

第五章

5.2

	Stratum			
	I	II	III	
N_i	132	92	27	$\sum N_i \sigma_i = 1333$
σ_i^2	36	25	9	
$N_i \sigma_i$	792	460	81	

From Equation (5.9), $n_i = n \frac{N_i \sigma_i}{\sum N_i \sigma_i}$

Then

$$n_1 = 30(792 / 1333) = 17.82 \approx 18$$

$$n_2 = 30(460 / 1333) = 10.35 \approx 10$$

$$n_3 = 30(81 / 1333) = 1.82 \approx 2$$

5.3

	Stratum			
	I	II	III	
N_i	132	92	27	$N = 251$
n_i	18	10	2	
\bar{y}_i	8.83	6.7	4.5	
s_i^2	81.56	50.46	24.50	

The estimate of the total number of man-hours lost during the given month is, from Equation (5.3),

$$\hat{\tau} = N\bar{y}_{st} = 132(8.83) + 92(6.7) + 27(4.5) = 1903.9$$

The estimated variance of $\hat{\tau}$ is, from Equation (5.4),

$$V(\hat{\tau}) = \hat{V}(N\bar{y}_{st}) = \sum N_i^2 \left(\frac{N_i - n_i}{N_i} \right) \frac{s_i^2}{n_i} = 114519.9$$

with a bound on the error of estimation

$$B = 2\sqrt{\hat{V}(\bar{y}_{st})} = 676.8$$

5.5

	Stratum			
	I	II	III	
N_i	112	68	39	$N = 219$
c_i	9	25	36	
σ_i^2	2.25	3.24	3.24	

$$n = \frac{\left(\sum N_k \sigma_k / \sqrt{c_k} \right) \left(\sum N_i \sigma_i \sqrt{c_i} \right)}{N^2 D + \sum N_i \sigma_i^2}$$

$$B = 2\sqrt{V(\bar{y}_{st})} \text{ or } V(\bar{y}_{st}) = \frac{B^2}{4} = D = 0.1$$

$$\sum \left(\frac{N_k \sigma_k}{\sqrt{c_k}} \right) = \frac{112(1.5)}{3} + \frac{68(1.8)}{5} + \frac{39(1.8)}{6} = 92.18$$

$$\sum N_i \sigma_i \sqrt{c_i} = 112(1.5)(3) + 68(1.8)(5) + 39(1.8)(6) = 1537.2$$

$$\sum N_i \sigma_i^2 = 112(2.25) + 68(3.24) + 39(3.24) = 598.68$$

$$n = \frac{92.18(1537.2)}{219^2(.1) + 598.68} = 26.3 \approx 27$$

To allocate the $n = 27$ to the three strata, use

$$n_i = n \frac{N_i \sigma_i / \sqrt{c_i}}{\sum N_k \sigma_k / \sqrt{c_k}}$$

Then

$$n_1 = 27 \frac{112(1.5)/3}{92.18} = 16.40 \quad n_2 = 27 \frac{68(1.8)/5}{92.18} = 7.17 \quad n_3 = 27 \frac{39(1.8)/6}{92.18} = 3.43$$

Rounding off yields: $n_1 = 16$, $n_2 = 7$, $n_3 = 3$

This adds to total sample size of 26, not 27. Add 1 to one of the sample sizes to achieve $n = 27$. Add to stratum 3 because 3.43 is closer to the next higher integer than any other sample sizes.

5.8
$$n = \frac{\left(\sum N_i \sigma_i \right)^2}{N^2 D + \sum N_i \sigma_i^2} \quad B = 1, \quad D = \frac{B^2}{4} = .25$$

Use $\frac{\text{range}}{4}$ to estimate σ_i .

	Stratum		
	I	II	
N_i	43	53	$N = 96$
Range	20-5=15	14-3=11	
σ_i	$\frac{15}{4} = 3.75$	$\frac{11}{4} = 2.75$	

$$n = \frac{[43(3.75) + 53(2.75)]^2}{(96)^2(.25) + [43(3.75)^2 + 53(2.75)^2]} = \frac{94249}{3309.5} = 28.48 \approx 29$$

5.10

	Stratum				Tot
	I	II	III	IV	
N_i	86	72	52	30	240
n_i	14	12	9	5	40
\bar{y}_i	63.36	183.00	340.557	472.40	
s_i^2	1071.79	9054.18	16794.28	72376.30	

$$\hat{\tau} = N\bar{y}_{st} = \sum N_i \bar{y}_i = 50505.60$$

$$\hat{V}(\hat{\tau}) = \sum N_i^2 \left(\frac{N_i - n_i}{N_i} \right) \frac{s_i^2}{n_i} = 18762430.98$$

$$B = 2\sqrt{\hat{V}(\hat{\tau})} = 8663.12$$

5.11

$$n = \frac{\left(\sum N_i \sigma_i \right)^2}{N^2 D + \sum N_i \sigma_i^2}$$

$$N^2 D = \frac{B^2}{4} = \frac{(5000)^2}{4} = (2500)^2$$

Use s_i^2 to estimate σ_i^2 .

$$\sum N_i s_i = 86\sqrt{1071.79} + 72\sqrt{16974.28} + 30\sqrt{72376.30} = 24476.20$$

$$\sum N_i s_i^2 = 86(1071.79) + 72(9054.18) + 52(16794.28) + 30(72376.30) = 3788666.11$$

$$n = \frac{24476.20^2}{(2500)^2 + 3788666.11} = 59.68 \approx 60$$

5.13

	Stratum				Tot
	I	II	III	IV	
N_i	97	43	145	68	353
p_i	.9	.9	.5	.5	
c_i	4	4	8	8	
$N_i \sqrt{p_i q_i / c_i}$	14.55	6.45	25.63	12.02	58.65
a_i	.248	.110	.437	.205	
$N_i^2 p_i q_i / a_i$	3413.63	1513.26	12027.53	5640.50	22594.92
$N_i p_i q_i$	8.73	3.87	36.25	17.00	65.85
n_i	39	17	69	33	158

where

$$a_i = \frac{N_i \sqrt{p_i q_i / c_i}}{\sum N_k \sqrt{p_k q_k / c_k}}$$

$$D = \frac{B^2}{4} = \frac{.05^2}{4} = (.025)^2$$

$$n = \frac{\sum N_i^2 p_i q_i / a_i}{N^2 D + \sum N_i p_i q_i} = \frac{22594.92}{(353)^2 (.025)^2 + 65.85} = 157.20 \approx 158$$

$$n_i = n a_i$$

5.14

	Stratum				Tot
	I	II	III	IV	
N_i	97	43	145	68	353
n_i	39	17	69	33	
\hat{p}_i	.87	.93	.60	.53	
$N_i^2 \left(\frac{N_i - n_i}{N_i} \right) \frac{\hat{p}_i \hat{q}_i}{n_i - 1}$	16.74	4.55	38.89	18.53	78.81

$$\hat{p}_{st} = \frac{1}{N} \sum N_i \hat{p}_i = \frac{1}{353} [97(.87) + 43(.93) + 145(.60) + 68(.53)] = .701$$

$$B = 2 \sqrt{\frac{1}{N^2} \sum N_i^2 \left(\frac{N_i - n_i}{N_i} \right) \frac{\hat{p}_i \hat{q}_i}{n_i}} = 2 \sqrt{\frac{78.71}{(353)^2}} = .0503$$

5.15 Total cost = $\sum n_i c_i = 400$

where c_i is the cost of obtaining one observation from stratum i

$$\text{But, } c_i = c_2 = \frac{c_3}{2} = \frac{c_4}{2}$$

Writing the equation in terms of c_1 only gives

$$n_1 c_1 + n_2 c_2 + n_3 c_3 + n_4 c_4 = 400$$

$$n_1 c_1 + n_2 c_1 + 2n_3 c_1 + 2n_4 c_1 = 400$$

$$c_1 (n_1 + n_2 + 2n_3 + 2n_4) = 400$$

$$n_1 + n_2 + 2n_3 + 2n_4 = 400 / c_1 = 100$$

$$na_1 + na_2 + 2na_3 + 2na_4 = 100$$

$$n(a_1 + a_2 + 2a_3 + 2a_4) = 100$$

Using the sampling fractions from Exercise 5.13,

$$n = 100 / [.248 + .110 + 2(.437) + 2(.205)] = 60.90 \cong 61$$

$$n_1 = na_1 = 61(.248) = 15.13 \approx 15$$

$$n_2 = na_2 = 61(.110) = 6.71 \approx 7$$

$$n_3 = na_3 = 61(.437) = 26.66 \approx 27$$

$$n_4 = na_4 = 61(.205) = 12.50 \approx 12$$

$$\text{Total cost} = 15(4) + 7(4) + 27(8) + 12(8) = \$400.$$

5.17

No. of Employees	Frequency	$\sqrt{\text{Frequency}}$	Cumulative $\sqrt{\text{Frequency}}$
0-10	2	1.41	1.41
11-20	4	2.00	3.41
21-30	6	2.45	5.86
31-40	6	2.45	8.31
41-50	5	2.24	10.55
51-60	8	2.83	13.38
61-70	10	3.16	16.54
71-80	14	3.74	20.28
81-90	19	4.36	24.64
91-100	13	3.61	28.25
101-110	3	1.73	29.98
111-120	7	2.65	32.62

$L = 4$ strata, $32.62 / 4 = 8.155$

Stratum boundaries should be as close as possible to: 8.155, 16.312, 24.468
Choose boundaries of 8.31, 16.54, 24.64.

Stratum 1: 0-40 employees
Stratum 2: 41-70 employees
Stratum 3: 71-90 employees
Stratum 4: 91-120 employees

5.19

	Stratum	
	I	II
\bar{y}_i	63.47	64.30
s_i^2	1.07	1.30
n_i	8 6	7 6

N_1 and N_2 are unknown. Assume that they are equal. Let N' represent both of these terms.

$$\hat{\mu} = \bar{y}_{st} = \frac{1}{N} \sum N_i \bar{y}_i = \frac{1}{2N'} [N \bar{y}_1 + N \bar{y}_2] = \frac{1}{2} (\bar{y}_1 + \bar{y}_2) = \frac{1}{2} (63.47 + 64.30) = 63.88$$

$$B = 2 \sqrt{\frac{1}{N^2} \sum N_i^2 \frac{s_i^2}{n_i}} = 2 \sqrt{\frac{N'^2}{(2N')^2} \sum \frac{s_i^2}{n_i}} = 2 \sqrt{\frac{1}{4} \sum \frac{s_i^2}{n_i}} = 2 \sqrt{\frac{1}{4} \left(\frac{1.07}{6} + \frac{1.30}{6} \right)} = .628$$

The shipment appears to be below the standard in average weight.

5.21 (a) $\hat{p} = \frac{\sum y_i}{n} = \frac{6+10}{100} = .16$

$$B = 2\sqrt{\frac{\hat{p}\hat{q}}{n-1}} = 2\sqrt{\frac{.16(.84)}{99}} = .074 \quad (\text{ignoring fpc})$$

(b) $\hat{p}_{st} = \frac{1}{N} \sum N_i \hat{p}_i = \sum \frac{N_i}{N} \hat{p}_i = .6 \frac{6}{38} + .4 \frac{10}{62} = .16$

$$B = 2\sqrt{\frac{1}{N^2} \sum N_i^2 \frac{\hat{p}_i \hat{q}_i}{n_i - 1}} = 2\sqrt{\sum \left(\frac{N_i}{N}\right)^2 \frac{\hat{p}_i \hat{q}_i}{n_i - 1}}$$

$$= 2\sqrt{(.6)^2 \left(\frac{6}{38}\right) \left(\frac{32}{38}\right) \left(\frac{1}{37}\right) + (.4)^2 \left(\frac{10}{62}\right) \left(\frac{52}{62}\right) \left(\frac{1}{61}\right)} = .081$$

There seems to be no good reason to poststratify here.

5.27 (a)

	Stratum		Total
	I	II	
N_i	20	26	
σ_i	25	47.5	
$N_i \sigma_i$	500	1235	1735
w_i	.29	.71	
$N_i \sigma_i^2$	12500	58662.5	71162.5

where

$\frac{\text{range}}{4}$ is used to estimate σ_i .

$$\sigma_1 \approx \frac{100-0}{4} = 25 \quad \text{for small plants (stratum I)}$$

$$\sigma_2 \approx \frac{200-10}{4} = 47.5 \quad \text{for large plants (stratum II)}$$

$$a_i = \frac{N_i \sigma_i}{\sum N_i \sigma_i}$$

$$a_1 = \frac{500}{1735} = .29 \quad a_2 = \frac{1235}{1735} = .71$$

(b) $B = 100$

$$N^2 D = \frac{B^2}{4} = \frac{(100)^2}{4} = 2500$$

$$n = \frac{\left(\sum N_i \sigma_i\right)^2}{N^2 D + \sum N_i \sigma_i^2} = \frac{(1735)^2}{2500 + 71162.5} = 40.87 \approx 41$$

$$n_1 = n a_1 = 41(.29) = 11.9 \approx 12$$

$$n_2 = n a_2 = 41(.71) = 29.1 \approx 29$$

Since there is only 26 “large” plants, we allocate $n_1 = 15$, $n_2 = 26$.

5.31

	Stratum		
	I	II	III
w_i	.5	.1	.4
No	417	29	240
	31.4	17.6	21.8
Yes	913	136	860
	68.6	82.4	78.2
Tot	1330	165	1100
	100%	100%	100%

(a) $\hat{p}_{st} = \sum \frac{N_i}{N} \hat{p}_i = \sum a_i \hat{p}_i = (.5)(.686) + (.1)(.824) + (.4)(.782) = .738$
 $\hat{V}(\hat{p}_{st}) = \sum a_i^2 \frac{\hat{p}_i \hat{q}_i}{n_i - 1}$ (ignoring the fpc)
 $= (.5)^2 \frac{(.686)(.314)}{1329} + (.1)^2 \frac{(.824)(.176)}{164} + (.4)^2 \frac{(.782)(.218)}{1099} = .74 \times 10^{-4}$

(b) $\hat{p}_1 - \hat{p}_2 = .686 - .824 = -.138$
 $B = 2\sqrt{\hat{V}(\hat{p}_1 - \hat{p}_2)} = 2\sqrt{\frac{\hat{p}_1 \hat{q}_1}{n_1} + \frac{\hat{p}_2 \hat{q}_2}{n_2}} = 2\sqrt{\frac{(.686)(.314)}{1330} + \frac{(.824)(.176)}{165}} = .0645$

(c) $\hat{p}_1 - \hat{p}_2 = .686 - .782 = -.096$
 $B = 2\sqrt{\hat{V}(\hat{p}_1 - \hat{p}_2)} = 2\sqrt{\frac{\hat{p}_1 \hat{q}_1}{n_1} + \frac{\hat{p}_2 \hat{q}_2}{n_2}} = 2\sqrt{\frac{(.686)(.314)}{1330} + \frac{(.782)(.218)}{1100}} = .036$

5.31

(a) $\hat{p}_{st} = \sum \frac{N_i}{N} \hat{p}_i = \sum a_i \hat{p}_i = (.5)(.686) + (.1)(.824) + (.4)(.782) = .738$
 $\hat{V}(\hat{p}_{st}) = \sum a_i^2 \frac{\hat{p}_i \hat{q}_i}{n_i - 1}$ (ignoring the fpc)
 $= (.5)^2 \cdot \frac{(.686)(.314)}{1329} + (.1)^2 \cdot \frac{(.824)(.176)}{164} + (.4)^2 \cdot \frac{(.782)(.218)}{1099} = .74 \times 10^{-4}$

$\Rightarrow 2\sqrt{\hat{V}(\hat{p}_{st})} = 2\sqrt{.74 \times 10^{-4}} = 0.01720465053$

(b) $\hat{p}_1 - \hat{p}_2 = 0.686 - 0.824 = -0.138$

$B = 2\sqrt{\hat{V}(\hat{p}_1 - \hat{p}_2)} = 2\sqrt{\frac{\hat{p}_1 \hat{q}_1}{n_1} + \frac{\hat{p}_2 \hat{q}_2}{n_2}} = 2\sqrt{\frac{(.686)(.314)}{1330} + \frac{(.824)(.176)}{165}} = 0.0645$

$\Rightarrow -0.138 \pm 0.0645 \Rightarrow (-0.2025, -0.0735) \Rightarrow$ 麻醉醫師與麻醉住院醫師有顯著差異 (存在工作超量安全極限的母體比例估計方面)

(c) $\hat{p}_1 - \hat{p}_2 = 0.686 - 0.782 = -0.096$

$B = 2\sqrt{\hat{V}(\hat{p}_1 - \hat{p}_2)} = 2\sqrt{\frac{\hat{p}_1 \hat{q}_1}{n_1} + \frac{\hat{p}_2 \hat{q}_2}{n_2}} = 2\sqrt{\frac{(.686)(.314)}{1330} + \frac{(.782)(.218)}{1100}} = 0.036$

$\Rightarrow -0.096 \pm 0.036 \Rightarrow (-0.132, -0.06) \Rightarrow$ 麻醉醫師與麻醉護士有顯著差異 ()

5.32 (a) $\bar{y}_{st} = \sum a_i \bar{y}_i = (.5)(7.63) + (.1)(7.74) + (.4)(6.55) = 7.209$

$$B = 2\sqrt{\hat{V}(\bar{y}_{st})} = 2\sqrt{\sum a_i^2 \frac{s_i^2}{n_i}} = 2\sqrt{(.5)^2 \frac{(15)^2}{1347} + (.1)^2 \frac{(35)^2}{163} + (.4)^2 \frac{(11)^2}{1095}} = .0073$$

(b) $\bar{y}_1 - \bar{y}_2 = 7.63 - 7.74 = -.11$

$$B = 2\sqrt{\hat{V}(\bar{y}_1 - \bar{y}_2)} = 2\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = 2\sqrt{\frac{(15)^2}{1347} + \frac{(35)^2}{163}} = .055$$

~~The confidence interval just touches 0, so there is no strong evidence that the residents have a higher mean than the non-resident anesthesiologists.~~

$$\bar{y}_2 - \bar{y}_3 = 7.74 - 6.55 = 1.19$$

$$B = 2\sqrt{\hat{V}(\bar{y}_2 - \bar{y}_3)} = 2\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = 2\sqrt{\frac{(35)^2}{163} + \frac{(11)^2}{1095}} = .055$$

~~The confidence interval overlaps 0, so there is evidence that the residents have a higher mean than the nurses.~~

5.32 (a) $\bar{y}_{st} = \sum a_i \bar{y}_i = (0.5)(7.63) + (0.1)(7.74) + (0.4)(6.55) = 7.209$

$$B = 2\sqrt{\hat{V}(\bar{y}_{st})} = 2\sqrt{\sum a_i^2 \frac{s_i^2}{n_i}} = 2\sqrt{(0.5)^2 \cdot \frac{(15)^2}{1347} + (0.1)^2 \cdot \frac{(35)^2}{163} + (0.4)^2 \cdot \frac{(11)^2}{1095}} = 0.0073$$

$$\Rightarrow 7.209 \pm 0.0073 = (7.2017, 7.2163) \quad \#$$

(b) $\bar{y}_1 - \bar{y}_2 = 7.63 - 7.74 = -0.11$

$$B = 2\sqrt{\hat{V}(\bar{y}_1 - \bar{y}_2)} = 2\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = 2\sqrt{\frac{(15)^2}{1347} + \frac{(35)^2}{163}} = 0.055$$

$$\Rightarrow -0.11 \pm 0.055 = (-0.165, -0.055) \Rightarrow \text{麻醉住院醫師的平均時間高於麻醉醫師} \quad \#$$

$$\bar{y}_2 - \bar{y}_3 = 7.74 - 6.55 = 1.19$$

$$B = 2\sqrt{\hat{V}(\bar{y}_2 - \bar{y}_3)} = 2\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = 2\sqrt{\frac{(35)^2}{163} + \frac{(11)^2}{1095}} = 0.055$$

$$\Rightarrow 1.19 \pm 0.055 = (1.135, 1.245) \Rightarrow \text{麻醉住院醫師的平均時間高於麻醉護士} \quad \#$$