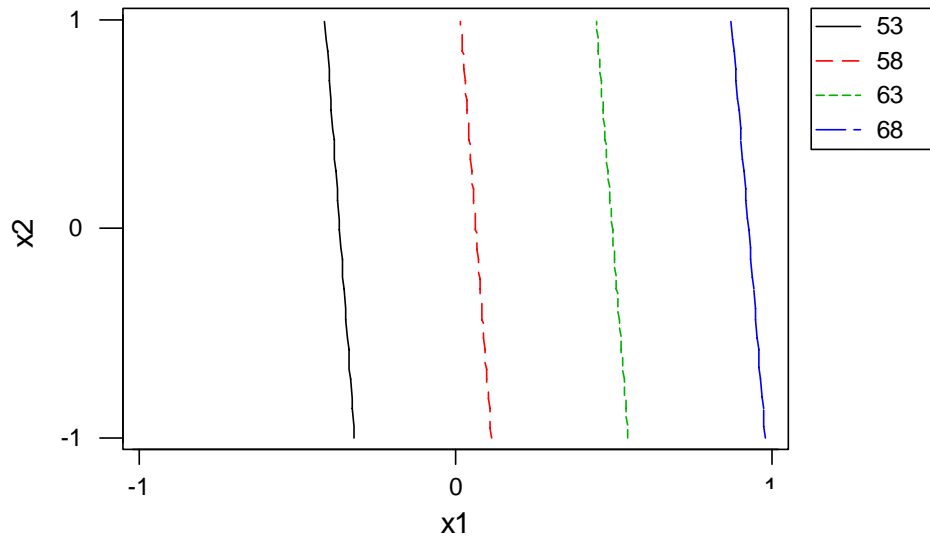
產生反應曲面圖和等高線圖



可顯示兩個因子的等高線圖或曲面圖

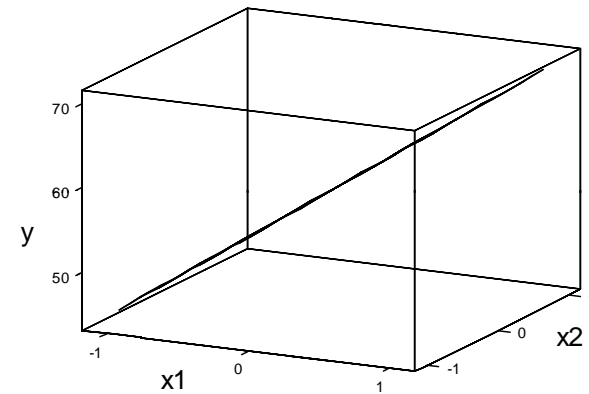
產生反應曲面圖和等高線圖

Contour Plot of y



Hold values: x3:-1.0 x4:-1.0

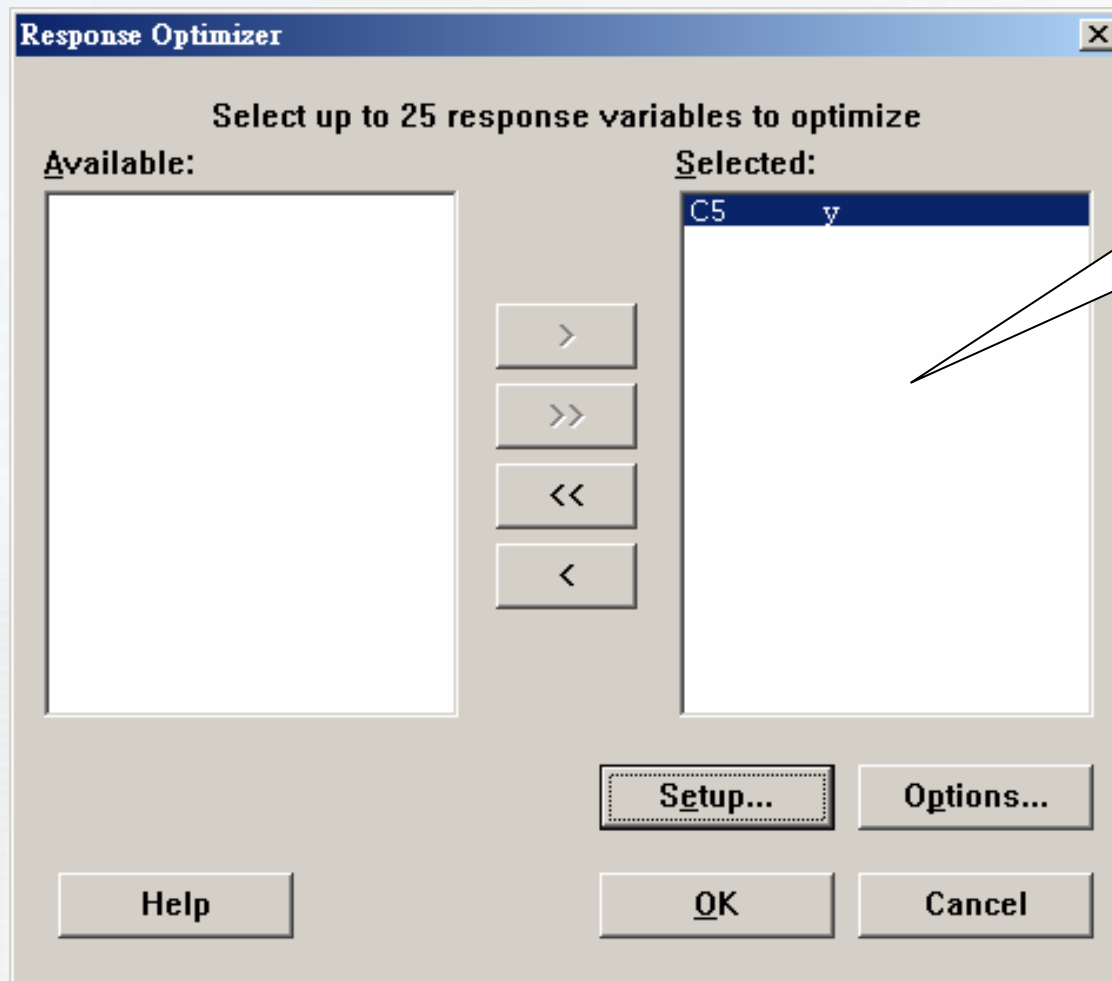
Surface Plot of y



Hold values: x3:-1.0 x4:-1.0

參數最佳化

- 延續先前例題
- Stat → DOE → Factorial → Response Optimizer



指定所要探討的反應值

參數最佳化

Response Optimizer - Setup

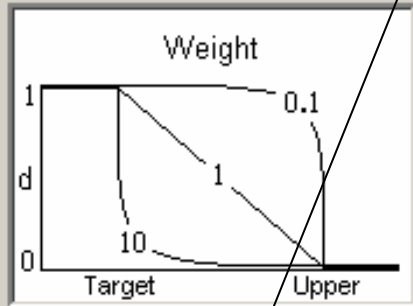
Response	Goal	Lower	Target	Upper	Weight	Importance
C5 y	Maximize	0	70			1

假設反應值為望大特性

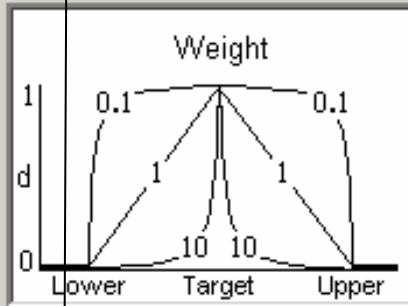
給定反應值可接受範圍，假設目標值為70，最小值是0

Desirability functions for different goals - how weights affect their shapes

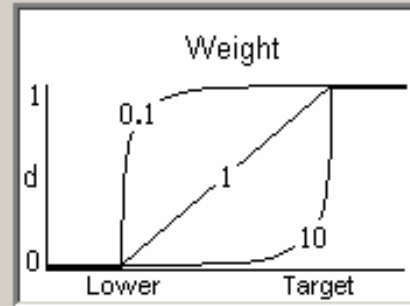
Minimize the Response



Hit a target value



Maximize the Response



Help

OK

Cancel

告知反應值範圍，極大值要給定下限和目標值，極小值要給定上限和目標值，若是望目特性，必須給予三個數值

Responses to optimize selected:

C5 y

Setup...

Options...

OK

Cancel

參數最佳化

Response Optimizer - Options

Factors in design	Starting value
x1	-1
x2	-1
x3	-1
x4	-1

給定因子起始搜尋值，其數值要在因子水準範圍內

Hold covariates at:

- High settings
 Middle settings
 Low settings

Name	Setting

- Optimization plot
 Store composite desirability values
 Display local solutions

Help

OK

Cancel

to 25 response variables to optimize

Selected:

C5	y
----	---

>

>>

<<

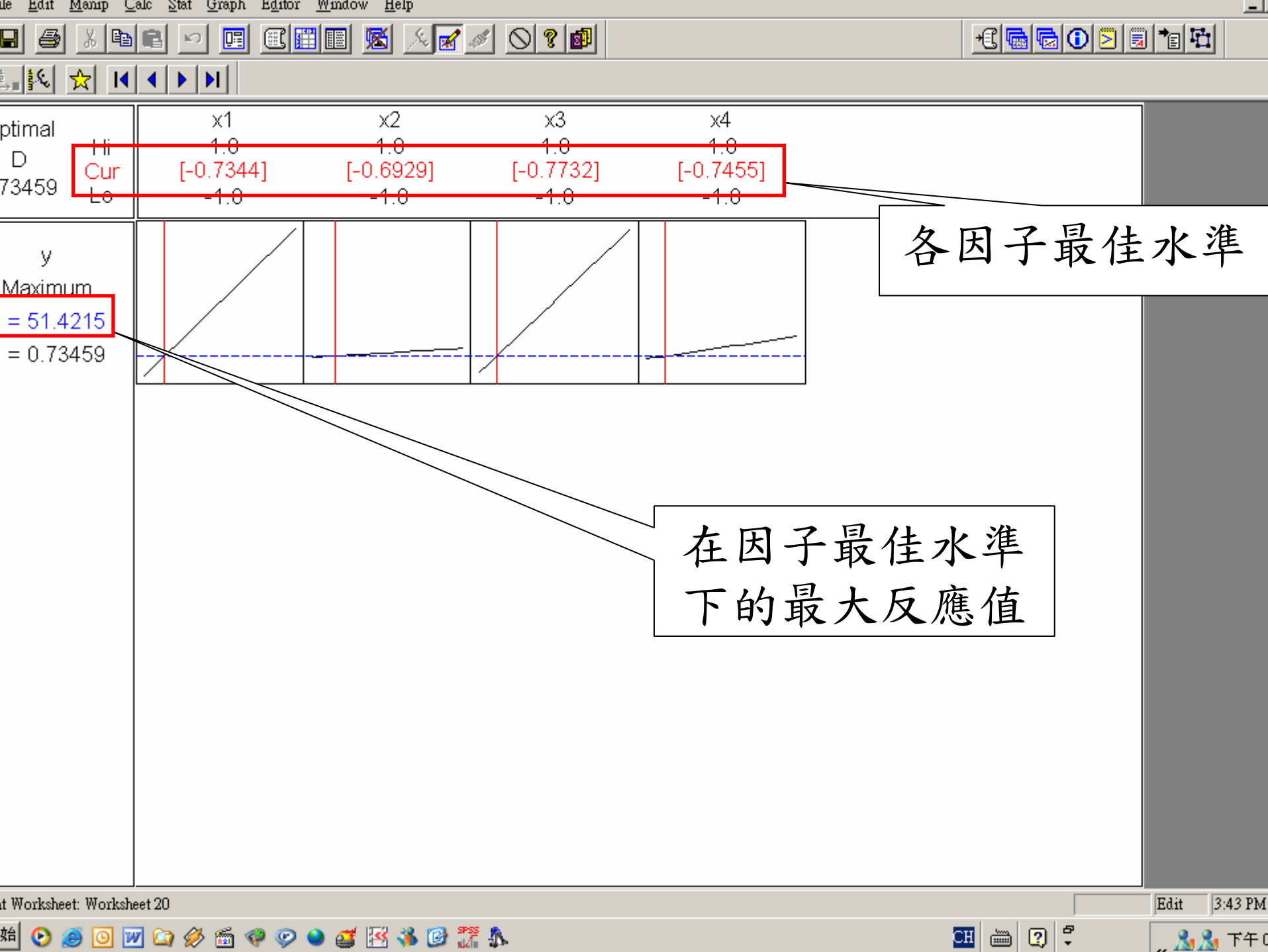
<

Setup...

Options...

OK

Cancel

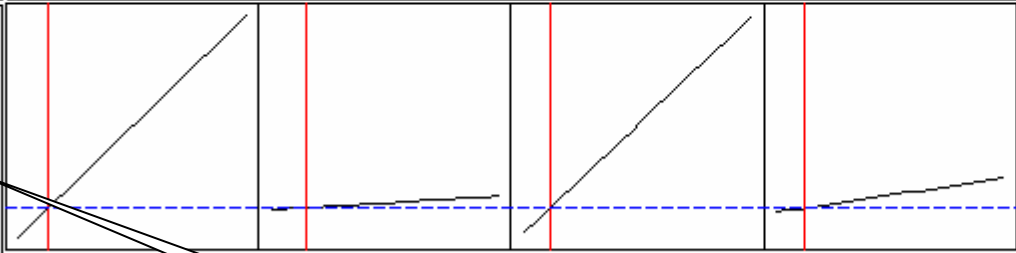


Optimal
D
73459

Hi
Cur
Lo

	x1	x2	x3	x4
Hi	1.0	1.0	1.0	1.0
Cur	[-0.7344]	[-0.6929]	[-0.7732]	[-0.7455]
Lo	-1.0	-1.0	-1.0	-1.0

y
Maximum
= 51.4215
= 0.73459



各因子最佳水準

在因子最佳水準下的最大反應值

品質與可靠度工程實驗室
Quality and Reliability Engineering Lab.

The END~~

Thank you