國立雲林科技大學
八十八學年度研究所博士班入學考試試題

所別：管理研究所
科目：統計學

1. (15%) An investment analyst must allocate a $1,000,000 fund among three given investments. Historically, each investment has averaged an 8% return. The standard deviations of the investment returns have been 2.5%, 3%, and 3.5%, respectively. The correlations of returns have been .50 (for investments 1 and 2), .60 (for 1 and 3), and -.20 (for 2 and 3). The analyst must choose among three possibilities: equal amounts to investments 1 and 2, equal amounts to 1 and 3, or equal amounts to 2 and 3. The investor does not like risk and proposes to invest all the money in the lowest-variation investment. Which possibility the investor will choose? Is this the lowest-variability strategy? Does any other possibility (other than the three above) have lower variability?

2. (15%) The quantitative score (X) and English score (Y) in an aptitude test are assumed to have a joint continuous distribution: $f(x,y)=\frac{x+y}{1000}, 0\le x\le 10, 0\le y\le 10$. What is the covariance of the two scores? What is the probability of $X\ge Y$?

3. (10%) New MBA graduates from a certain business school hunger for jobs with a certain consulting company. Half the MBA graduates major in finance. The company actually hires 10% of all those it interviews, regardless of major.

(a) If a student (assumed to be randomly chosen from the class of graduates) requests an interview, what is the chance that the student will be hired?

(b) If a randomly chosen student is hired, what is the probability that the student did not major in finance?

4. (10%) A copy machine fails according to a Poisson process with a rate 0.5 breakdowns per month. It is assumed that the copy machine can be fixed immediately after its breakdown.

(a) What is the probability that the first breakdown will take place in a month? How would you interpret the probability value?

(b) What is the probability that the second breakdown will take place in 2 months?

5. (10%) In a simulation study, two scheduling rules were experimented *separately* (分別) to compare the daily output of a factory:

Rule A	102	101	96	95	98	98	102	99	99	102
Rule B	96	99	97	98	99	98	99	101	103	103

It is assumed the daily outputs are independently and normally distributed.

(a) Test if the two rules have different variations in output at 0.05 significance level.
(b) Test if the two rules have different average outputs at 0.05 significance level. What is the p value of the test.

6. (15%) Many newspapers, when reporting results of political polls, say that "with 95% confidence, the results are in error by no more than ± 3 percentage points." The allowance for error is intended to cover both sampling variability and the effect of small biases.

(a) What is the conservative (保守的) sample size required to construct a 95% confidence interval with 3% half width for the proportion? (7%)
(b) When there are many political candidates, as in the early stages of a presidential primary, a candidate is favored by 30 of 1500 likely voters in a sample, construct a 95% confidence interval for his favoring proportion. (8%)

7. (10%) Suppose that in the flexible time-scheduling, a random sample of 216 workers yields the following frequencies:

	Office				
Favored Plan	1	2	3	4	Total
1	15	32	18	5	70
2	8	29	23	18	78
3	1	20	25	22	68
Total	24	81	66	45	216

Carry out the χ^2 test of independence using $\alpha = .05$.

8. (15%) A simple linear relationship is hypothesized for the independent variable (X) and response variable (Y). A regression analysis gives the following computer printout:

The regression equation
Y = - 0.786 + 0.685 X

Predictor	Coef	Stdev	t-ratio	p
Constant	-0.7861	0.5418	-1.45	0.185
X	0.6850	0.1802	3.80	0.005

s = 1.083   R-sq = 64.4%   R-sq(adj) = 59.9%

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Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	16.932	16.932	14.45	0.005
Error	8	9.377	1.172		
Total	9	26.309			

$\bar{x} = 2.33, \bar{y} = 0.81, S_{XX} = 36.081, S_{YY} = 26.309, S_{XY} = 24.717$

(a) What model assumptions are required for the analysis above?

(b) Under what hypothesis does the F statistics in the ANOVA table have an F distribution?

(c) Construct a 90% confidence interval for the slope (斜率) of the regression function.

(d) Based on the result of (c), is there a linear relationship between X and Y at 0.1 significance level? Why?

(e) Construct a 90% prediction interval for the response Y given $X = 2.0$.

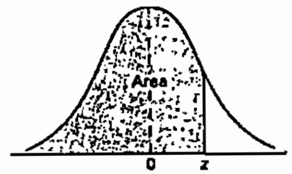

Table A.3 (continued) Areas Under the Normal Curve

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9278	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

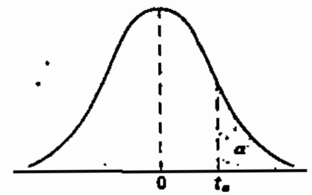

Table A.4 Critical Values of the t-Distribution

	α						
v	0.40	0.30	0.20	0.15	0.10	0.05	0.025
1	0.325	0.727	1.376	1.963	3.078	6.314	12.706
2	0.289	0.617	1.061	1.386	1.886	2.920	4.303
3	0.277	0.584	0.978	1.250	1.638	2.353	3.182
4	0.271	0.569	0.941	1.190	1.533	2.132	2.776
5	0.267	0.559	0.920	1.156	1.476	2.015	2.571
6	0.265	0.553	0.906	1.134	1.440	1.943	2.447
7	0.263	0.549	0.896	1.119	1.415	1.895	2.365
8	0.262	0.546	0.889	1.108	1.397	1.860	2.306
9	0.261	0.543	0.883	1.100	1.383	1.833	2.262
10	0.260	0.542	0.879	1.093	1.372	1.812	2.228
11	0.260	0.540	0.876	1.088	1.363	1.796	2.201
12	0.259	0.539	0.873	1.083	1.356	1.782	2.179
13	0.259	0.537	0.870	1.079	1.350	1.771	2.160
14	0.258	0.537	0.868	1.076	1.345	1.761	2.145
15	0.258	0.536	0.866	1.074	1.341	1.753	2.131
16	0.258	0.535	0.865	1.071	1.337	1.746	2.120
17	0.257	0.534	0.863	1.069	1.333	1.740	2.110
18	0.257	0.534	0.862	1.067	1.330	1.734	2.101
19	0.257	0.533	0.861	1.066	1.328	1.729	2.093
20	0.257	0.533	0.860	1.064	1.325	1.725	2.086
21	0.257	0.532	0.859	1.063	1.323	1.721	2.080
22	0.256	0.532	0.858	1.061	1.321	1.717	2.074
23	0.256	0.532	0.858	1.060	1.319	1.714	2.069
24	0.256	0.531	0.857	1.059	1.318	1.711	2.064
25	0.256	0.531	0.856	1.058	1.316	1.708	2.060
26	0.256	0.531	0.856	1.058	1.315	1.706	2.056
27	0.256	0.531	0.855	1.057	1.314	1.703	2.052
28	0.256	0.530	0.855	1.056	1.313	1.701	2.048
29	0.256	0.530	0.854	1.055	1.311	1.699	2.045
30	0.256	0.530	0.854	1.055	1.310	1.697	2.042
40	0.255	0.529	0.851	1.050	1.303	1.684	2.021
60	0.254	0.527	0.848	1.045	1.296	1.671	2.000
120	0.254	0.526	0.845	1.041	1.289	1.658	1.980
∞	0.253	0.524	0.842	1.036	1.282	1.645	1.960

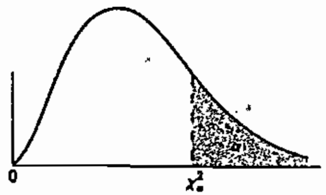

Table A.5 Critical Values of the Chi-Squared Distribution

v	0.995	0.99	0.98	0.975	0.95	0.90	0.80	0.75	0.75	0.50
	α									
1	0.0^4393	0.0^3157	0.0^3628	0.0^3982	0.00393	0.0158	0.0642	0.102	0.148	0.455
2	0.0100	0.0201	0.0404	0.0506	0.103	0.211	0.446	0.575	0.713	1.386
3	0.0717	0.115	0.185	0.216	0.352	0.584	1.005	1.213	1.424	2.366
4	0.207	0.297	0.429	0.484	0.711	1.064	1.649	1.923	2.195	3.357
5	0.412	0.554	0.752	0.831	1.145	1.610	2.343	2.675	3.000	4.351
6	0.676	0.872	1.134	1.237	1.635	2.204	3.070	3.455	3.828	5.348
7	0.989	1.239	1.564	1.690	2.167	2.833	3.822	4.255	4.671	6.346
8	1.344	1.646	2.032	2.180	2.733	3.490	4.594	5.071	5.527	7.344
9	1.735	2.088	2.532	2.700	3.325	4.168	5.380	5.899	6.393	8.343
10	2.156	2.558	3.059	3.247	3.940	4.865	6.179	6.737	7.267	9.342
11	2.603	3.053	3.609	3.816	4.575	5.578	6.989	7.584	8.148	10.341
12	3.074	3.571	4.178	4.404	5.226	6.304	7.807	8.438	9.034	11.340
13	3.565	4.107	4.765	5.009	5.892	7.042	8.634	9.299	9.926	12.340
14	4.075	4.660	5.368	5.629	6.571	7.790	9.467	10.165	10.821	13.339
15	4.601	5.229	5.985	6.262	7.261	8.547	10.307	11.036	11.721	14.339
16	5.142	5.812	6.614	6.908	7.962	9.312	11.152	11.912	12.624	15.338
17	5.697	6.408	7.255	7.564	8.672	10.085	12.002	12.792	13.531	16.338
18	6.265	7.015	7.906	8.231	9.390	10.865	12.857	13.675	14.440	17.338
19	6.844	7.633	8.567	8.907	10.117	11.651	13.716	14.562	15.352	18.338
20	7.434	8.260	9.237	9.591	10.851	12.443	14.578	15.452	16.266	19.337
21	8.034	8.897	9.915	10.283	11.591	13.240	15.445	16.344	17.182	20.337
22	8.643	9.542	10.600	10.982	12.338	14.041	16.314	17.240	18.101	21.337
23	9.260	10.196	11.293	11.688	13.091	14.848	17.187	18.137	19.021	22.337
24	9.886	10.856	11.992	12.401	13.848	15.659	18.062	19.037	19.943	23.337
25	10.520	11.524	12.697	13.120	14.611	16.473	18.940	19.939	20.867	24.337
26	11.160	12.198	13.409	13.844	15.379	17.292	19.820	20.843	21.792	25.336
27	11.808	12.879	14.125	14.573	16.151	18.114	20.703	21.749	22.719	26.336
28	12.461	13.565	14.847	15.308	16.928	18.939	21.588	22.657	23.647	27.336
29	13.121	14.256	15.574	16.047	17.708	19.768	22.475	23.567	24.577	28.336
30	13.787	14.953	16.306	16.791	18.493	20.599	23.364	24.478	25.508	29.336

Table A.5 (continued) Critical Values of the Chi-Squared Distribution

v	0.30	0.25	0.20	0.10	0.05	0.025	0.02	0.01	0.005	0.001
	α									
1	1.074	1.323	1.642	2.706	3.841	5.024	5.412	6.635	7.879	10.827
2	2.408	2.773	3.219	4.605	5.991	7.378	7.824	9.210	10.597	13.815
3	3.665	4.108	4.642	6.251	7.815	9.348	9.837	11.345	12.838	16.268
4	4.878	5.385	5.989	7.779	9.488	11.143	11.668	13.277	14.860	18.465
5	6.064	6.626	7.289	9.236	11.070	12.832	13.388	15.086	16.750	20.517
6	7.231	7.841	8.558	10.645	12.592	14.449	15.033	16.812	18.548	22.457
7	8.383	9.037	9.803	12.017	14.067	16.013	16.622	18.475	20.278	24.322
8	9.524	10.219	11.030	13.362	15.507	17.535	18.168	20.090	21.955	26.125
9	10.656	11.389	12.242	14.684	16.919	19.023	19.679	21.666	23.589	27.877
10	11.781	12.549	13.442	15.987	18.307	20.483	21.161	23.209	25.188	29.588
11	12.899	13.701	14.631	17.275	19.675	21.920	22.618	24.725	26.757	31.264
12	14.011	14.845	15.812	18.549	21.026	23.337	24.054	26.217	28.300	32.909
13	15.119	15.984	16.985	19.812	22.362	24.736	25.472	27.688	29.819	34.528
14	16.222	17.117	18.151	21.064	23.685	26.119	26.873	29.141	31.319	36.123
15	17.322	18.245	19.311	22.307	24.996	27.488	28.259	30.578	32.801	37.697
16	18.418	19.369	20.465	23.542	26.296	28.845	29.633	32.000	34.267	39.252
17	19.511	20.489	21.615	24.769	27.587	30.191	30.995	33.409	35.718	40.790
18	20.601	21.605	22.760	25.989	28.869	31.526	32.346	34.805	37.156	42.312
19	21.689	22.718	23.900	27.204	30.144	32.852	33.687	36.191	38.582	43.820
20	22.775	23.828	25.038	28.412	31.410	34.170	35.020	37.566	39.997	45.315
21	23.858	24.935	26.171	29.615	32.671	35.479	36.343	38.932	41.401	46.797
22	24.939	26.039	27.301	30.813	33.924	36.781	37.659	40.289	42.796	48.268
23	26.018	27.141	28.429	32.007	35.172	38.076	38.968	41.638	44.181	49.728
24	27.096	28.241	29.553	33.196	36.415	39.364	40.270	42.980	45.558	51.179
25	28.172	29.339	30.675	34.382	37.652	40.646	41.566	44.314	46.928	52.620
26	29.246	30.434	31.795	35.563	38.885	41.923	42.856	45.642	48.290	54.052
27	30.319	31.528	32.912	36.741	40.113	43.194	44.140	46.963	49.645	55.476
28	31.391	32.620	34.027	37.916	41.337	44.461	45.419	48.278	50.993	56.893
29	32.461	33.711	35.139	39.087	42.557	45.722	46.693	49.588	52.336	58.302
30	33.530	34.800	36.250	40.256	43.773	46.979	47.962	50.892	53.672	59.703

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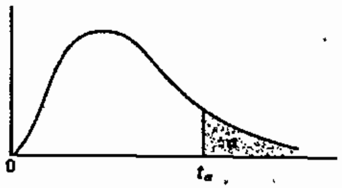

Table A.6* *Critical Values of the F-Distribution*

$f_{0.05}(v_1, v_2)$

v_2 \ v_1	1	2	3	4	5	6	7	8	9
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88

*Reproduced from Table 18 of *Biometrika Tables for Statisticians*, Vol. I, by permission of E. S. Pearson and the Biometrika Trustees.

Table A.6 *(continued)* *Critical Values of the F-Distribution*

$f_{0.05}(v_1, v_2)$

v_2 \ v_1	10	12	15	20	24	30	40	60	120	∞
1	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.36
6	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77	1.71
26	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

國立雲林科技大學
八十八學年度研究所博士班入學考試試題

所別：管理研究所
科目：管理文獻

The following questions are based on the paper entitled "The Discipline of Innovation" by Peter F. Drucker. Please read the paper and answer these questions.

1. Peter Drucker points out, "innovation is the responsibility of every executive, and it begins with a conscious, purposeful search for innovation opportunities." What does it mean for this statement in terms of the generation of innovation? 25%

2. As the paper discusses for sources of innovation including four areas of opportunity within a company or industry and three sources of opportunity outside a company, can you illustrate one or more innovative examples that are from these sources of opportunity based on your experience or observation? 25%

3. As the paper discusses, "innovation is work rather genius. It requires knowledge. It often requires ingenuity. And it requires focus. There are clearly people who are more talented as innovators than others, but their talents lie in well-defined areas." From above statement, how can you explain what are the important roles being played for good knowledge management in research and development (R & D)? Knowledge management is currently very popular area for information management researchers and practitioners. 25%

4. Based on the paper and your experience, can you discuss what the basic principles are for the effective innovation? 25%

Innovation can be systematically managed if one knows where and how to look.

The Discipline of Innovation

by Peter F. Drucker

Today, no one needs to be convinced of the importance of innovation – intense competition, along with fast-changing markets and technologies, has made sure of that. How *to innovate is the key question.*

To help answer the question, we turned to this classic HBR article by Peter Drucker, published in the May–June 1985 issue. As Drucker points out, innovation is the responsibility of every executive, and it begins with a conscious search for opportunities. Those opportunities can be categorized but not predicted. Finding those opportunities – and exploiting them with focused, practical solutions – requires disciplined work.

At a time of rapid growth in the practice of knowledge management, there's a danger that fancy equipment and techniques will simply play back a sophisticated version of what is already known. Drucker's article is a timely reminder that the latest tools are never enough to keep executives alert to opportunities.

– The editors

DESPITE MUCH DISCUSSION THESE DAYS OF the "entrepreneurial personality," few of the entrepreneurs with whom I have worked during the last 30 years had such personalities. But I have known many people – salespeople, surgeons, journalists, scholars, even musicians – who did have them without being the least bit "entrepreneurial." What all the successful entrepreneurs I have met have in common is not a certain kind of personality but a commitment to the systematic practice of innovation.

Innovation is the specific function of entrepreneurship, whether in an existing business, a public service institution, or a new venture started by a lone individual in the family kitchen. It is the means by which the entrepreneur either creates new wealth-producing resources or endows existing resources with enhanced potential for creating wealth.

Today, much confusion exists about the proper definition of *entrepreneurship.* Some observers use the term to refer to all small businesses; others, to all new businesses. In practice, however, a great many well-established businesses engage in highly successful entrepreneurship. The term, then, refers not to an enterprise's size or age but to a certain kind of activity. At the heart of that activity is innovation: the effort to create purposeful, focused change in an enterprise's economic or social potential.

Peter F. Drucker is professor emeritus at the Claremont Graduate University in Claremont, California. He is the author of dozens of HBR articles published over the past five decades. This article was originally adapted from his book Innovation and Entrepreneurship: Practice and Principles *(Harper & Row, 1985).*

Sources of Innovation

There are, of course, innovations that spring from a flash of genius. Most innovations, however, especially the successful ones, result from a conscious, purposeful search for innovation opportunities, which are found in only a few situations.

Four such areas of opportunity exist within a company or industry:

- unexpected occurrences
- incongruities
- process needs
- industry and market changes

Three additional sources of opportunity exist outside a company in its social and intellectual environment:

- demographic changes
- changes in perception
- new knowledge

True, these sources overlap, different as they may be in the nature of their risk, difficulty, and complexity, and the potential for innovation may well lie in more than one area at a time. But together, they account for the great majority of all innovation opportunities.

Unexpected Occurrences. Consider, first, the easiest and simplest source of innovation opportunity: the unexpected. In the early 1930s, IBM developed the first modern accounting machine, which was designed for banks. But banks in 1933 did not buy new equipment. What saved the company–according to a story that Thomas Watson, Sr., the company's founder and long-term CEO, often told–was its exploitation of an unexpected success: the New York Public Library wanted to buy a machine. Unlike the banks, libraries in those early New Deal days had money, and Watson sold more than a hundred of his otherwise unsalable machines to libraries.

Fifteen years later, when everyone believed that computers were designed for advanced scientific work, business unexpectedly showed an interest in a machine that could do payroll. Univac, which had the most advanced machine, spurned business applications. But IBM immediately realized it faced a possible unexpected success, redesigned what was basically Univac's machine for such mundane applications as payroll, and within five years became the leader in the computer industry, a position it has maintained even to this day.

The unexpected failure may be an equally important innovation-opportunity source. Everyone knows about the Ford Edsel as the biggest new-car failure in automotive history. What very few people seem to know, however, is that the Edsel's failure was the foundation for much of the company's later success. Ford planned the Edsel, the most carefully designed car to that point in American automotive history, to give the company a full product line with which to compete with General

ARTWORK BY CHRIS McALLISTER

Motors. When it bombed, despite all the planning, market research, and design that had gone into it, Ford realized that something was happening in the automobile market that ran counter to the basic assumptions on which GM and everyone else had been designing and marketing cars. No longer was the market segmenting primarily by income groups; the new principle of segmentation was what we now call *lifestyles*. Ford's response was the Mustang – a car that gave the company a distinct personality and reestablished it as an industry leader.

Unexpected successes and failures are such productive sources of innovation opportunities because most businesses dismiss them, disregard them, and even resent them. The German scientist who around 1905 synthesized novocaine, the first nonaddictive narcotic, had intended it to be used in major surgical procedures like amputation. Surgeons, however, preferred total anesthesia for such procedures; they still do. Instead, novocaine found a ready appeal among dentists. Its inventor spent the remaining years of his life traveling from dental school to dental school making speeches that forbade dentists from "misusing" his noble invention in applications for which he had not intended it.

This is a caricature, to be sure, but it illustrates the attitude managers often take to the unexpected: "It should not have happened." Corporate reporting systems further ingrain this reaction, for they draw attention away from unanticipated possibilities. The typical monthly or quarterly report has on its first page a list of problems – that is, the areas where results fall short of expectations. Such information is needed, of course; it helps prevent deterioration of performance.

But it also suppresses the recognition of new opportunities. The first acknowledgment of a possible opportunity usually applies to an area in which a company does better than budgeted. Thus genuinely entrepreneurial businesses have two "first pages" – a problem page and an opportunity page – and managers spend equal time on both.

Incongruities. Alcon Laboratories was one of the success stories of the 1960s because Bill Conner, the company's cofounder, exploited an incongruity in medical technology. The cataract operation is the world's third or fourth most common surgical procedure. During the last 300 years, doctors systematized it to the point that the only "old-fashioned" step left was the cutting of a ligament. Eye surgeons had learned to cut the ligament with complete success, but it was so different a procedure from the rest of the operation, and so incompatible with it, that they often dreaded it. It was incongruous.

Doctors had known for 50 years about an enzyme that could dissolve the ligament without cutting. All Conner did was to add a preservative to this enzyme that gave it a few months' shelf life. Eye surgeons immediately accepted the new compound, and Alcon found itself with a worldwide monopoly. Fifteen years later, Nestlé bought the company for a fancy price.

Such an incongruity within the logic or rhythm of a process is only one possibility out of which innovation opportunities may arise. Another source is incongruity between economic realities. For instance, whenever an industry has a steadily growing market but falling profit margins – as, say, in the steel industries of developed countries between 1950 and 1970 – an incongruity exists. The innovative response: minimills.

An incongruity between expectations and results can also open up possibilities for innovation. For 50 years after the turn of the century, shipbuilders and shipping companies worked hard both to make ships faster and to lower their fuel consumption. Even so, the more successful they were in boosting speed and trimming fuel needs, the worse the economics of ocean freighters became. By 1950 or so, the ocean freighter was dying, if not already dead.

All that was wrong, however, was an incongruity between the industry's assumptions and its realities. The real costs did not come from doing work (that is, being at sea) but from *not* doing work (that is, sitting idle in port). Once managers understood where costs truly lay, the innovations were obvious: the roll-on and roll-off ship and the container ship. These solutions, which involved old technology, simply applied to the ocean freighter what railroads and truckers had been using for 30 years. A shift in viewpoint, not in technology, totally changed the economics of ocean shipping and turned it into one of the major growth industries of the last 20 to 30 years.

Process Needs. Anyone who has ever driven in Japan knows that the country has no modern highway system. Its roads still follow the paths laid down for – or by – oxcarts in the tenth century. What makes the system work for automobiles and trucks is an adaptation of the reflector used on American highways since the early 1930s. This reflector lets each car see which other cars are approaching from any one of a half-dozen directions. This minor invention, which enables traffic to move smoothly and with a minimum of accidents, exploited a process need.

> The attitude managers often take to the unexpected – "It should not have happened" – is further ingrained by corporate reporting systems.

What we now call "the media" had their origin in two innovations developed around 1890 in response to a process need. One was Ottmar Mergenthaler's Linotype, which made it possible to produce a newspaper quickly and in large volume. The other was a social innovation, modern advertising, invented by the first true newspaper publishers, Adolph Ochs of the *New York Times*, Joseph Pulitzer of the *New York World*, and William Randolph Hearst. Advertising made it possible for them to distribute news practically free of charge, with the profit coming from marketing.

Industry and Market Changes. Managers may believe that industry structures are ordained by the Good Lord, but these structures can–and often do–change overnight. Such change creates tremendous opportunity for innovation.

One of American business's great success stories in recent decades is the brokerage firm of Donaldson, Lufkin & Jenrette, recently acquired by the Equitable Life Assurance Society. DL&J was founded in 1960 by three young men, all graduates of the Harvard Business School, who realized that the structure of the financial industry was changing as institutional investors became dominant. These young men had practically no capital and no connections. Still, within a few years, their firm had become a leader in the move to negotiated commissions and one of Wall Street's stellar performers. It was the first to be incorporated and go public.

New opportunities rarely fit the way an industry has always approached the market, defined it, or organized to serve it.

In a similar fashion, changes in industry structure have created massive innovation opportunities for American health-care providers. During the last 10 or 15 years, independent surgical and psychiatric clinics, emergency centers, and HMOs have opened throughout the country. Comparable opportunities in telecommunications followed industry upheavals–both in equipment (with the emergence of such companies as Rolm in the manufacturing of private branch exchanges) and in transmission (with the emergence of MCI and Sprint in long-distance service).

When an industry grows quickly–the critical figure seems to be in the neighborhood of 40% growth in ten years or less–its structure changes. Established companies, concentrating on defending what they already have, tend not to counterattack when a newcomer challenges them. Indeed, when market or industry structures change, traditional industry leaders again and again neglect the fastest growing market segments. New opportunities rarely fit the way the industry has always approached the market, defined it, or organized to serve it. Innovators therefore have a good chance of being left alone for a long time.

Demographic Changes. Of the outside sources of innovation opportunity, demographics are the most reliable. Demographic events have known lead times; for instance, every person who will be in the American labor force by the year 2000 has already been born. Yet because policy makers often neglect demographics, those who watch them and exploit them can reap great rewards.

The Japanese are ahead in robotics because they paid attention to demographics. Everyone in the developed countries around 1970 or so knew that there was both a baby bust and an education explosion going on; half or more of the young people were staying in school beyond high school. Consequently, the number of people available for traditional blue-collar work in manufacturing was bound to decrease and become inadequate by 1990. Everyone knew this, but only the Japanese acted on it, and they now have a ten-year lead in robotics.

Much the same is true of Club Mediterranee's success in the travel and resort business. By 1970, thoughtful observers could have seen the emergence of large numbers of affluent and educated young adults in Europe and the United States. Not comfortable with the kind of vacations their working-class parents had enjoyed–the summer weeks at Brighton or Atlantic City–these young people were ideal customers for a new and exotic version of the "hangout" of their teen years.

Managers have known for a long time that demographics matter, but they have always believed that population statistics change slowly. In this century, however, they don't. Indeed, the innovation opportunities made possible by changes in the numbers of people–and in their age distribution, education, occupations, and geographic location–are among the most rewarding and least risky of entrepreneurial pursuits.

Changes in Perception. "The glass is half-full" and "the glass is half-empty" are descriptions of the same phenomenon but have vastly different meanings. Changing a manager's perception of a glass from half-full to half-empty opens up big innovation opportunities.

All factual evidence indicates, for instance, that in the last 20 years, Americans' health has improved with unprecedented speed–whether measured by mortality rates for the newborn, survival rates for the very old, the incidence of cancers (other than lung cancer), cancer cure rates, or other factors. Even so, collective hypochondria grips the nation. Never before has there been so much concern with or fear about health. Suddenly, everything seems to cause cancer or degenerative heart disease or premature loss of memory. The glass is clearly half-empty.

Rather than rejoicing in great improvements in health, Americans seem to be emphasizing how far away they still are from immortality. This view of things has created many opportunities for innovations: markets for new health-care magazines, for all kinds of health foods, and for exercise classes and jogging equipment. The fastest growing new U.S. business in 1983 was a company that makes indoor exercise equipment.

A change in perception does not alter facts. It changes their meaning, though–and quickly.

A change in perception does not alter facts. It changes their meaning, though–and very quickly. It took less than two years for the computer to change from being perceived as a threat, and as something only big businesses would use, to something one buys for doing income tax. Economics do not necessarily dictate such a change; in fact, they may be irrelevant. What determines whether people see a glass as half-full or half-empty is mood rather than fact, and a change in mood often defies quantification. But it is not exotic. It is concrete. It can be defined. It can be tested. And it can be exploited for innovation opportunity.

New Knowledge. Among history-making innovations, those based on new knowledge–whether scientific, technical, or social–rank high. They are the superstars of entrepreneurship; they get the publicity and the money. They are what people usually mean when they talk of innovation, although not all innovations based on knowledge are important.

Knowledge-based innovations differ from all others in the time they take, in their casualty rates, and in their predictability, as well as in the challenges they pose to entrepreneurs. Like most superstars, they can be temperamental, capricious, and hard to direct. They have, for instance, the longest lead time of all innovations. There is a protracted span between the emergence of new knowledge and its distillation into usable technology. Then there is another long period before this new technology appears in the marketplace in products, processes, or services. Overall, the lead time involved is something like 50 years, a figure that has not shortened appreciably throughout history.

To become effective, innovation of this sort usually demands not one kind of knowledge but many. Consider one of the most potent knowledge-based innovations: modern banking. The theory of the entrepreneurial bank–that is, of the purposeful use of capital to generate economic development–was formulated by the Comte de Saint-Simon during the era of Napoleon. Despite Saint-Simon's extraordinary prominence, it was not until 30 years after his death in 1825 that two of his disciples, the brothers Jacob and Isaac Pereire, established the first entrepreneurial bank, the Credit Mobilier, and ushered in what we now call *finance capitalism.*

The Pereires, however, did not know modern commercial banking, which developed at about the same time across the channel in England. The Credit Mobilier failed ignominiously. A few years later, two young men – one an American, J.P. Morgan, and one a German, Georg Siemens – put together the French theory of entrepreneurial banking and the English theory of commercial banking to create the first successful modern banks, J.P. Morgan & Company in New York and the Deutsche Bank in Berlin. Ten years later, a young Japanese, Shibusawa Eiichi, adapted Siemens's concept to his country and thereby laid the foundation of Japan's modern economy. This is how knowledge-based innovation always works.

> The greatest praise an innovation can receive is for people to say: "This is obvious!"

The computer, to cite another example, required no fewer than six separate strands of knowledge:

- binary arithmetic;
- Charles Babbage's conception of a calculating machine, in the first half of the nineteenth century;
- the punch card, invented by Herman Hollerith for the U.S. census of 1890;
- the audion tube, an electronic switch invented in 1906;
- symbolic logic, which was developed between 1910 and 1913 by Bertrand Russell and Alfred North Whitehead;
- concepts of programming and feedback that came out of abortive attempts during World War I to develop effective anti-aircraft guns.

Although all the necessary knowledge was available by 1918, the first operational digital computer did not appear until 1946.

Long lead times and the need for convergence among different kinds of knowledge explain the peculiar rhythm of knowledge-based innovation, its attractions, and its dangers. During a long gestation period, there is a lot of talk and little action. Then, when all the elements suddenly converge, there is tremendous excitement and activity and an enormous amount of speculation. Between 1880 and 1890, for example, almost 1,000 electric-apparatus companies were founded in developed countries. Then, as always, there was a crash and a shakeout. By 1914, only 25 were still alive. In the early 1920s, 300 to 500 automobile companies existed in the United States; by 1960, only 4 remained.

It may be difficult, but knowledge-based innovation can be managed. Success requires careful analysis of the various kinds of knowledge needed to make an innovation possible. Both J.P. Morgan and Georg Siemens did this when they established their banking ventures. The Wright brothers did this when they developed the first operational airplane.

Careful analysis of the needs – and, above all, the capabilities – of the intended user is also essential. It may seem paradoxical, but knowledge-based innovation is more market dependent than any other kind of innovation. De Havilland, a British company, designed and built the first passenger jet airplane, but it did not analyze what the market needed and therefore did not identify two key factors. One was configuration – that is, the right size with the right payload for the routes on which a jet would give an airline the greatest advantage. The other was equally mundane: how could the airlines finance the purchase of such an expensive plane? Because de Havilland failed to do an adequate user analysis, two American companies, Boeing and Douglas, took over the commercial jet-aircraft industry.

> If an innovation does not aim at leadership from the beginning, it is unlikely to be innovative enough.

Principles of Innovation

Purposeful, systematic innovation begins with the analysis of the sources of new opportunities. Depending on the context, sources will have different importance at different times. Demographics, for instance, may be of little concern to innovators of fundamental industrial processes like steelmaking, although Mergenthaler's Linotype machine became successful primarily because there were not enough skilled typesetters available to satisfy a mass market. By the same token, new knowledge may be of little relevance to someone innovating a social instrument to satisfy a need that changing demographics or tax laws have created. But – whatever the situation – innovators must analyze all opportunity sources.

Because innovation is both conceptual and perceptual, would-be innovators must also go out and look, ask, and listen. Successful innovators use both the right and left sides of their brains. They look at figures. They look at people. They work out analytically what the innovation has to be to satisfy an opportunity. Then they go out and look at potential users to study their expectations, their values, and their needs.

To be effective, an innovation has to be simple, and it has to be focused. It should do only one thing; otherwise it confuses people. Indeed, the greatest praise an innovation can receive is for people to say, "This is obvious! Why didn't I think of it? It's so simple!" Even the innovation that creates new users and new markets should be directed toward a specific, clear, and carefully designed application.

Effective innovations start small. They are not grandiose. They try to do one specific thing. It may be to enable a moving vehicle to draw electric power while it runs along rails, the innovation that made possible the electric streetcar. Or it may be the elementary idea of putting the same number of matches into a matchbox (it used to be 50). This simple notion made possible the automatic filling of matchboxes and gave the Swedes a world monopoly on matches for half a century. By contrast, grandiose ideas for things that will "revolutionize an industry" are unlikely to work.

In fact, no one can foretell whether a given innovation will end up a big business or a modest achievement. But even if the results are modest, the successful innovation aims from the beginning to become the standard setter, to determine the direction of a new technology or a new industry, to create the business that is – and remains – ahead of the pack. If an innovation does not aim at leadership from the beginning, it is unlikely to be innovative enough.

Above all, innovation is work rather than genius. It requires knowledge. It often requires ingenuity. And it requires focus. There are clearly people who are more talented as innovators than others, but their talents lie in well-defined areas. Indeed, innovators rarely work in more than one area. For all his systematic innovative accomplishments, Thomas Edison worked only in the electrical field. An innovator in financial areas, Citibank for example, is not likely to embark on innovations in health care.

In innovation, as in any other endeavor, there is talent, there is ingenuity, and there is knowledge. But when all is said and done, what innovation requires is hard, focused, purposeful work. If diligence, persistence, and commitment are lacking, talent, ingenuity, and knowledge are of no avail.

There is, of course, far more to entrepreneurship than systematic innovation – distinct entrepreneurial strategies, for example, and the principles of entrepreneurial management, which are needed equally in the established enterprise, the public service organization, and the new venture. But the very foundation of entrepreneurship – as a practice and as a discipline – is the practice of systematic innovation. ⛉

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